1st Periodic Report of the CopPeR Project

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Declaration by the project coordinator

I, as co-ordinator of this project and in line with my obligations as stated in Article II.2.3 of the Grant Agreement declare that:

- The attached periodic report represents an accurate description of the work carried out in this project for this reporting period;
- The project (tick as appropriate):
  - ☐ has fully achieved its objectives and technical goals for the period;
  - ☑ has achieved most of its objectives and technical goals for the period with relatively minor deviations[1];
  - ☐ has failed to achieve critical objectives and/or is not at all on schedule.
- The public Website is up to date, if applicable.
- To my best knowledge, the financial statements which are being submitted as part of this report are in line with the actual work carried out and are consistent with the report on the resources used for the project (section 3.6) and if applicable with the certificate on financial statement.
- All beneficiaries, in particular non-profit public bodies, secondary and higher education establishments, research organisations and SMEs, have declared to have verified their legal status. Any changes have been reported under section 5 (Project Management) in accordance with Article II.3.f of the Grant Agreement.

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[1] If either of these boxes is ticked, the report should reflect these and any remedial actions taken. (Please see text on page 22 and corresponding)

Table of Contents

1 Publishable summary 4

2 Project objectives for the period 8

3 Work progress and achievement during the period 11

3.1 WP1: Material Requirements and Specification 11

3.2 WP2: Simulation Based System Quantification and Scale-up 15

3.3 WP3: Copper Deposition from Non-Aqueous Solvents 17

3.4 WP4: Proof-of-Concept 23

3.5 WP5: Instrumentation and Metrology for Nanocharacterisation 25

3.6 Overview of the use of effort 28

4 Deliverables and milestones 30

5 Project management 34

5.1 Summary of Task 6.1: Project Management 34

5.1.1 Project management activities 34

5.1.2 Problems, solutions, changes within the project 38

5.1.3 Project planning and status 39

5.1.4 List of project meetings and telephone conferences 43

5.2 Summary of Task 6.2: Dissemination and Standardisation 46

5.2.1 Project website 46

5.2.2 Dissemination activities during the first project year 48

5.3 Summary of Task 6.3: IPR and Exploitation framework 49

6 Explanation of the use of resources 50

7 Financial statements 54

8 Certificates 63

9 List of Abbreviations 64

1 Publishable summary

Introduction and General Technical Goals

The collaborative FP7 ICT STREP CopPeR (Copper Interconnects for Advanced Performance and Reliability) project aims to develop a novel copper deposition process based on the use of non-aqueous solvents – more precisely of liquefied ammonia and ionic liquids - in order to overcome the limitations of currently applied interconnect formation processes enabling further device scaling beyond the 32 nm technology node. The scheme for this novel interconnect processes consists of a barrier pre-conditioning, a seedless copper deposition as well as a copper post-treatment. This non-aqueous process will open novel routes to implement direct-on-barrier plating, focussing on tantalum as diffusion barrier. The process developed and implemented within the CopPeR project aims to significantly improve the quality of the Cu metallization due to the fact that the conductivity limiting seed-Cu will be eliminated and thinner barrier films can be applied, e.g. by ALD (atomic layer deposition); so more volume is available in trenches for high quality, low resistivity Cu.

Description of Work done in the first year and results

The project started in January 2008, it is running for 30 months and it consists of three phases whereby in the first phase, which corresponds to the first project year, the focus was put on the analyses and selection of materials and the cell design.

Therefore first of all in WP 1 the requirements for copper interconnects and barrier layers to be integrated for future nodes during the project, were defined. The electrolytes – the solvents and their supporting ingredients, the wafer materials used as substrates as well as barrier materials were characterised with regard to their ability towards the aimed non-oxidizing, seedless deposition approach. Especially liquefied water free ammonia was investigated as solvent for the direct-on-barrier plating process and several salts and additives were investigated to optimise the plating results. Thus a plating bath formulation was defined.
The focus of research in terms of barriers was laid on Ta/TaN barriers, whereby Ru barriers were used for comparison purposes. In addition basic physical properties were investigated, deposition methods (with a focus on electrolytic copper deposition in the first year) were assessed, and test structures of the wafers were designed. Several supporting electrolytes were investigated for achieving a high conductivity of ammonia based plating baths. Additives for improving adhesion and enabling superfilling were screened. As a main result of these research activities a formulation for copper deposition, which meets the required deposition rate, was achieved.

On the basis of these findings as well as of various modelling and numerical simulation work on the complex mechanism of electrodeposition based on multi-ion macro-models for copper deposition a deposition cell design was proposed in WP 2. The aim was to develop a preliminary design for a 300mm plating cell. Therefore a potential model was developed for the non-aqueous copper deposition process - based on the cathodic and anodic polarization in the relevant process window. Simulations showed that a standard fountain plating cell yields a quite non-uniform deposition over the wafer, which is due to non-negligible stray currents through the stainless steel of the plating chamber. Because of this unwanted effects an electrical isolation of the walls was necessary. So a new improved cell concept was developed. Additional modifications will provide further improvements to the uniformity of deposition and to control the deposition process. The WP2 team also started to develop

and design several elements such as the counter electrode and different types of reference electrodes.

In parallel WP 3 started to develop the process for copper deposition from non-aqueous solvents. Deposition from liquefied ammonia was developed resulting in a plating bath based on ammonia salts as supporting electrolytes, complexing agents acting as adhesion intermediator and superfilling additives. The deposition of copper seed layers from ionic liquids was investigated under vacuum to exclude any traces of water and oxygen. Special aspects like the nucleation density and uniformity as well as the repeatability in deposition have been investigated in more detail – the nucleation potential was one main issue in this aspect. The effect of additives on copper nucleation and adhesion of deposits was studied and clear differences of the behaviour of additives in ionic liquids and aqueous electrolytes were observed. WP 3 did a series of plating experiments in order to improve specific aspects; afterwards the formation of closed copper layers was analysed. In addition in WP 3 the partners aimed to develop a detailed multi-ion model that takes into account all the relevant phenomena in copper superfilling from non-aqueous solution. Therefore the electrochemistry solver had to be extended with basic models for ionic transport in ionic liquids. Furthermore a grid generator capable of tackling small spatial scales as well as new algorithms describing nucleation and adsorption processes had to be developed. The last subtask to model the superfilling process is the integration of electrode shape-change algorithms, which will be done in the next period. As the main result of these research activities in the first project year a preliminary list of additives suitable for superfilling has been compiled.

The focus of WP 4 laid on the design of the prototype which affects the different components: pressurized deposition chamber, the pressurized mixed tank, the piping and instrumentation, the salt ports and the chuck. The research activities are based on the simulation results of WP 2 and consider the necessary flexibility of the design to accommodate and position the complementary or supplementary counter and steerable anodes. The chamber design has been finished, draft chuck designs for processing 300 and 200 mm wafers were created and a P&I flow plan defined. The manufacturing of the autoclave (full scale plating chamber prototype and ammonia storage tank) has begun during M10. The chamber installation will take place most likely during the second quarter of the year 2.

In WP 5 a major task was dealing with the nano-characterization of samples in general and with the element specific analysis of sub 10 nm thick interfacial layers – especially the presence of oxygen in the copper-tantalum interface. A combination of techniques offering high spatial resolution and analytical sensitivity was evaluated to enable adequate analysis of the deposited films and interfaces. Among other things a set of acquisition parameters for qualitative analysis has been identified and high resolution phase contrast imaging for structural and crystallographic investigations are available.

As a result of all the research activities in the five technical CopPeR project workpackages during the first project year, a baseline definition of the geometry for the first 300 mm cell design has been reached.

The next phase will focus on the development of the copper deposition process based on the findings from phase one with the additional support of micro-modelling. The process will be scaled and integrated into a 300 mm proof-of-concept. In the third and final phase, the process will be integrated into a complete interconnect scheme, and optimized according to the industrial chip manufacturer’s needs.

The CopPeR project has successfully proven direct-on-barrier plating from non-aqueous solvents. The CopPeR deposition process is facilitating advanced interconnect designs without the need for deposition on a PVD seedlayer.

CopPeR Project Partners

The final goal of the CopPeR project will be achieved through collaborations within a very strong consortium based on a team with outstanding scientific, engineering and manufacturing qualifications. The consortium consists of 8 European leading companies and academic institutions (Technikon Forschungs- und Planungsgesellschaft mbH (AT), SEZ AG (AT), Katholieke Universiteit Leuven (BE), FELMI - Technische Universität Graz (AT), ELSYCA N.V. (BE), Vrije Universiteit Brussel (BE), Infineon Technologies AG (G) and Cormet OY (FIN)). Together they represent a vertically integrated consortium, with excellence in plating technologies and knowledge stretching from basic research to the design and marketing of products. This includes the production, evaluation and impacts on the ITRS Roadmap as well as intimate knowledge of the end-user market.

CopPeR Project Consortium

The total volume of the project is estimated to be 4.7 Million Euro, part of which will be contributed by the EC. For more information about the CopPeR project please visit the project's website **www.copper-project.eu** or contact

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Figure 1: CopPeR Consortium at Kick-off-Meeting in Villach February 2008

CopPeR Logo

Figure 2: CopPeR Logo

CopPeR Disclaimer

All public information will be marked with the following CopPeR project disclaimer:

The information in this document is provided "as is", and no guarantee or warranty is given that the information is fit for any particular purpose. The user thereof uses the information at its sole risk and liability.

2 Project objectives for the period

The major objective of CopPeR is to cope with the challenges of introducing new interconnect materials and deposition techniques for the 32 nm, 22 nm and 18 nm technology nodes by the implementation of a unique copper deposition process, that allows further scaling of interconnects. For this purpose the CopPeR research team will develop a prototype for a direct-on-barrier copper deposition process on the basis of non-oxidizing solvents.

In this context the CopPeR project has the following derived objectives, which target the provision of this novel copper interconnect scheme:

- copper deposition from non-oxidizing solvents for high-performance copper/barrier-interfaces,
- elimination of the copper seed layer for void-free superfilling beyond 32 nm and improved grain size enlargement,
- surface conditioning of barriers for seedless copper deposition with beneficial impact on nucleation and adhesion.

The main aim of **WP 1** is to provide the target specifications and to define the requirements on the interconnect structures and the prototype as well as of the wafer materials. Also the definition of value adding electrolytes and additives as well as of all the relevant basic physical and electrochemical parameters is part of the goal. The following list shows the concrete objectives of WP 1 for the first project year:

Requirements and specifications

- definition of test layers and test structures
- specification on electrical and mechanical behaviour of the Cu interconnect
- specification on barrier layer properties
- metrology concept and specification on metrology methods: state-of-the-art methods for application in WP3 and WP4, and development requirements for sub 32 nm metrology in WP5

Characterization and selection of the electrolyte materials (solvents and additives) and barrier materials

- Identification of non-oxidizing and non-hydrolysing electrolyte compositions
- Evaluation of solvent candidates for direct-on-barrier copper deposition – especially investigation of liquid ammonia and the reduction of the vapour pressure of liquid ammonia by addition of salts and/or co-solvents
- Determination of key parameters for all solvents
- Screening of potential additives used for improving nucleation and adhesion, and supporting superfilling
- Study of promising electrolyte solutions in rotating disk electrode voltammetry

→ **Electrolyte Baseline Definition available**

→ **Material Baseline Definition available**

Definition of the requirement and specification of wafer materials

- Preparation of blanket wafers with different types of barrier layers
- Preparation of blanket wafers with state-of-the-art electroplated copper for benchmarking
- Analysis of all layers for key parameters (thickness, elemental composition, crystal structure)
- Detailed studies on barrier layers (especially of Ta and Ta/TaN)

The major goal of **WP 2** is to develop the cell design of the prototype plating cell for 300 mm wafer plating on the basis of an initial potential model for the non-aqueous Cu plating process. This first design will be improved by multi-ion models, which give more detailed information on the influence of the macro-scale process parameters on the nano-scale plating behavior. Below you can find the corresponding objectives of this WP for the first project year:

Characterisation and validation of deposition model

- initial model parameter fit for the potential model describing the Cu deposition process in non-aqueous solution
- lab scale measurements in order to determine the polarization behaviour and conductivity of the non-aqueous Cu-plating electrolyte

Plating cell design for 300 mm prototype

- first design of the 300 mm prototype on the basis of the potential model and fluid flow simulation software
- increase of the present software - development of a grid generator capable of tackling small spatial scales (with a zoom toward a local feature up to and smaller than 1 nm)·

→ Cell design for 300mm prototype

Design and engineering of cell peripherals

- Development of a suitable water-free reference electrode for high-pressure ammonia environment
- sealing of the rotating shaft
- prevent wafer contamination
- opening mechanism of the plating chamber

The main objectives of **WP 3** are to develop a direct-on-barrier copper deposition process and to optimize non-aqueous deposition processes for semiconductor needs. In addition the electrochemical characterization of electrolytes in non-aqueous media is important. The objectives of WP 3 for the first project year were:

Nucleation and Layer Growth

- Study the nucleation of copper on tantalum and tantalum nitride in order to control the nucleation and conformal layer growth
- Investigate the effect of additives and overpotential on the nucleation density (nucleation densities of at least 2 1011 nuclei per cm² are aimed)
- investigation of the bond strength between deposited layer and the substrate

→ Nucleation density of copper suitable for sub 32 nm, nucleation test results verified by electron microscopy

Micromodelling of superfilling

- derivation and quantification of detailed multi-ion models of the non-aqueous Cu deposition process on a micro scale (incl. simulations)
- extension of the electrochemistry solver with basic models for ionic transport in ionic liquids
- development of a grid generator capable of tackling small spatial scales
- develop and integrate new algorithms describing nucleation and adsorption processes
- integration of electrode shape-change algorithms such that the superfilling process can be modeled

Cu superfilling of vias and electroless Cu deposition

- Study of the copper superfilling of vias and the electroless deposition of copper layers from non-aqueous plating solutions (started with vias of 1 micron and will gradually be downscaled to 32 nm vias during the project)
  - electrolytic superfilling from ammonia and ionic liquids and
  - electroless deposition from ionic liquids
- bath chemistry
- electrochemical measurements
- Development of ammonia and ionic liquid based electrolytes for electrolytic copper plating (lowering the vapour pressure of ammonia and the viscosity of ionic liquids by use of co-solvents)
- Development of superfilling chemistry for the electrolytic copper deposition of vias.
- Development of chemistry for barrier pre-conditioning, e.g. elimination of surface oxides, and implementation of an activation layer for electroless deposition.

→ **List of additives suitable for superfilling available, deposition test results verified by electron microscopy**

The goal of **WP 4** is to proof the concept for the developed processes of seedless Cu deposition for sub 32 nm nodes. The deposition process will be integrated into a full process flow and final electrical and mechanical characterization and reliability tests will be performed. The objectives for the first project year were:

Prototype design and building

- Development of a design of the pressurized chamber
  - Design of the pressurized deposition chamber and the mixing tank
  - Design of piping and instrumentation
  - Design of chuck

The goal of **WP 5** is to provide access and applicability to top-nodge scientific characterization techniques for the development and qualification phases of the project by transferring and adapting existing investigation methods to sub-32 nm levels, to explore the limits of current state-of-the-art characterization techniques and to find new concepts with the potential to go beyond. The work package's objectives for the first project year were:

Element specific interface analysis

- qualify methods for element specific analysis of buried layers thinner than 10 nm
- identification and quantification of accidental oxygen impurities
- obtain diffusion profiles and gradient maps
- feasibility of tomographic techniques proved

Metrology for crystal grain characterization

- deliver analytical methods for the characterisation of crystal grains

In the first CopPeR project year the partners have done good progress and are well on the way to achieve the project final goals.

3 Work progress and achievement during the period

The CopPeR project aims to develop a novel copper deposition process based on the use of non-aqueous solvents – more precisely of liquefied ammonia and ionic liquids - in order to overcome the limitations of currently applied interconnect formation processes enabling further device scaling beyond the 32 nm technology node. This chapter shows the activities performed by each work package towards reaching the goals for the first project period from M01 to M12.

3.1 WP1: Material Requirements and Specification

Summary of progress towards objectives

Task 1.1 "Requirements and Specification"

The requirements of copper interconnects were described by SEZ and IFX, highlighting the changes when stepping from current technology nodes to future nodes, especially beyond 32 nm. An initial description was given at the very start of the project, and has been updated at the end of the first year.
For comparability of test results, test and material standards were defined in terms of substrate material, dielectric layer and barrier layer. The main focus of the project is on direct-on-barrier deposition of copper on Ta/TaN barriers. Ru barriers should be used for comparison purposes, if appropriate.
IFX together with SEZ has specified the requirements and the specifications of the electroplated layers (sheet resistance, film-stress, roughness, etc.). The specifications of the ammonia based Cu layers are according to the actual Cu layers (from H_2SO_4 based Cu chemistry) used in production.
A literature search was carried out to for specification of electroless plated layers.
Mechanical and electrical specifications on the copper were listed including both inputs from industry (industrial partner IFX) and the ITRS.
The requirements have been defined for both electrolytically and electroless deposited copper, but the focus was on electro-deposited copper.
EHS requirements on the process have been shortly described.

To assess the mechanical and electrical material properties, metrology methods were agreed upon by the industrial partners IFX and SEZ, as well as the university partner FELMI. Based on this, FELMI delivered a detailed metrology concept comprising all relevant methods, suitable for sub 32 nm metrology with state-of-the-art methods for application in WP3 and WP4. Where not available, research will be performed within WP5 to extend the metrology portfolio at mature project phases.

A calculation model for Cost-of-Ownership (CoO) was defined with all necessary input parameters. CoO targets have been discussed between the industrial partners IFX and SEZ.

Task 1.2 "Electrolyte Characterisation"

Several water free solvents have been discussed for direct-on-barrier electroplating of copper. Two main groups have been chosen and investigated by KUL and SEZ: liquefied ammonia and a group of quaternary ammonium based ionic liquids.

Liquid ammonia was chosen for the following reasons:

- Oxygen and water free solvent avoiding tantalum oxidation
- Low viscosity allowing high mass transfer rates
- Low surface tension allowing good wetting even in narrow trenches
- Fair solubility of supporting electrolytes and copper salts.

Several ammonium salts were investigated as supporting electrolytes, including Ammonium bromide NH_4Br, Ammonium chloride NH_4Cl, Ammonium iodide NH_4I, Ammonium thiocyanate NH_4SCN and Ammonium fluoride NH_4F. Ammonium bromide NH_4Br proved to be the most promising salt for supporting a fast and uniform copper deposition process: good solubility, high conductivity of the solution, no side reaction within the targeted potential window. It will be used as the main supporting electrolyte for deposition from liquid ammonia.
Several copper salts were investigated as a source for copper, including Copper (I) bromide CuBr, Copper (I) chloride CuCl, Copper (I) iodide CuI, Copper (I) fluoride CuF and Copper tetrafluoroborate $Cu(BF_4)_{1\text{-}2}$. Copper bromide CuBr proved to show the best feasibility: fair solubility, no side reactions within the targeted potential window, easy drying cleaning of the raw material. It will be used as the main copper source for the deposition process from liquid ammonia.
Besides copper salts, the usage of a copper anode is targeted, but depends on feasibility testing on a full-wafer scale.
Diffusion coefficients for the Cu(I) cation were investigated by experiments determining the Levich plot. Depending on the concentration, the diffusion coefficient is in the range of 2 to 5 10^{-5} cm²/s.
Other additives were screened, mainly to improve wetting and improve the adhesion properties of the deposited copper metal on tantalum. Tartrates and salts of other dicarbonic acids (citrates, malates) were investigated. Their usage at low concentrations (ppm level) is mandatory for good adhesion.
Based on these results a plating bath formulation was developed. This formulation contains a rather low concentration of copper, limiting its deposition rate, but improving the deposition uniformity and mechanical properties.
Finally, also ammoniates were investigated in order to reduce the vapour pressure of the plating bath to below 1 atm or slightly above. Ammonium thiocyanate proved to be stable at room temperatures and ambient pressure. Its high conductivity allows high mass transport rates, but its viscosity is reducing the ion mobility.
Lab scale experiments were designed and performed by SEZ and ELS to determine the conductivity and the polarization behaviour of the copper electroplating process from liquid ammonia. However, due to the limitations of the set-up and the experimental approach the polarization curve did not cover the entire range of current densities needed in the simulations, and a correction for the ohmic drop in the rotating disk cell was not possible. Therefore a new set-up and experimental approach was proposed by ELS. Using this new approach the polarization measurements were repeated. ELS used these measurements in WP2 to obtain the necessary input parameters for the potential model simulations.

Ionic liquids suitable for copper electrodeposition possess the following requirements:

- Oxygen and water free solvent avoiding tantalum oxidation
- Broad electrochemical window
- Low melting point (<40 °C). Thermal stability up to 200 °C

- Electrical conductivity higher than 0.5 Ω-1m-1 and a viscosity below 100 mPas (both at room temperature)
- Air stable
- Fair solubility of copper salts and nucleation modifiers.

Three ionic liquids were selected for testing of copper deposition:

- butyl-1-methyl-pyrrolidinium bis(trifluoromethylsulfonyl)imide (BMP[Tf2N]);
- 1-Ethyl-3-methylimidazolium bis(trifluoromethylsulfonyl)imide (EMIm[Tf2N]);
- 1-Ethyl-3-methylimidazolium chloride (EMIm[Cl]).

Copper salts with common anions $Cu[Tf_2N]_2$, CuCl, $CuCl_2$ and Cu(II)-tartrate were tested in combination with selected ionic liquids. Due to the problem of tantalum oxide formation, the plating bath should be water-free and anhydrous salts should be used for electrolyte preparation. In case of crystallohydrates, the plating bath has been treated under vacuum to remove all water.
To improve deposit properties and reach the required nucleation density and superfilling on tantalum barriers, surface active additives can be employed in electrodeposition process. Main selection criteria are:

- Solubility in ionic liquids
- Electrochemical stability in potential range
- Grain refining effect
- Ability to increase the number of nucleation centers
- Accelerating and suppressing effect for "superfilling" additives.

All three selected ionic liquids satisfy the requirements. Electrochemical windows of ionic liquids were determined by cyclic voltammetry under Ar atmosphere and in vacuum. In comparison with EMIm[Cl] (electrochemical window 2.8 V) with T_{melt}= 78 °C, the other two ionic liquids ($BMP[Tf_2N]$ and $EMIm[Tf_2N]$) are liquid at room-temperature and have electrochemical window up to 5 V. Nevertheless the complexing role of $[Cl]^-$ anion in EMIm[Cl] is important for the solubility of copper compounds and additives.
The purity of ionic liquids was characterized by cyclic voltammetry and the influence of impurities and concentration of H_2O in "ppm" range on electrochemistry was evident. Difference between commercially available and vacuum dried IL's proves the importance of pretreatment to remove traces of water.
Solubility tests of $Cu[Tf_2N]_2$, Cu(I)- and Cu(II)-chlorides show that copper chlorides and Cu-tartrate are soluble only in "first generation" ionic liquid EMIm[Cl], while $Cu[Tf_2N]_2$ can be used only in bistriflimides. Cyclic voltammograms of the ionic liquids containing suitable copper compounds were recorded and a simulation program was developed to identify the equilibrium potentials, the diffusion coefficients and the anodic and cathodic transfer coefficients from the recorded CV's. Copper concentration of 0.5 $mol \cdot dm^{-3}$ was used for preparation of plating solution. To prevent Cu comproportionation, the transformation of Cu^{2+} to Cu^+ was required. To determine the amount of Cu^{2+} in a stabilized solution, UV-VIS spectroscopy was performed. From acquired spectra it can be concluded that the equilibrium concentration of Cu^{2+} is negligible.

A range of organic additives (accelerators suppressors, levelers etc.) was selected to promote high nucleation density and achieve superfilling during Cu deposition. Solubility tests of 29 additives in ionic liquid were performed at different temperatures. It was determined that half of selected organic substances, commonly used in aqueous electrolytes for copper electrodeposition, can be used with IL's. Influence of them on copper nucleation is discussed in WP3.
The search for suitable reducing and chelating agents for electroless copper was done. Solubility of lithium borohydrate, borane-trimethyl amine glyoxilic acid, Na-hypophosphite, citric acid and HEDTA were tested in all three ionic liquids.

Task 1.3 "Wafer Material Preparation"

Following wafers were manufactured by IFX and cut by IFX project partners:

- Tantalum barrier: TaN 10 nm / Ta 40 nm
- Tantalum barrier with copper seed layer: TaN 10 nm / Ta 40 nm / Cu 100 nm
- Ruthenium barrier: Ru 5 nm and 50 nm
- Platinum, Gold: 60 – 100 nm, used a reference
- Tantalum barriers with vias for superfilling tests.

IFX has delivered substrate material with barrier/seedlayers on blanket wafers for plating experiments to SEZ, KUL and ELS (see WP3). IFX has delivered substrate material with barrier/seedlayers on structured wafers with trenches for plating experiments to SEZ, KUL and ELS (see WP3).
The same material has also been provided to FELMI and structural and chemical properties, investigated e.g.:

- layer thickness
- crystal structure, texture and grain size
- presence of a tantalum oxide film on the tantalum surface and between tantalum and the deposited copper
- analysis of residual halides.

Stripping tests were performed by KUL and SEZ in deposition baths based on liquid ammonia and ionic liquids to remove the protective Cu layer at different anodic potentials. Small amounts of copper ($4 \cdot 10^{15}$ $Cu \cdot cm^{-2}$) on Ta surface were registered by RBS spectroscopy after stripping.
Several attempts were made to pre-etch the tantalum barrier surface in liquid ammonia and in BMP[Tf_2N] by using by using tetramethylammonium hydroxide (TMAH), NH_4F and other fluoride containing substances.

Results

- Copper plating baths were developed based on liquid ammonia or ionic liquids containing copper salts and other additives.
- Copper deposition from liquid ammonia can be achieved from formulations containing NH_4Br and CuBr capable to meet the required deposition rates.
- Copper deposition from three ionic liquids was achieved after applying vacuum treatment to remove residual water.
- The copper deposition was studied by electrochemical methods and the morphology of the copper deposits was investigated by SEM.
- Solubility of the copper and supporting salts are high enough to meet the required deposition rate and quality.
- Additives have been used to validate good copper adhesion.
- Additives for superfilling have been tested in terms of solubility.

Deviations from Annex 1

Interfacial tantalum oxide layer:
EELS/STEM analysis revealed a thin tantalum oxide layer formed between copper and tantalum. This layer has no impact on the copper adhesion. Based on industry experience, the layer is expected to have no negative impact on electric characteristics of the copper interconnect.
If a negative impact would show up, different approaches are planned to avoid the layer (purification of plating bath by vacuum or chemical treatment) or remove the oxide (reductive plasma or wet etching techniques).

Solubility of additives in ionic liquids:
Solubility tests of copper salts and other additives in ionic liquids proved sufficient solubility at room temperature. Special applications may need higher deposition rates and therefore higher salt concentrations or different additives.
A test of new tetrafluoroborate based ionic liquids is planned to improve the solubility of copper salts and additives. Standard accelerating additive for superfilling - bis(3-sulfopropyl)disulfide (SPS) is soluble only in EMIm[Cl]. Use of ionic liquid mixtures EMIm[Cl] with T_{melt}= 78°C and room-temperature BMP[Tf_2N] ionic liquids can improve the solubility of such compounds.
Solubility tests for new reducing and chelating agents (Ti(III)-chloride, nitrilotriacetic acid etc.) that could be used in the electroless deposition of copper from ionic liquids should be performed.

3.2 WP2: Simulation Based System Quantification and Scale-up

Summary of progress towards objectives

Task 2.1 "Characterisation and validation of deposition model"

Measurements of the polarization curves and the conductivity of the electrolyte have been performed by SEZ. However, due to some technical issues with the reference electrode, the obtained data cannot be used in a consistent way to obtain the polarization data. In agreement between SEZ and Elsyca it was decided to redo some of these experiments and to ensure that the window of operation for the RDE measurements is similar as for the actual plating cell. A new set of experiments and a measuring approach were defined by Elsyca. Based on this new approach SEZ performed the experiments in their lab scale test cell.

Based on these measurements, Elsyca has developed a potential model, including the anodic and cathodic polarization curve, for the non-aqueous copper deposition process. A technical report describing the measurement approach, the potential model and some preliminary simulations has been submitted.

Task 2.2 "Plating cell design for 300 mm prototype"

Simulations have been performed to show the behaviour of a standard fountain plating cell for the non-aqueous copper deposition process. A strong non-uniform deposition is obtained, and the control possibilities are limited.

Simulations of the stray current in the prototype plating cell have been performed. Based on the polarization data obtained by Elsyca from measurements performed at SEZ, the influence of the stainless steel body of the high pressure plating cell was examined. From the simulations it becomes evident that a significant part of the current will flow through the stainless steel walls of the plating chamber. This will also change the current density and deposit thickness distribution over the wafer, making the spread much bigger. To avoid these unwanted effects it is proposed to electrically insulate the stainless steel walls from the plating cell.

Based on simulations an improved concept for the plating cell is proposed, based on a controllable grid of electrodes. From the simulations it is shown that the resulting

uniformity is much better, with a decrease in standard deviation of the deposit thickness from 60% to 6.8%. The new design offers much more options to control the deposition process, both in space and time. It is expected that a non-uniformity of less than 5% over a 300mm is possible.

Based on the same concept further improvements are possible, by optimizing the current on each pen in time, and by using a combination of both anodes and cathodes in the grid. Also, local pattern dependent non-uniformity can be dealt with by the same approach. Simulations have been performed to show the capabilities of this new approach. Based on these results it was decided to adapt the prototype design to incorporate this controllable electrode structure.

Task 2.3 "Design and engineering of cell periphals"

Cormet's objective was the development and design of electrochemical and other peripherals for cell, the manufacturing of the reference electrode and the rotation sealing for the pressurised plating cell (liquid ammonia).

Cormet designed the cell and the ammonia storage tank as well as the rotating electrode instrument in cooperation with SEZ by M12. The cell manufacturing has begun during M10.

The working electrode connection and counter electrode design were designed as a part of the cell. The feasibility of Pd/H_2 and $Ni/NiO/ZrO_2$ solid-state reference electrodes has been studied.

Results

The potential model, including the cathodic and anodic polarization in the relevant process window is obtained from the lab measurements by SEZ.

Based on this model simulations have been performed to design an optimized plating cell. Due to the high non-uniformity of the deposit over the wafer, a new improved cell concept was developed. Simulations on this new concept show that it is very flexible and able to produce very uniform deposits regardless of the seed layer thickness and other inherent non-uniformities in the cell design.

Cormet designed the cell and the ammonia storage tank as well as the rotating electrode instrument in cooperation with SEZ by M12. The cell manufacturing has begun during M10. The cell installation will take place probably during Q1/09.

The working electrode connection and counter electrode design were designed as a part of the cell. The feasibility of Pd/H_2 and $Ni/NiO/ZrO_2$ solid-state reference electrodes has been studied.

Reference electrode candidates must be tested and calibrated using liquid ammonia cells in the future.

Deviations from Annex 1

The reference electrodes have not been manufactured yet. Their design is available, but they cannot be tested and calibrated before the prototype will be available.

3.3 WP3: Copper Deposition from Non-Aqueous Solvents

Summary of progress towards objectives

Task 3.1 "Nucleation and Layer Growth"

The deposition of copper seed layers was investigated in liquid ammonia (SEZ) and pyrrolidinium- and imidazolium-type ionic liquids (KUL). The composition of the plating baths were: CuBr as a copper source, NH_4Br as supporting electrolyte for liquid ammonia bath and BMP[Tf_2N], BMIm[Tf_2N], EMIm[Cl] ionic liquids mixed with copper bistriflimide, chloride and tartrate based salts (0.5 mol·dm^{-3}). Plating tests were made in pure electrolytes and in the presence of additives to obtain the required adhesion and nucleation density. Voltammetric and microscopy analysis showed that copper can be deposited from both liquid ammonia and ionic liquids.

TaN/Ta barriers on blanket wafers, covered with different Cu, Pt, Ru and Au seed layers (provided by IFX and Infineon) were used as substrates for plating experiments. To prevent oxidation of tantalum barriers, the protecting seed layer was anodically removed in-situ in the plating bath. Structural and analytical TEM investigations of Cu deposits were performed by FELMI.

Nucleation in liquid ammonia

The nucleation density was controlled via the nucleation potential, the use of nucleation pulses (again including potential control), and the use of additives.

The nucleation behaviour was studied by performing cyclic voltammetry experiments. Nucleation loops were applied at different cathodic potentials (-0.7 to 6.0 V vs. OCP) resulting in nucleation densities of about 5.10^{11} nuclei per m^{-2}. The deposition potential had a significant influence on the nucleation density, but potentials in the far negative regime yielded severe hydrogen formation with bubbles leading to extremely un-uniform nucleation. Increasing the system pressure by pressurized nitrogen allowed the inhibition of bubble formation, and good results were obtained in the range of -0.8 to -1.0 V. Locally, the nucleation density has been increased to 10^{13} nuclei per m^{-2}. Uniform nucleation densities have not been obtained so far at those potentials on tantalum. Copper deposition on platinum yielded more uniform nucleation.

Pulsing and preconditioning steps have been introduced to improve nucleation uniformity and repeatability. Anodic passivation led to the formation of tantalum oxide, and nucleation was inhibited.

Nucleation of copper in ionic liquids

To prevent the risk of tantalum oxide formation at the interface between Ta barrier and deposited Cu layer, two schemes were investigated:

- Electrodeposition under inert Ar atmosphere (glove box with <0.5 ppm of H_2O and O_2). Ionic liquids cleaned under vacuum at 100°C.
- Electrochemical deposition directly under vacuum (EVD) at < $1{\cdot}10^{-6}$ mbar.

Nucleation of copper on tantalum requires a certain overpotential which leads to a nucleation loop. According to cyclic voltammetry and SEM, stabilization step in Cu[Tf_2N]$_2$ / BMP[Tf_2N] ionic liquids is required to prevent comproportionation. Nucleation tests performed in additive-free Cu[Tf_2N]-BMP[Tf_2N] ionic liquids result in higher nucleation density and formation of much smaller (0.1 µm) crystals than in Cu[Tf_2N]$_2$ containing bath. According to SEM (additive-free electrolyte), the copper layer is not fully

closed even after several minutes of deposition (µm-thick deposits). A series of experiments was made using pulse-reverse deposition (t_p/t_{rp}= 1/2) under vacuum, resulting in formation of nuclei smaller than 30 nm.

In order to increase the nucleation density, the effect of additives was investigated. More than 29 additives were screened by solubility tests. The effect of 13 selected additives (saccharin, polyethylene glycols, benzotriazole, thiourea, 2-picolinic and glyoxilic acids etc.) on copper nucleation and adhesion of deposits was characterized by voltammetry, SEM and adhesion-test. It was found that the behaviour of additives in ionic liquids is different from aqueous electrolytes. Some of the tested additives (saccharin, benzotriazole etc.) do not modify the structure of deposits in ionic liquids. The use of polyethylene glycols (standard suppressor in superfilling) led to the growth of compact nanostructured deposits with 80 nm crystallites. However, the use of only PEG does not lead to the formation of closed Cu seed layers. Very encouraging results were observed using 2-picolinic and glyoxilic acids. Both show tendency for 2D copper growth on Ta barriers. TEM analysis (made by FELMI) of 110 nm thick deposits showed the formation of completely closed copper layers.

In order to control the nucleation density of copper, studies of the early stages of electrocrystallisation were performed by analysing current transients during nucleation. The theory of Scharifker and Hills was applied to estimate the nucleation density from potentiostatic current transients. Calculations were performed for different deposition potentials. According to this model, nucleation densities lie around $3 \cdot 10^9$ nuclei per m^{-2} for copper nucleation from ionic liquids containing additives. At this nucleation density, the copper layer becomes a continuous layer at the thickness around 10 µm. However, the layer is already continuous at a thickness of 110 nm as shown by both SEM and TEM microscopy. Hence, the nucleation density is at least $2.6 \cdot 10^{13}$ nuclei per m^2.

The most recent experiments performed in mixed ionic liquids, where both bistriflimide ($Cu[Tf_2N]$) and chloride anions (EMIm[Cl]) are mixed together, showed that copper can form closed layer already at a thickness below 20 nm! A distinguishing feature of this mixed ionic liquid is that the presence of Cl- allows to dissolve most of the additives.

Task 3.2 "Micromodelling of superfilling"

The objective of task 3.2 is to develop a detailed multi-ion model that takes into account all the relevant phenomena in copper superfilling from non-aqueous solutions. This involves 4 subtasks.

3.2.1. Extension of the electrochemistry solver with basic models for ionic transport in ionic liquids.

The electrochemistry solver was extended with two ionic transport models.

The first one uses the same transport equations as for dilute electrolyte solutions, but the diffusion coefficients are now an exponentially decaying function of the sum of the concentrations of the dissolved species.

The second one is the mean spherical approximation (MSA) and has its origins in statistical mechanics. It assigns an effective diameter to each ion and allows to calculate the activity coefficients and Onsager coefficients that describe the ionic transport. The applicability of the MSA is restricted by the assumption of a continuous solvent. For simple aqueous electrolyte solutions it is applicable up to an electrolyte concentration of

about 1 mol/L. If needed, other (semi-)empirical models for the transport coefficients can be implemented as well.
For obtaining the model parameters, four types of measurements are needed at different concentrations ranging from dilute (10^{-4} M) to moderately concentrated (1 M) or saturation for each individual electrolyte:

- the mean activity coefficient of the electrolyte,
- the specific conductivity (S/m),
- the cation transport number, and
- the mutual diffusion coefficient (m^2/s).

So this subtask is ready. For practical use of some of the models, measurements of electrolytic solutions are to be performed.

3.2.2. Develop a grid generator capable of tackling small spatial scales (up to and smaller than 1 nm).

The geometrical scale at which the models will be applied (nanometers up to a few 100 micrometers) involves particular problems for mesh generation.

A first problems is due to accuracy of the geometrical representation of drawings in a CAD system. SolidWorks for instance rounds of at 1 micrometer. In order to solve this problem for all geometries a scaling process has been introduced for all dimensions (x, y, z). Drawing and grid generation is performed at the higher scale and a special software was developed to convert all dimensions to the right value.
For the moment these modifications involve that we are able to generate unstructured and hybrid grids (grids with controlled structured layers along electrodes and walls that are filled up internally with an unstructured grid) for all two-dimensional geometries (2D and axisymmetrical) and unstructured grids for all three-dimensional geometries. Considering the small size of the geometries that will be modelled, having structured layers is not really critical as we are entirely in the diffusion layer. Nevertheless the development of hybrid three-dimensional grids is ongoing.

3.2.3. Develop and integrate new algorithms describing nucleation and adsorption processes.

A literature study on superfilling mechanisms has been performed. Several mechanisms are possible. They all include the adsorption of additives in one or another way.

It is clear that no specific mechanism can be defined now such that it makes sense to develop a general applicable framework that can deal with all specific situations.

Based on the these considerations a list of modifications to the existing simulation code was constructed:

- A new type of variable must be introduced: the surface fraction for each adsorbate, the number of adsorbates being a parameter.
- Each adsorbate has certain properties: valence, surface diffusion coefficient, maximum surface concentration (Mol/m^2)
- A new type of balance equation must be introduced: the change of the surface fraction with time due adsorption or desorption, incorporation or release from the metal, surface diffusion, surface migration and surface reactions.
- A numerically stable scheme must be found for the discretization of all terms in this equation.

Also the implementation of the electrode reactions must be changed:

- for each electrode reaction it must be specified on which surface fraction it occurs
- oxidizing and reducing agents can be volumetric species or adsorbed species.

These modifications will keep the framework general. We prefer no ad hoc implementations. On the other hand they involve a serious modification of the existing code as one can now consider that there is no longer one computational domain (the electrolyte) with boundary conditions (walls and electrode reactions) but a set of computational domains (the electrolyte and each electrode) that have to be coupled. Electrode reactions become coupling conditions.

A new PhD student started in September 2008 and will work on this subtask.

3.2.4. Integration of electrode shape-change algorithms such that the superfilling process can be modelled.

We did not yet start this subtask as it was also seen as part of the work of the new PhD student.

3.2.5. Identification and validation of model mechanisms and model parameters, for the different Cu deposition baths

In this subtask the models that describe the superfilling mechanisms are identified and quantified. Applying these models in the developed electrochemistry solvers will allow to model superfilling at t=0 and, when coupled with the electrode shape change algorithms, also as a function of time. The validation consists in comparing the simulated profiles with measured profiles.
This work is also related to task 2.1 and D02.4.

NH_3+CuBr bath studied by SEZ
Additive free model
Based on the measured data received from SEZ a multi-ion model has been derived. The main characteristics of this model are: four species: Cu^+, H^+, Br^-, CuBr, one homogeneous reaction ($CuBr <> Cu^+ + Br^-$) and one electrode reaction (Cu^+ reduction).
This model has been used already for multi-ion simulations in microstructures (will be described in D03.2 report) as well as on a larger scale, as needed for task 2.1 and 2.2 (will be described in D02.3 Report).

Additive containing model
So far no data on additive containing baths are available.

Task 3.3 "Cu superfilling of vias and electroless Cu deposition"

Additives for superfilling have been selected, with a focus on species used in aqueous systems. Solubility tests in liquid ammonia and ionic liquids have been performed, showing sufficient solubility. Polyethylene glycol (PEG) and bis(3-sulfopropyl)disulfide (SPS) have been investigated on blanket tantalum surfaces showing a clear trend to increase the nucleation density. Deposition tests were performed on µm-structured Ta wafers with defined trenches (supplied by IFX). It was shown that additives favour conformal deposition inside the vias, nevertheless the superfilling effect of these additives should be investigated more thoroughly by changing the molar ratios and concentrations in order to optimise the suppressing/accelerating effect during deposition.

Performed tests on superfilling on µm-structured wafers show the significant approach to reach superfilling on sub-32 nm scale. The superfilling additives (SPS, PEG) used in aqueous plating baths are soluble in both liquid ammonia and in mixtures of ionic liquid. Preliminary tests on the influence of these additives on nucleation in pure bistriflimide ionic liquids were performed at the beginning of the project. Mixture EMIm[Cl] – Cu[Tf_2N]

was mainly investigated to achieve superfilling due to optimum solubility of both SPS and PEG additives. First tests indicate that SPS works as an accelerator of deposition rate at the bottom of vias. From the SEM analysis it is clear that the copper layer grows selectively at the bottom of structures. Suppression of the deposition rate in presence of PEG still needs to be demonstrated. Formation of smooth seed layer (15-200 nm) in SPS-PEG containing ionic liquid was observed, however further increasing of deposition time leads to formation of microstructured coatings. It is important that the use of PEG in ionic liquids, in comparison to aqueous electrolytes, results in grain refining behaviour instead of inhibition of layer growth (leveling). Well known levelers benzotriazole and dodecyltrimethylammonium chloride should be tested in the future to reach the proper rate of suppressing. Tests on sub 32 nm will be the next step to confirm the superfilling at nanoscale structures.

The following reducing agents were used for electroless copper deposition in ionic liquids: Na-hypophosphite, glyoxilic acid lithium borohydrate, borane-trimethyl amine. Deposition tests were performed mainly in pyrrolidinium-type ionic liquids at 90 °C. As was observed, only lithium borohydrate and borane-trimethyl amine reduce copper in this ionic liquid, while the other reducing agents do not support electroless process even without chelating of copper cations. At present, attempts to form the copper seed layer on Ta barriers and to suppress the spontaneous reduction of copper in the bulk of electrolyte are performed.

Task 3.4 "Grain size enlargement"

At present, no work was done to look at the self-annealing of the deposited layers after deposition.

Results

- Copper deposition was achieved from liquid ammonia and ionic liquids.
- Formation of microcrystalline non closed deposits was found in pure additive-free electrolytes. Presence of Cu(+) cations and use of pulse reverse plating in case of ionic liquids resulted in a decrease of the copper grain size to around 30 nm.
- The effect of 13 selected additives on copper nucleation and adhesion of deposits was studied.
- Tendency for 2D growth and the formation of closed copper layer was observed with 2-picolinic and glyoxilic acids.
- In liquid ammonia, nucleation was controlled by deposition potential, pulsing sequences and additives (PEG, SPS and thiourea).
- Nucleation densities in liquid ammonia have been achieved in the range between 5.10^{11} and 10^{13} nuclei per m^{-2}.
- Estimation of nucleation densities by applying of Scharifker and Hill model to deposits formed in ionic liquids showed a deviation between calculated results (10^9 nuclei per m^{-2}) and experimental data.
- According to SEM and TEM microscopy (110 nm closed layer), the nucleation density is at least $2.6 \cdot 10^{13}$ nuclei per m^{-2}.
- Combination of anions in used ionic liquids (EMIm[Cl]-Cu[Tf_2N]) results in formation of electrochemically stable electrolytes.
- It was shown that EMIm[Cl]-Cu[Tf_2N] ionic liquid inherits the useful properties of both EMIm[Cl] (excellent solubility of compounds) and BMP[Tf_2N]] (liquid at room-temperature) ionic liquids.
- Preliminary list of additives suitable for superfilling is compiled.

- Influence of polyethylene glycol and bis(3-sulfopropyl)disulfide as suppressor/ accelerator additives for superfilling on nucleation density was studied in liquid ammonia and ionic liquids.
- First deposition tests on structured wafers are performed in ionic liquids.
- Different reducing and chelating agents were tested in ionic liquids for electroless deposition.
- Solubility and deposition tests showed that lithium borohydrate and borane-trimethyl amine are prospective reducing agents.
- The extensions of the ionic transport model for ionic liquids have been made and are finished.
- The hybrid grid generator suited for small spatial scales in two dimensions (2D, AX) is ready.
- The unstructured grid generator for small spatial scales in three dimensions (3D) is ready.
- A study of the literature on adsorption and from this a description of the changes to be made to the existing electrochemistry solver is available.
- The identification and quantification of a model for the additive free NH3+CuBr bath has been made. This model is already applied to micro and macro geometries.

Deviations from Annex 1

- Not all aqueous superfilling additives (example: SPS is soluble only in EMIm[Cl]) are soluble in selected IL. Therefore, the solubility of 29 additives was tested in the three selected ionic liquids. The solubility and effect of even more additives will be investigated to find suitable accelerators and depressors of copper deposition from ionic liquids.
- At present, the adhesion of copper deposited from ionic liquids on tantalum is too low. Several attempts to improve the adhesion strengths by increasing the nucleation density and activating the tantalum barrier by anodic activation using small concentrations of fluorides are in progress.
- Nucleation density in liquid ammonia is not uniform. Activation and/or pre-conditioning of the tantalum will be assessed to achieve uniform nucleation.
- Formation of a ~3nm thick oxide layer at the Ta barrier / Cu interface (TEM analysis) results in weak adhesion properties. Wafers were sent to FELMI to find whether oxide appears during wafer production stage or as a result of passivation in ionic liquids.
- It was found that proper chelating agent should be selected to prevent non-controlled reduction of copper in the bulk of the electrolyte. Well-known chelating agents like citric acid, HEDTA, nitrilotriacetic acid are not soluble in bistriflimide ionic liquids. However, all of these chelating compounds are soluble in EMIm[Cl], which will be used in the future electroless deposition tests.
- The electroless processes that were tried out are all based on the Canizzarro reaction which requires the presence of hydroxide ions which can passivate Ta barrier. To initiate electroless reduction on metal surface, potential prepulsing will be tested. Reduction behavior of Ti^{3+}/Ti^{4+} is planned to overcome passivation of tantalum.
- The implementations needed to model superfilling (adsorption) encounter delay due to employment problems. A PhD student started in September. After a training period, he will start with the implementation. Having made clear what the efforts are to implement adsorption, we expect to finish this work at the end of the year, first results will be sooner available. This delay has no influence on other WP's.
- The integration with electrode shape change algorithms encounter delay due to employment problems. At the cost of more manual interventions between two consecutive time steps, the problem of full integration can be circumvented. We believe that the superfilling models deserve priority. Two-dimensional electrode shape changes will be integrated by September 2009. This delay also has no influence on other WP's.

3.4 WP4: Proof-of-Concept

Summary of progress towards objectives

Task 4.1 "Prototype design and building"

The transfer of the results found in work package 3 to full wafers will be focussed on 300 mm. Based on the experience from work with copper deposition tools with aqueous plating bath, SEZ developed a concept to transfer the technology to ammonia based systems. The main difficulty is the design of pressurized chambers and a concept to load and unload the wafer. The design of the prototype has been divided into three major parts:

- design of the pressurized deposition chamber and the mixing tank
- design of piping and instrumentation, including salt ports to bring in solid salts into the system
- design of chuck. This device will be available for 300 as well as 200 mm

Sourcing for all parts except for P&I has been clarified.

Based on the basic dimension limitations from SEZ, ELS performed simulations in WP2 to give guidelines for the design of the deposition chamber. Especially important is the flexibility of the design to accommodate and position the steerable anode. Additionally, the necessary control and feeding network connections need to be positioned through the stainless steel walls of the plating chamber. In close collaboration with COR the necessary connections have been specified and included in the design.

COR has designed the full scale plating chamber prototype and ammonia storage tank. Part of the chamber design is a open/close mechanism which will allow manual and semi-automatic wafer loading. The chamber design contains also connections for liquids and gases as well as for peripherals such as reference electrode and pressure gauge. The manufacturing of the 300 mm deposition chamber and the mixing tank has started. After completion, they will be functionally tested.

A P&I flow sheet has been designed by SEZ, stainless steel tubing and instrumentation materials have been specified, and the evaluation process for sourcing partners has started.

The wafer chuck has been designed by SEZ and a sourcing partner selected.

For prototype building several tests are necessary to obtain optimal functionality from start on. To get best started with the process development on prototype, optimization on the test-reactor has to be done. For the test-reactor evaluation several materials-surfaces were provided by IFX (Pt; Au, Cu, Cu structured, with different barrier layers underneath, Ta, TaN). These samples where sawed mechanically into useful pieces depending on users' needs (KUL, SEZ, ELS). A copy of the samples where delivered to FELMI for detailed analysis. The samples from IFX have been analyzed by FELMI with respect to Ta(/TaN) layer characterization, oxidation of Ta at the interface, $\beta \rightarrow \alpha$ phase transition with and without thermal post-treatment, and oxidation behaviour of α-Ta.

Task 4.2 "Process Integration and Verification"

Process integration will start M16, but preparation work has been accomplished.
Deposition experiments by SEZ have been designed in respect to scalability. KUL contributed design help in up scaling the deposition process developed in WP3 to a full

wafer prototype. Main part of this was to compare theoretical results with experimental results.

Despite its focus on 300 mm, process integration will include 200 mm processing from the beginning. Discussions inside IFX showed that there might not appear a high barrier to restart deposited wafers from outside IFX in integration. This task will rise up in the second half of the project.
Two chucks will be prepared for 200 and 300 mm. The deposition chamber will be capable to run 300 mm. For 200 mm processing, a shield cylinder will be inserted in the chamber. Simulations performed by ELS showed that the shield cylinder will have no negative impact on the fluid flow and current density distributions. As a matter of fact, the process window is expected to be wider for 200 mm.

Task 4.3 "Characterisation and Reliability"

The samples mentioned in Task 4.1 were characterized at FELMI. For reliability measurement on metal lines special test structures were designed. Even down to 20 nm measurements might be possible. The test structure contains straight lines, meander and a normal pad to contact. On one test device "dummy" structures where designed for a copper CMP process to minimize dishing.

Task 4.4 "Roadmap Impact"

Depending on superfilling behaviour the ITRS impact on TSV is given. Technikon started to prepare the knowledge base to work on and develop the roadmap foreseen within the project. The focus of this task is at the end of the project where an outlook will be given on its impact on future technology nodes.

Results

The design of the 300 mm prototype has been finished and manufacturing started. The prototype will consist of a pressurized deposition chamber, a mixing tank, P&I and wafer chuck.
Wafer preparation is ongoing and is serving WP 3 and 5, while the material selection is driven by the requirements for WP 4. Wafer characterization techniques have been investigated also in respect of this work package.

Deviations from Annex 1

Sourcing partner for P&I is still open and manufacturing timelines by COR are not completely visible. Major milestone 2 "Prototype ready for full wafer process" is not expected to be threatened, but full functionality of the prototype may be delayed. The sourcing process has been intensified to ensure delivery in time.

3.5 WP5: Instrumentation and Metrology for Nanocharacterisation

Summary of progress towards objectives

Task 5.1 "Element specific interface analysis"

Task objectives

- Qualify methods for element specific analysis of sub 10nm thick interfacial layers
- Light element analysis (primarily oxygen) in TEM combined with analytical techniques like EELS and EFTEM
- Quantify oxygen concentrations, acquire line scans and diffusion gradient maps
- Optimize acquisition parameters to optimize sensitivity limits
- Employ tomographic techniques to reveal 3D-chemistry

Description of performed work

Task 5.1 represented the focus for this phase of the project, as most of to-date sample-related concerns were falling into this task category. TEM and Scanning TEM turned out to fulfil the requirement to study structural features with the needed high spatial resolution, yet allowing reasonable fast sample characterization for timely process feed-back to the partners. High resolution phase contrast imaging and high-angle annular dark-field STEM techniques as well as electron diffraction techniques (SAED, CBED) could be applied successfully to focused ion beam milled samples, and have provided structural, crystallographic (α,β-Ta, IFX) and chemistry related information on Cu, Ta (/TaN) and interfacial layers. Required layer widths, layer crystallography and chemical composition could be verified and falsified in some cases on differently processed samples from SEZ, KUL and IFX (cf. respective WPs). This was selectively cross-checked with gracing incidence x-ray diffraction GI-XRD. STEM EELS in HAADF mode and EFTEM were employed effectively for the detection of interfacial oxygen layers, grace to its superior light element sensitivity, reaching ~ 1at%, under optimized working conditions. The conditions to achieve good HAADF contrast and EELS sensitivity have been elaborated, and significantly depend on the collected scattering (and convergence) angles and hence on the camera lengths selected, which was found to be ideal at around 100 mm, for sample thicknesses of ~50 nm featuring layer chemistries of this kind. Spectral signal-to-noise for EFTEM could be optimized using 30 eV filtering window widths and 40 µm objective apertures, both minimizing TEM imaging aberrations. Under those conditions, electron probe sizes of typically 0,5 nm in STEM EELS have been stepped over layer (-interfaces) to pick up small oxygen amounts as line scan profiles. The oxygen variation could be extracted by integrating the EELS net intensities and normalization with ionization cross-sections, revealing mostly rather uniform composition within the layer. For many samples that have been processed insufficiently (environmental oxygen, unprotected layers) oxygen layer thicknesses seemed to equilibrate at ~ 3 nm, confirmed by 2D elemental distribution maps via EFTEM (IFX, KUL). Issues like layer cracking (KUL, SEZ), non-flat interfaces (KUL, SEZ), oxidation of Cu along grain boundaries (KUL, IFX) and halide contamination (SEZ) (detected by x-ray spectroscopy), was found on some SEM pre-analyzed samples, and has been reported to the respective partners together with recommendations for improvement. So far more than 30 samples have been fully characterized and the associated analysis reports have been made available to the KUL, IFX and SEZ in the form of presentations followed by discussions.
The implementation of electron tomographic techniques will constitute a focus for the next months within this task. It will be carried out by a PhD student, starting in January 2009. However, this part is not crucial for the project, yet it would be beneficial to gain extra information on fully processed wafers particularly for IFX.

Task 5.2 "Metrology for crystal grain characterisation"

Task objectives

- Explore methods to study grain-structure, -size, -orientation relationships compatible with sub 32 nm technologies
- Stress and strain measurements

Description of performed work

For grain analysis with respect to size (distribution), structure and orientation, crystalline grains of Cu and Ta larger than 50nm, electron back-scatter diffraction EBSD in SEM is established (SEZ), and readily applicable in house, whereas, at present state, for smaller grain sizes hardly any other image forming alternatives exist. As TEM analogues, three possible routes could be identified via literature search combined with initial TEM experiments:

1.) **Circular Scanning Dark-field Diffraction (CS-DFD)**. Angle-resolved dark-field images can be transformed into calculated diffraction patterns that can be analyzed for orientation. As this technique offers both large field-of-view and fairly high spatial resolution (<10 nm) it was followed up more closely. Feasibility of implementation has been proven, and acquisition scripts for an automated illumination angle change plus collection of several hundred DF images have been generated. Issues such as an accurate image stack alignment still needs to be resolved. A test sample was sent out to a lab to check applicability for the sample types covered in this project. Once practicability is demonstrated, a complete installation of the technique is planned.

2.) **Scanning Diffraction Electron Precession (SDEP).** A precessing scanned e-beam is forming more or less kinematic electron diffraction spot patterns, which then can be matched to simulated templates. As this requires expensive hardware additions, attempts will be taken first to delineate its advantages over the other technique by contacting the manufacturer and identifying possible partners for sample test analysis. Obvious disadvantage is the rather limited pixel resolution of the scanned area, so that this technique was not given the utmost attention.

3.) **Scanned Convergent Beam Diffraction Imaging.** In a first step, this technique was implemented by installing software and hardware to allow the acquisition of pixel-based CBED patterns. Grain stress and strain can now be analysed for each pixel ie. CBED pattern individually at nanometer resolution, by comparison to simulated patterns. Continuing efforts will be undertaken to extend this to larger areas.

Task 5.3 "Nano roughness analysis"

Task objectives

- Show up pathways to determine nano-roughness of surfaces, interfaces and sidewalls

Description of performed work

Several pathways have been determined, from which currently an electron microscopic approach via STEM was followed more closely. We were using a (prototype) algorithm, recently introduced by EMETRICOS Inc. (a US start-up) for SEM pictures, able to determine the line-edge roughness based on high-contrast TEM images, employing digital filters. For the first time, input data from FELMI such as HAADF-(S)TEM images were used, from which we could calculate the RMS roughness, the contour length of each edge, as well as the average and RMS variation of the line width on samples from IFX. This

technique offers the advantage to deliver fast results as it is immediately applicable to thin TEM cross-sections, despite being a through projection analysis technique. We consider to extend this approach by combining it with a FIB "slice and view mode" to enable 3D information in the course of this project. The usage of FIB-taylored AFM tips inside especially FIB prepared contacts will be followed as well, but was not yet started.

Task 5.4 "Methods for electrical testing"

At present no work was carried out to look at methods for electrical testing. This task will get more focus once suitable structures have become available.
IFX has internally expertise on reliability measurement. This expertise has to be developed down to 20 nm structures, within a discussion in the project year two. Macroscopic adhesion test is stetted up (pull test). When samples from prototype processing are available, comparisons will be done. Measurement place is under installation (at IFX) to measure thermal conductivity via 3 Omega method which will also give more detailed view on material properties.

Results

Methods

- STEM EELS and EFTEM established as capable techniques for sub-10nm element specific interface analysis. Recognized as most suitable for light element sensitivity wrt. spatial resolution and time-to-result
- Best set of acquisition parameters for quantitative analysis have been identified
- High resolution phase contrast imaging and CBED for structural and crystallographic investigations suitable
- Implemented a quick method to determine interface roughness via STEM
- Methods to study grain sizes, - structures and – orientation via TEM have been found. Presumably CS-DFD will be made available.
- Infrastructure for electron tomography was set up
- Complimentary techniques like GI-XRD for cross-checking TEM results occasionally invoked

Material

- Topics studied: Ta(/TaN) layer characterization (IFX, KUL), influence of electrochemical process parameters on stripping efficiency (KUL), deposit thickness and roughness (KUL), monitoring of deposit thickness and roughness (KUL), influence of vacuum, Ar atmosphere and protection layers (KUL), Cu characterization wrt. Oxidation (SEZ, KUL, IFX), oxidation of Ta at the interface (SEZ, KUL, IFX), $\beta \rightarrow \alpha$ phase transition with and without thermal post-treatment (IFX), oxidation behavior of α-Ta (IFX), observation of formation of closed copper layers (KUL, IFX), nucleation (KUL, SEZ), void formation inside Cu (SEZ, KUL)
- Information on grain size and estimation of nucleation density (KUL).
- Interfacial oxygen between Ta and Cu constituted a problem for several samples independent of provider, ~3 nm thick
- Grain boundary oxidation observed
- Timely process feed back given to SEZ, IFX, KUL

Deviations from Annex 1

No critical failures were identified. So no major deviations encountered or corrections were needed.

3.6 Overview of the use of effort

During the first project year, the project partners have used the following amount of PMs to carry out the work towards the project objectives.
The actual used effort is compared to the average planned effort, which is calculated via a linear calculation of PMs per period while taking into account the starting and ending month of the WP. (For example: WP4 starts on M07 and ends on M30, the total duration of 24 months. In the first period (M01-M12) the WP lasted for 6 months, and therefore to calculate the average planned PMs for first period of WP4, the total planned PMs of WP4 per partner will be multiplied with 6/24.)
So the following table gives an overview of linearly planned person months in comparison to the actual used person months in the first project year.

		TEC	SEZ	ELS	KUL	FELMI	IFX	COR	VUB	TOTAL
WP1: Material requirements and specification*										
Planned	M01-M12	-	8,73	2,18	5,45	2,18	2,18	-	-	20,72
Actual	M01-M12	-	**8,00**	**4,00**	**2,00**	**0,70**	**2,20**	-	-	**16,90**
WP2: Simulation based system quantification and scale-up*										
Planned	M01-M12	-	2,40	8,00	-	-	-	2,00	2,40	14,80
Actual	M01-M12	-	**2,30**	**18,00**	-	-	-	**4,00**	**0,15**	**24,45**
WP3: Copper deposition from non-aqueous solvents										
Planned	M01-M12	-	6,40	-	17,20	3,60	0,80	-	8,40	36,40
Actual	M01-M12	-	**6,10**	-	**6,00**	**3,60**	**0,00**	-	**9,20**	**24,90**
WP4: Proof-of-Concept										
Planned	M01-M12	1,00	5,50	1,50	3,00	1,25	1,50	1,25	-	15,00
Actual	M01-M12	**1,04**	**5,20**	**1,00**	**0,00**	**1,40**	**1,20**	**2,20**	-	**12,04**
WP5: Instrumentation and metrology for nano-characterisation										
Planned	M01-M12	-	2,40	-	2,40	7,20	1,20	-	-	13,20
Actual	M01-M12	-	**2,00**	-	**0,00**	**7,02**	**0,24**	-	-	**9,26**
WP6: Project Management, Dissemination and Standardisation										
Planned	M01-M12	7,60	2,40	0,40	0,40	0,40	0,40	0,40	0,40	**12,40**
Actual	M01-M12	**8,57**	**1,65**	**0,50**	**0,00**	**0,58**	**0,00**	**0,40**	**0,70**	**12,40**
Total Planned PMs		8,60	27,83	12,08	28,45	14,63	6,08	3,65	11,20	112,52
Total Actual PMs		**9,61**	**25,25**	**23,50**	**8,00**	**13,30**	**3,64**	**6,60**	**10,05**	**99,95**

Table 1: Effort table –
Comparison of linearly planned person months and the actual used person months

* Here we want to point out that especially in WP 1 and WP 2 the major part of work was in the first project year and therefore the linear calculation does not correspond to the actual used effort. Due to the fact that the WP-durations continue also after the first project year, a linear calculation was used, although the main work was done in the first year and only a few tasks remain for the next periods.

Relevant explanations of use of person months:

TEC

Technikon was involved in WP4 and WP6. In total at TEC 8,57 person months were spent on management issues and 1,04 person months on research. During the project starting phase especially TEC as the Coordinator and the WP6-Leader committed major effort to get all processes started successfully, the project web pages and IT Infrastructure, presentations and project templates created. This is the reason why we have used approximately 13% more in person months than a linear forecast would allow for the first 12 months. Because of the intensive work at the early phase of the project we expect that the relative overall effort of Technikon will decrease in the next project period. Our efforts within the technical Work packages are according to plan.

SEZ

The focus of SEZ was almost equally on WP1, 3 and 4. Less effort was spent on WP2, 5 and 6. No major deviations occurred for the effort used, but efforts were slightly less then planned for all activities. Being in line with the project objectives, this gives room for additional workload in the second year (focus on WP3 and 4).

ELS

The two work packages WP 1 and WP2 are planned at the beginning of the project. In fact WP1 is already finished and WP2 for a significant part, so it is logical that ELS has spent much more than the linear extrapolation.

KUL

The deviation between the planned (28.45 MM) and actual PM (8 MM) is due to the fact that a PhD student is currently working full time on this project, but is not paid from it. As such, the number of real PM's is in fact 20 MM and not 8. Also, MTM is involved in a KUL project on ionic liquids, involving four other research groups from KULeuven, totaling 10 researchers all working on ionic liquids. The synthesis, physical and chemical characterization of ionic liquids used in this project happens within the framework of this project and are also not charged to this project. Lastly, we have trouble finding personnel with an electrochemical back-ground, but hope to recruit another post-doc for the CopPeR project before the summer of 2009.

FELMI TU Graz

The gap between total planned PMs and actual PMs is due to the delayed, effective start of the project. WP1 activities started slower than expected. Although pre-investigations have been carried out for WP1, relevant process-sample have been received and investigated starting Q4. WP 3,4,5 are roughly in accordance with the expected volume. However, administrative activities in WP6 were somewhat too high.

IFX

Actual person months differ from planned person months due to focus of IFX work in the 2nd part (last 18 month) of the project. IFX is responsible mainly for proof of concept, due to that there must be a working process installed (target is after 1st year).

COR

Instrument design and preparation of drawings has taken considerable time in WP 2 and WP4.

4 Deliverables and milestones

Deliverables (excluding the periodic and final reports)

DELIVERABLES									
Del. no.	**Deliverable name**	**WP no.**	**Lead participant**	**Nature**	**Dissemination level**	**Due delivery date from Annex I**	**Delivered Yes/No**	**Actual / Forecast delivery date**	**Comments**
D 01.1	Definition of requirements for interconnects in accordance to the ITRS	WP02	SEZ	R	PP	M03	Yes	29.05.2008	delivered in time
D 06.1	Project website and internal IT communication infrastructure	WP06	TEC	O	PU	M03	Yes	15.05.2008	delivered in time
D 06.2	Project dissemination Plan	WP06	TEC	R	PU	M04	Yes	13.06.2008	delivered in time
D 02.1	Simplified model for engineering purposes	WP03	ELS	R	PU	M06	Yes	13.08.2008	Improved version of D02.1 delivered on the 08.09.2008

D 01.2	Results Electrolyte Characterisation	WP01	SEZ	R	CO	M09	Yes	15.11.2008	delivered in time
D 01.3	Metrology concept for sub-32 nm structures	WP01	SEZ	R	PP	M09	Yes	21.11.2008	delivered in time
D 03.1	Copper nucleation density control	WP03	KUL	R	CO	M10	Yes	12.12.2008	delivered in time
D 01.4	Update 1 of interconnect requirements	WP01	SEZ	R	PP	M12	Yes	21.01.2009	delivered in time
D 01.5	Studies on behavior of additives on copper deposition	WP01	SEZ	R	CO	M12	Yes	21.01.2009	delivered in time
D 02.2	Reference electrode for pressurized plating chamber	WP02	ELS	D	RE	M12	Yes	21.01.2009	delivered in time
D 02.3	Initial cell design for 300 mm prototype based on electrical potential and fluid flow simulation	WP02	ELS	R	RE	M12	Yes	21.01.2009	delivered in time

Table 2: Deliverables overview table

Milestones

MILESTONES					
Milestone no.	**Milestone name**	**Due achievement date from Annex I**	**Achieved Yes/No**	**Actual / Forecast achievement date**	**Comments**
M 06.1	Project start and kick-off, successful start and all legal requirements ready	M01	Yes	13.02.2008	reached in time
M 06.4	Dissemination environment available (Public project website on-line, IT communication infrastructure implemented)	M03	Yes	15.05.2008	reached in time
M 06.5	Project dissemination Plan completed	M04	Yes	13.06.2008	reached in time
M 01.1	Electrolyte Baseline Definition	M06	Yes	13.08.2008	reached in time
M 01.2	Material Baseline Definition	M09	Yes	21.11.2008	reached in time
M 03.1	Nucleation density of copper suitable for sub 32 nm	M10	No, but in progress	M18	Milestone has been reached partly: nucleation densities that are commensurate with 32 nm vias have been reached in ionic liquids but not yet from liquid ammonia

M 03.2	Working model of superfilling	M10	No, but in progress	M20	Delayed, because the development and integration of the new algorithms is not completed so far, but work is already in progress and parts of the subtasks are finished. No impact on other work.
M 02.1	Cell design for 300 mm prototype	M12	Yes	21.01.2009	reached in time
M 03.3	List of additives suitable for superfilling available	M12	No, but in progress	M20	Milestone has been reached partly: Superfilling of 32 nm vias has been reached, neither from liquid ammonia nor from ionic liquids. However, the superfilling additives (SPS, PEG) used in aqueous plating baths are soluble in both liquid ammonia and in mixtures of ionic liquids.
M 06.2	Annual progress report delivered to EC	M12	Yes	06.02.2009	reached in time

Table 3: Milestones overview table

5 Project management

The major goal of Project Management is to establish a sound basis for a good and fruitful cooperation of the project partners towards the research objectives. This can be realized through providing all the relevant management components like contractual, financial, legal, technical, administrative and ethical issues as well as catching upcoming obstacles well ahead of time. Project Management is an ongoing process, but the main objectives of WP 6 for the first project year were:

- The establishment of efficient management structures and project bodies
- the set-up and maintenance of an internal and external communication infrastructure
- the support of dissemination and standardization activities through structures and processes for dissemination and standardization activities like the project website with event calendar, blogs, wiki and forum and the production of press releases and templates and
- the establishment of an efficient IPR project framework with rules for the use of Foreground, Sideground and Background and it's distribution within the project as well as rules for handling sensitive or confidential information

5.1 Summary of Task 6.1: Project Management

5.1.1 Project management activities

Within Task 6.1 the partners and especially Technikon as the Coordinator and WP6-Leader is responsible for the operational management which comprises administrative, contractual, financial and legal as well as technical and ethical issues.

All partners participated in the daily/quarterly project management activities.

Establishment of Management Structures and Processes

During the first quarter of the project, the project coordinator and all the other CopPeR partners put major effort into the successful launch of the project, where the focus was laid on organisational aspects as well as on the technical infrastructure. TEC acted as the focal point in organisational aspects of getting the project started and provided the technical infrastructure as well as the organisational framework for the cooperation within the CopPeR project.

- **Management structures**

  The General Assembly as well as the Executive Board were constituted during the Kick-off-Meeting. The GA has met twice during the first year; the Executive Board assembled from all WP leaders has also met twice and had in addition three telephone conferences.

- **Preparation, organisation, chairing and moderating project meetings**

  Kick-off Meeting

  The main tasks within the first few weeks of the project included the organisation, preparation, chairing and moderation of the Kick-off meeting (Villach, February 11-13, 2008) to introduce the consortium to the organisational side of the project. Technikon organised, chaired and moderated the meeting. The program of the meeting consisted of the contractual issues, an introduction to the reporting and deliverables, and the establishment of a common understanding of process the project management's practical side. In addition each WP-Leader presented the

plan of his work package. Furthermore, the meeting was used to carry out the first General Assembly meeting to vote on several points, that were important in the beginning of the project, like the composition of the management bodies and votes on the distribution of the pre-financing. In addition also the Executive Board used the opportunity for a first technical meeting.

WP-Leader TELCOs

Furthermore, TEC has organised three WP Leader teleconferences (TELCOS of the Executive Board) in order to cross-correlate the knowledge and effort within the project.

Meetings of the Project Management Team

In addition, the Project Management team (TEC as the Coordinator and the SEZ as the Technical Leader) had 7 meetings and several ad hoc telephone calls for a bilaterial project management update; in these meetings organisational aspects were discussed in detail.

General Assembly Meeting

Technikon also organised, chaired and moderated the 2nd General Assembly Meeting in November in Leuven, where the progress of work and the results of each work package during the first year were reflected on and an outlook of the planned work in the next project phase was done. The local organisational activities were carried out by our project partner VUB.

We provided full meeting minutes for the General Assembly meetings as well as for the telephone conferences of the Executive Board.

- **Contractual issues**

  In the first phase of the project, TEC as the Coordinator took care of the completion of all legal requirements. Because of the formal correctness in the course of an amendment by KUL, a further signature to the Consortium Agreement of all partners was necessary. This process was completed by all partners by the end of March. Nevertheless, technical work started as planned in January. With the finalisation and the signature of the Consortium Agreement by all partners all legal requirements were ready for the CopPeR-project. In addition TEC took care of distributing the contracts and familiarising the partners with obligations within the CopPer project.

- **Monitoring of the project cooperation & continuous risk management**

  The Project Management Team took the lead in monitoring the overall progress of the project. To carry out the monitoring task efficiently TEC established a project-internal control system with regular reports. We introduced an internal intermediate project reporting system with Quarterly Management Reports (QMR). TEC provided the partners with a QMR reporting template to be filled in and added the contributions of all partners into consolidated final quarterly reports.

  In addition the Project Management team kept track of the technical progress via organising and participating in telcos where the technical status/progress was discussed.

Internal & external Communication Infrastructure

In the first half year of the project major efforts were taken to create a common platform for the project consortium to allow for an efficient project information exchange. This includes a common design of templates for project deliverables and reporting as well as the IT infrastructure, which includes the project website, a secure webspace, a file versioning tool and mailing lists.

Technikon has set up and maintained an IT infrastructure composed of a various number of tools on a secure level. The access is structured along a single authentication, maintained and managed by TEC.
Among these tools we have implemented the following IT-services:

- Web Content Management System
- File Versioning System (SVN)
- Realtime Communication (Jabber)
- Mailinglist-Services

The following picture presents the overall architecture of the IT infrastructure:

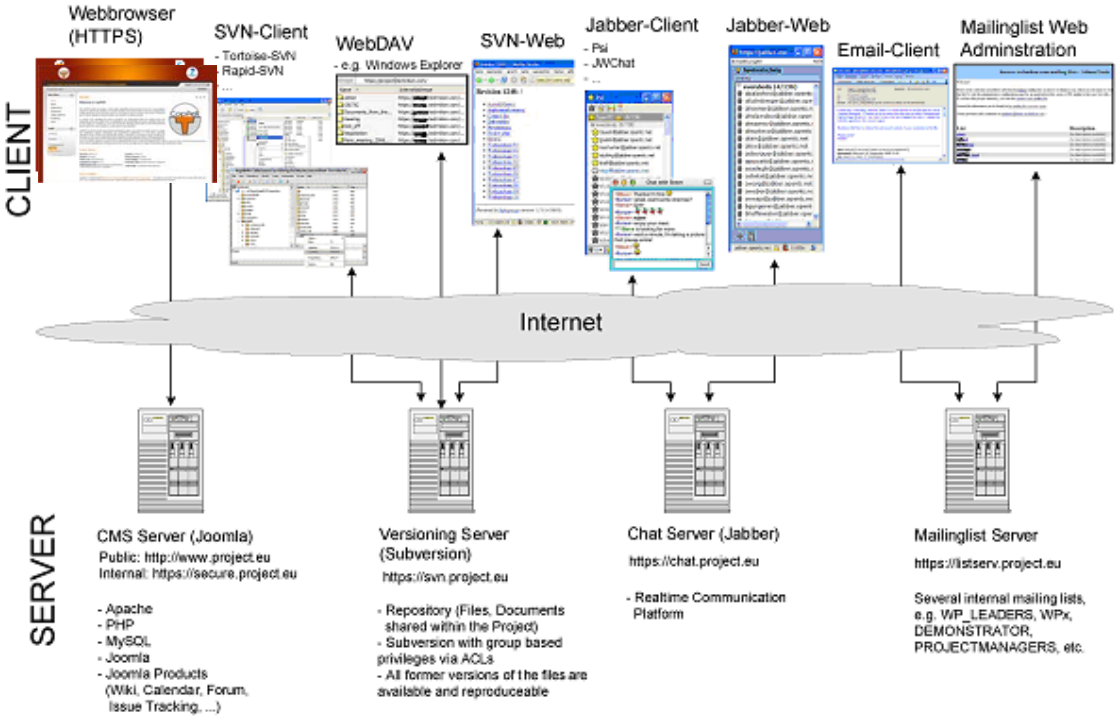


Figure 3: CopPeR project IT infrastructure

- **CopPeR project Website**
  Technikon hosts the CopPeR project website on www.copper-project.eu and has established a website structure, which includes several useful features/functions for general public as well as for the internal use. The project website is the contact point to the public, as well as the internal secure area for storage of project documents like GA, CA, deliverables, press releases or leaflet. The website has to be considered as a dynamic process because it will be supplemented and updated on an ongoing basis during the whole duration of the project.

- **Mailing lists**
  Additionally a mail server is managed providing mailing lists for 10 different project groups. These mailing lists provide convenient information exchange between the pre-defined user groups. The subscription/unsubscription to the mailing lists can be done by each project member directly via the project website. An online archive is provided for all subscribers.

- **SVN**
  For an efficient data exchange TEC installed a File Versioning System (subversion server). The server allows partners to upload and download project documents from a common server, thereby securing fast and efficient information exchange. The SVN functions as a central repository for all project related information and it is easily accessible for the project partners via local clients, the Internet or WebDav.

- **IT-Support**
  In addition to the comprehensive IT infrastructure TEC provided support to CopPeR partners for using the IT-tools; therefore we developed a helpful IT infrastructure tutorial, reworked this tutorial in the course of extensions/upgradings of the IT infrastructure and we provided online support in case of further questions.

Support Service

We keep a close contact to all project partners and WP Leaders. The TEC team is available via mail, telephone or real time communication. In this way TEC serves as a helpdesk for all the other partners for financial, legal and general reporting issues.

Interface between Project Consortium and EC

- **Contact to the EC**
  Technikon is the single contact point between the CopPeR consortium and the EC. For the exchange of sensitive information with the EC and the reviewers (e.g. deliverables, periodic reporting) we have set up a secure workspace.

- **Quality Assurance for Deliverables and Project Plan**
  Technikon edited and monitored all produced deliverables, submitted them to the EC and kept the overall overview of the project plan by monitoring the partners respectively. We also handled the request for additional information on clarification in respect to the CopPeR deliverables.

- **Reporting for the first review**
  Technikon has the overall responsibility to provide the data and reports requested by the contract to the EC. And so we put major effort in the collection of all relevant information for the first periodic reporting. Technikon created personalised templates for financial and organisational reports for the periodic report and all partners provided their contributions to the finalisation of the report.

Financial Issues

- **Distribution of pre-financing**
  Technikon distributed the payment of the first pre-financing tranche to all partners within 7 days after the common decision.

Achievements of WP6

The **main achievements of WP6** in the first project year are/were:

- successful project start
- establishment of all legal requirements and of the contractual framework
- project management structures and processes in place
- a comprehensive IT-infrastructure for the internal & external project communication
- structures & processes for risk management and project controlling
- establishment project marketing tools for external communication and dissemination

- dissemination plan and the realisation of first specific dissemination activities
- 4 milestones achieved and 3 deliverables submitted (including 1st periodic report)
- trusty and lively cooperation
- open and friendly project atmosphere
- main milestones/objectives were achieved and pave the way for a successful second project year

5.1.2 Problems, solutions, changes within the project

Technical challenges

The major challenges during the first year were related to the difficulties due to direct-on-tantalum plating.
Although an efficient way to achieve good copper adhesion on tantalum was known to the project partners at the start of the project, experimental work during the first six months demonstrated the necessity for a strict control of the deposition environment and the cleanliness of the additives used. The issues are solved and documented, but a strict monitoring is required to permit a reliable process.
The formation of a thin oxide layer at the copper – tantalum interface is difficult to avoid. A very strict control of the environment in ionic liquids revealed a solution for this issue, and similar efforts may work in liquid ammonia as well. Additional solutions to this thin oxide layer growth are being discussed - however experimental verification of their implementation to a production process has not been shown. Some efforts within work package 1 and 3 have to be shifted from the first year to the second year.
The condition of the tantalum surface is very important for the early phase of copper deposition as non-uniformities of nucleation showed. Large effort has been made during the first year to introduce pulsing steps and screen additives. However, the milestone for reaching sufficient nucleation densities for sub 32 nm structures has not been reached to date. Significant progress during the last two months looks very promising and is expected to lead to a successful completion of the milestone within the first half year of 2009. The consequence is a shift of work load for work package 3 from the first to the second year.
Difficulties have been also encountered during transfer of the modelling results to the first chamber design. The requirements for pressure (high pressure for ammonia, vacuum for ionic liquids) put limitations on the chamber size. The current design allows for a compromise between chamber volume and deposition uniformity. The concept of a steerable anode will allow for acceptably good results with this design. Additional improvements will be made through the optimization of the liquid inlet and outlet design, resulting however in increased chamber costs. All issues are under control, however the efficiency of the solution can only be proven after the 300 mm prototype is in place.

Challenges regarding project management issues

The project experienced some possible problem-creating issues in the beginning connected to the amendments to the Consortium Agreement that were requested by K.U.Leuven. Although the General Assembly accepted KUL's list of background the repeated signature of all consortium partners was necessary because of the formal correctness with regard to the Consortium Agreement. Nevertheless all

CopPeR partners signed duly and the CopPeR project fulfilled all legal requirements for a successful project start.

March 2008, SEZ became a division of U.S.-headquartered Lam Research Corporation. The acquisition of SEZ through the leading company for dry plasma etch did not have any direct negative effects on the CopPeR project. SEZ remains a corporation located in Villach, Austria.

In the second half of August TEC moderated the re-submission of the Deliverable D02.1 between the receiving party, the technical leader and the responsible WP2 leader. The process lasted for 2½ weeks and was successfully completed.

5.1.3 Project planning and status

The CopPeR project consists of three major phases to support the development of a copper deposition process for semiconductor interconnects on 200 and 300 mm wafers. At the end of each phase, a major milestone has to be reached to ensure the success of the project. The following figure shows an overview of the project phases.

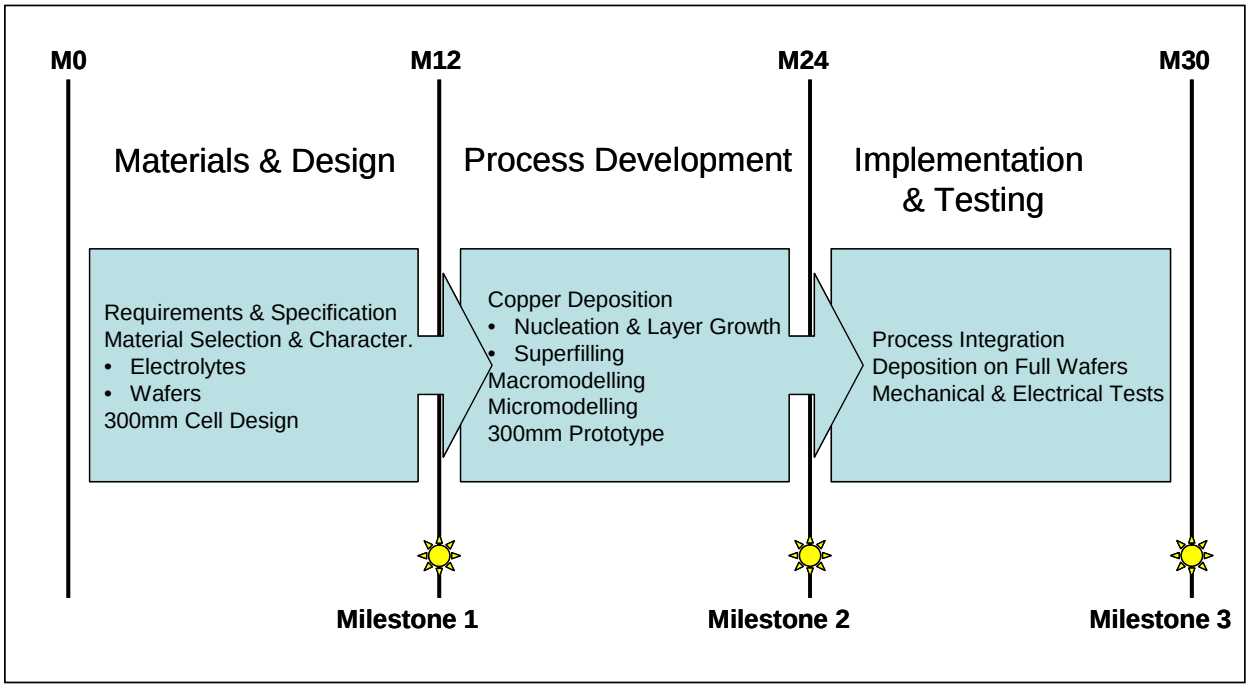


Figure 4: CopPer Project phases

Phase 1 (Months 1-12): Requirements and specifications are defined, electrolyte and wafer materials selected, basic physical properties investigated, and the first 300mm cell design finished.
Phase 2 (Months 7-24): The seedless copper deposition development will take place, supported by macro- and micro-model simulations and nano-characterisation methods, and a 300mm prototype will be manufactured.
Phase 3 (Months 21-30): The copper deposition process will be implemented into a complete interconnect scheme and mechanically and electrically tested on fully integrated test structures.

The 1st CopPeR project year

The first year of the project was dedicated to developments of a deeper understanding of the direct-on-tantalum copper deposition from non-aqueous solvents. Based on these basic investigations, electrochemical modelling provided the geometry baseline of the cell design. The ultimate goal of the first year was the design of the 300 mm prototype chamber.

At the very beginning of the project, work package 1 provided the specifications for the development of work packages 2, 3 and 5. The description of the requirements embraced electrolyte materials used for deposition, the wafer materials used as substrates, and the products – the fully integrated copper interconnect devices.
Based on these requirements, wafer material has been designed and manufactured within work package 4. During the first year deposition experiments have been performed on blanket wafers, but the designs for several types of structured wafers have been provided.
A quick generation of plating results was necessary to provide early information to work package 2. For this reason, the electrolytes have been screened within work package 1 and the copper deposition process on tantalum (and other materials such as platinum) was investigated within work package 3. These results have been shared between the related project partners. Even if not all necessary information was available, a simplified model for the deposition process was generated in work package 2.

The development of the plating process made excellent progress during the first year. The joint efforts within work packages 1 and 3 allowed a clear focus on the materials, electrolytes and deposition additives within this short period of time. Further work on this topic will be necessary in the second year. The work load within these work packages will be shifted continuously for improvements and fine tuning. The current focus is on the improvement of nucleation densities. Other questions, such as deposition rate and adhesion have been solved already, with a couple of issues remaining (such as a thin oxide layer at the copper – tantalum interface).
The results of work package 2 aimed at the design of the 300 mm prototype. The main questions have been answered, such as deposition chamber diameter, electrode distance (related to the chamber height) and possible features to improve the deposition uniformity.
By providing the geometry baseline for the deposition chamber, the first major milestone was reached.

Based on these findings, additional design work for the prototype has been carried out: the design of the deposition chamber connections, a mixing chamber, piping and instrumentation, reference electrodes, and a wafer holder.
At the beginning of the early stages of the project, the wafer materials have been analyzed within work package 5. Early investigations have been done on unprocessed wafers as well as processed wafer pieces. This early work was necessary to assess the available analytical methods, to optimize the related parameters, and to provide critical information about the layers itself: textures, interface layers, elemental composition and more.
The project management was carried out in work package 6. This included IT support and control of the work progress which has been made visible in the deliverables.

The 2nd CopPeR project period (outlook)

During the second year, work package 3 will strongly focus on superfilling of nanostructures. Superfilling is the key technique to allow bottom-up deposition in narrow trenches. While superfilling additives may show similar effects in liquid ammonia as in water, little is known about their behaviour in ionic liquids. Significant effort will also be paid to electroless deposition both in ammonia and ionic liquids. Both topics will be followed at least until month 24.
Work package 2 will optimize the models for deposition by the multi-ion approach on a macro scale in order to improve the chamber design. Parallel to this, work package 3 will apply such models to the micro scale to support the parameter optimization for the copper deposition process.
Within work package 4 the manufacturing of the prototype will be finalized, and copper deposition on full wafers will be demonstrated. The results obtained in work packages 1 and 3 on copper deposition during the first year are sufficient to start working on scaling up the process to 200 and 300 mm. The main activities will be focusing on the deposition rate and uniformity, which will closely relate to the results from work package 2 and may reveal the need for chamber design changes. The transfer of the deposition involving superfilling is not likely to occur before month 24. This will mainly involve results obtained in work package 3 by using superfilling additives and micro modelling approaches.
Work package 5 will face new challenges when small structures will be filled by copper. The focus may shift to crystal grain analysis, but the chemical analysis of layer interfaces may remain important. Current planning assumes all major analytical methods being identified by month 24.
Besides project management activities work package 6 will put the focus on supporting dissemination and standardisation activities.

The major milestones during the next period will be the finalization of the prototype for full wafers (intermediate milestone) and the demonstration of superfilling at the end of the second year.

On the basis of these findings in the last six project months the integration of copper deposition process into a complete interconnect scheme on full wafers will be performed. During these research and development activities the consideration of the needs of industrial chip manufacturers will be of high importance. This work will be accompanied by mechanical and electrical tests of the fully integrated wafers for the technical characterisation as well as for the testing of the reliability. These efforts, which will mainly be made in the work packages 4 and 5 and will result in the last major milestone of the CopPeR project – the proof of concept for the novel copper deposition process, which is based on the use of non-aqueous solvents.

The following deliverables are planned for the 2nd project period:

- D06.3 - Midterm standardisation report (M14)
- D01.6 - 22 nm Damascene demonstrator for superfilling (M15)
- D03.2 - Superfilling model of electrolytic copper deposition from non-aqueous electrolytes (M15)
- D05.1 - Metrology methods for sub 32 nm-structures (M15)
- D03.3 - Conformal electroless Cu deposit from ionic liquids (M18)
- D04.1 - Prototype for full wafer processing (M18)
- D06.4 - Report on IPR status and issues within CopPeR (M18)

- D03.4 - Superconformal electrolytic copper deposit from liquid ammonia (M21)
- D04.2 - Full integrated lot for processing (M21)
- D01.7 - Update 2 of interconnect requirements (M22)
- D02.4 - Identification reduced multi-ion model parameters for the copper deposition process in non-aqueous solutions (M24)
- D04.3 - Report on superfilling on full wafers (M24)
- D05.2 - Studies on chemical interface composition (M24)
- D05.3 - Method for electrical testing (M24)
- D04.4 - Report on results of Copper process on electrical behavior in full integrated lot (M29)
- D02.5 - Improved cell design for 300 mm prototype based on reduced multi-ion model (M30)
- D06.5 - Exploitation Report (M30)
- D06.6 - Report about all external cooperation and dissemination activities (M30)
- D06.7 - Final standardisation report (M30)
- D06.8 - Annual reports according to EC regulations of the model contract (M30)

In addition to the deliverables mentioned above it is aimed to reach the following milestones in the next CopPer project period:

- M06.3 - Technical leader report on Copper design development and strategy released (M14)
- M06.6 - Midterm standardisation report (M14)
- M01.3 - Damascene Structures for Superfilling (M15)
- M03.1 - Nucleation density of copper suitable for sub 32 nm (M18)
- M04.1 - Prototype for full wafer processing available (M18)
- M03.2 - Working model of superfilling (M20)
- M03.3 - List of additives suitable for superfilling available (M20)
- M05.1 - Methods for sub-32 nm interconnect characterisation available (M21)
- M03.4 - Superconformal deposition from liquid ammonia (M22)
- M02.2 - First workable reduced multi-ion model (M24)
- M04.2 - Superfilling on full wafers proved (M24)
- M05.2 - Method for electrical testing available (M24)
- M06.2 - Annual progress report delivered to EC (M24)
- M02.3 - Minimum validation of behaviour (M27)
- M06.3 - Technical leader report on Copper design development and strategy released (M28)
- M04.3 - Proof-of-concept available (M29)
- M06.7 - Final report on ITRS activities ready (M30)
- M06.2 - Annual progress report delivered to EC (M30)

5.1.4 List of project meetings and telephone conferences

During the first project year several project meetings and telephone conferences took place. The following section provides an overview of the CopPeR project meetings and teleconferences that took place during the first project period (M01-M12).

Meeting	Date	Location	Meeting content	Participants
1st project discussion	09.01.2008	SEZ	Getting to know each other; preliminary discussion of the project kick-off	SEZ, TEC
Technical project discussion	11.01.2008	SEZ	Discussion of the technical aspects of the project	SEZ, TEC
Kick-off-preparation-Meeting	08.02.2008	TEC	Final correlation for the Kick-off-Meeting	SEZ, TEC
CopPeR Kick-off Meeting	11.02.2008 - 13.02.2008	Congress Center Villach	Presentation of relevant information; Constitution of the General Assembly and first votes; Introduction of the workplan and WP presentations; Technical Meetings	All partners: TEC, SEZ, ELS, KUL, FELMI, IFX, VUB, COR
WP2-Meeting	15.02.2008	Villach	First discussion on ideas for the wafer plating cell design	SEZ, ELS
WP2-Meeting	03.04.2008	Infineon Regensburg	Visit of plating installations in Regensburg; discussion on wafer plating cell design	IFX, ELS
Meeting on WP5	11.04.2008	FELMI TU Graz	Introduction to FELMI, discussion about WP5 activities, results presentation	SEZ, FELMI, IFX
Project-Management-Team Meeting	21.04.2008	SEZ	Information exchange about the technical and organisational progress of the project; Discussion of the project-website and of the IT-infrastructure	SEZ, TEC
Technical discussion with KUL	30.04.2008	TELCO	Information exchange about analysis results obtained	FELMI, KUL
Project-Management Meeting	14.05.2008	TEC	Two-Way update; Discussion of the status of the project; organisational, technical, financial issues	SEZ, TEC
WP2-Meeting	28.05.2008	Villach	Design of Cell	SEZ, COR and Logitex
WP5-Meeting	11.06.2008	FELMI TU Graz	Discussion concerning analysis needs	FELMI, SEZ
1st WP-Leader-TELCO	16.06.2008	TELCO	Information exchange about the progress of each WP	SEZ, ELS, IFX, FELMI, TEC

WP2-Meeting	23.06.2008 - 24.06.2008	Leuven/Wijgmaal, B (Elsyca offices)	Discussion of necessary data for the simulations	SEZ, ELS
WP3-Meeting	23.06.2008 - 24.06.2008	Leuven	Exchange of information about nucleation experiments and cell design between the ammonia and ionic liquids teams; visit of the research infrastructure of the Dept. MTM of KUL	SEZ, KUL, ELS, VUB
Technical discussion with KUL	30.06.2008	TELCO	Information exchange about analysis results obtained	FELMI, KUL
WP5-Meeting	2nd Quarter		showing proposed test structures and discussing test	FELMI, IFX
Technical discussion with KUL	03.07.2008	TELCO	Information exchange about analysis results obtained	FELMI, KUL
2nd WP-Leader-TELCO	12.08.2008	TELCO	Information exchange about the progress of each WP	SEZ, ELS, KUL, TEC
Proposals for the improvement of the D02.1	27.08.2008	SEZ	Jointly proposals for the optimisation of the rejected D02.1	SEZ, TEC
WP5-Meeting	24.09.2008	FELMI TU Graz	Clarification of sample preparation	FELMI, SEZ
Agenda for General-Assembly-Meeting	24.09.2008	SEZ	Review of a DRAFT-Agenda and discussions about the organisation of the technical meetings	SEZ, TEC
3rd WP-Leader-TELCO	29.09.2008	TELCO	Information exchange about the progress of each WP	SEZ, ELS, KUL, IFX, FELMI, VUB, TEC
WP2-TELCO	01.10.2008	TELCO	Improvement ideas of chamber Design	ELS, SEZ
WP3-TELCO	03.10.2008	TELCO	Status of WP3; Additivities for copper deposition, enhancing the nucleation densities, interpretation of cyclic voltammograms, discussion on morphologies of deposited copper	SEZ, KUL
Technical discussion with KUL	13.10.2008	TELCO	Information exchange about analysis results obtained	FELMI, KUL
Technical discussion with KUL	14.10.2008	TELCO	Information exchange about analysis results obtained	FELMI, KUL
Technical discussion with SEZ	16.10.2008	TELCO	Information exchange about analysis results obtained	FELMI, SEZ

Technical discussion with IFX	17.10.2008	TELCO	Information exchange about analysis results obtained	FELMI, IFX
GA-Preparation Meeting	29.10.2008	SEZ	Discussion and preparation of the General Assembly Meeting	SEZ, TEC
Technical discussion with SEZ	30.10.2008	TELCO	Information exchange about analysis results obtained	FELMI, SEZ
General Assembly Meeting	04.11.2008 - 05.11.2008	Leuven	General Synchronisation, Introduction to the review process (periodic reporting / review meeting), First preparations for the review (review story), Future planning	All partners: TEC, SEZ, ELS, KUL, FELMI, IFX, VUB, COR

Table 4: Project meetings and telephone conferences overview table

5.2 Summary of Task 6.2: Dissemination and Standardisation

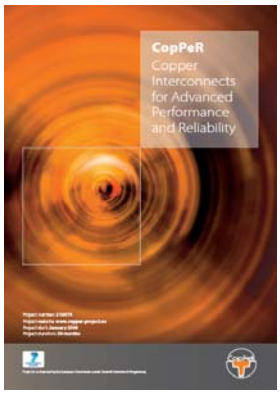
In course of Task 6.2 the focus of work was laid on the establishment of structures and processes for communication and dissemination enabling the transfer of CopPeR related knowledge. In this context the major tasks were:

- production of templates for presentations and publications
- CopPeR project website
- production of an official CopPeR press release
- production of an official CopPeR leaflet
- development of a dissemination plan
- dissemination activities of the various WPs

Below some selected project marketing tools are described in more detail:

- **CopPeR logo**
  For the improvement of the visibility a CopPeR project logo was designed. This logo combines the CopPeR word mark with a figurative mark which outlines the objective of the project (the seedless / direct-on-barrier copper plating). The logo is used on all internal templates as well as on external dissemination tools.

- **CopPeR leaflet**
  The official CopPeR leaflet is a four-sided, informative and graphically appealing A4 flyer which includes the most important general project related information. On the one hand it can be handed out in printed form, e.g. at conferences or other events; on the other hand also an electronic version (e.g. a PDF file) can be circulated. TEC distributed the leaflet to all partners. In addition these leaflets were distributed at various project dissemination events, which are mentioned under heading "Specific dissemination activities". A copy can be downloaded from the public website.



- **CopPeR press release**
  Furthermore, we composed a project start press release. A copy can be downloaded from the public website.

5.2.1 Project website

A first preliminary version of the CopPeR project website with basic information (the project objective, the project phases, and lists of the work packages as well as of the CopPeR-project partners) was already available in M01. However the fully official website was being prepared in parallel.

The official project website of the CopPeR project gives a general introduction to the project. The website is based on the content management system Joomla!, which has been adapted by the integration of an open area for the public and a closed area for the project partners. The usage of a readily available open source solution, which also includes a number of tools for online WYSIWYG editing, and the adaptation of it to the project needs helped to keep the development costs down. The website can be viewed with a standard web browser. The website will be kept alive throughout the project period and a few years afterwards.

The CopPeR project website is available on the following link:
http://www.copper-project.eu.

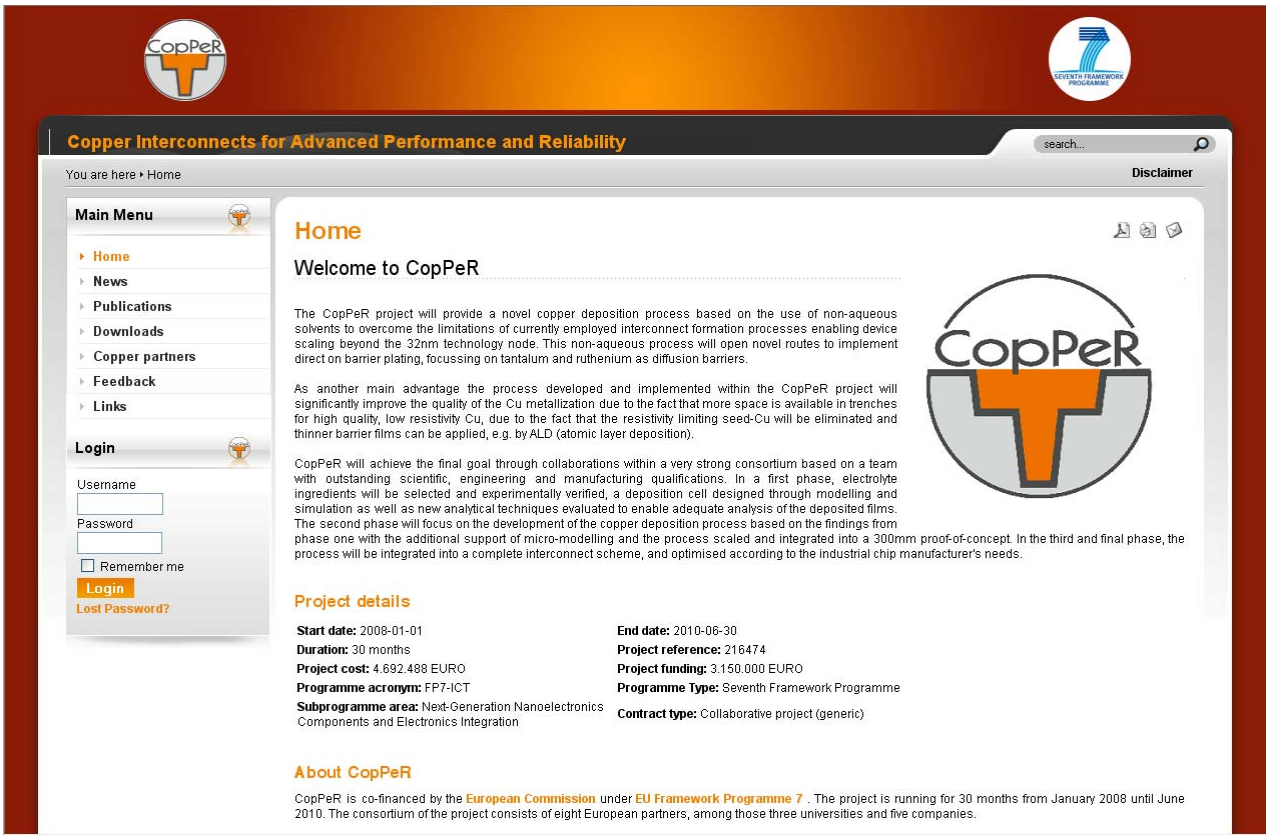


Figure 5: First page of the CopPeR website

The project website serves as the most versatile information and communication tool, because on the one hand it provides the opportunity to provide information for a worldwide audience and enables on the other hand a comprehensive provision of information as well as a platform for the project team. So the website's structure aims to provide both easily accessible basic information for external visitors and special information in more detail for registered users.

The webpage informs the users about general information about the CopPeR project, its activities and its achievements as well as background information, contact details and events. It informs the visitor about the project partners and through clicking on the name/logo of a partner the user can reach the adequate homepage of the company. Furthermore publications can be downloaded and useful links are given.

Parallel to the general accessible area there is a special domain on the CopPeR website with password protected pages and thus made accessible to selected individuals and/or groups. So the website also serves as a platform of the project and may be used by the CopPeR members for internal communication. Only registered CopPeR partners with username and password can use this special user menu and can benefit from the options offered there: e.g.:

- Calendar for appointments and meetings,
- Forum for information exchange concerning special topics,
- Wiki function to post and to deal with some articles,
- Mailing lists for reaching special mailing groups

5.2.2 Dissemination activities during the first project year

- **Dissemination plan**
  TEC and all the other partners were involved in the creation and editing of the dissemination plan, where the main planned contributions of all partners where collected and put together.

- **Specific dissemination activities:**
  - **Open Space for European Research**
    Representing partner: TEC
    Location: Vienna
    Date: April 2008
    → Public event organised by the Austrian Government, where the CopPeR project was publicly displayed as an outstanding ICT project

  - **9th Flemish Congress of Young Chemists**
    Representing partner: KUL
    Location: Antwerpen
    Date: April 2008
    → Title of the talk: "Electrochemische vacuümdepositie (EVD) uit Ionische Vloeistoffen"

  - **Presentation of "CopPeR" at TU Graz seminar**
    Representing partner: FELMI TU Graz
    Location: Graz
    Date: April 2008

  - **Conference "EUCHEM 2008"**
    Representing partner: KUL
    Location: Copenhagen
    Date: August 2008
    → Title of the talk: "Direct Cu-on-Ta electroplating from ionic liquids in high vacuum"

  - **ICT4you**
    Representing partner: TEC
    Location: Vienna
    Date: October 2008
    → distribution of leaflets at an ICT information booth

  - **ICT Meeting Lyon 2008**
    Representing partner: TEC
    Location: Lyon
    Date: November 2008
    → distribution of leaflets

5.3 Summary of Task 6.3: IPR and Exploitation framework

The acquisition of SEZ by Lams caused a short uncertainty until it became clear that the European company SEZ was sustained without any impact for the project.

We established an efficient IPR project framework to maximise project exploitation. The contractual basis is laid down in our Consortium Agreement where explicit rules for use of Foreground, Sideground and Background and its distribution within the project as well as rules for handling sensitive or confidential information were established.

At the beginning of the project year KUL made an amendment to Annex 4 of the GA with a list of background, which has been added in order to be excluded from obligations to grant access rights. This amendment has been accepted by a vote of the General Assembly. But because of the formal correctness with regard to the Consortium Agreement whereby all amendments and modifications to this Consortium Agreement require the signature of all parties, the Coordinator organised a second round of signature, which has been completed in the first quarter of the year.

Apart from that no special moderation of disputes was needed during the first year.

In the first project year also two patents have been filed:

- A patent on the "controllable anode structure", dealing with the way to control the current and to determine the pattern in time has been filed by ELS.
- A patent on the "deposition from ionic liquids", dealing with the direct deposition of copper on tantalum barriers from ionic liquids was filed by KUL. SEZ is in the process of filing this patent worldwide.

6 Explanation of the use of resources

SEZ

Work package(s)	Cost items	Amount (in €)	Explanations
1, 2, 3, 4, 5	Personnel	251.971,00	Salaries of research engineers and managers for electrochemical experiments, hardware engineering, and related scientific work
1, 3	Personnel	32.880,00	Salaries of one post-doc student and one consultant for electrochemical experiments according to GA II.14/15
6	Personnel	22.773,00	Salaries of research manager (technical leader) for project management
1, 2, 3	Equipment	27.312,00	Deposition cell, piping & instrumentation, electrochemical analyzer
1, 3	Consumables	9.480,00	Chemicals and Wafers
1, 3	other costs	29.454,00	Costs for metrology, analysis, patent fees
2, 3, 5, 6	Travels	12.106,00	Workpackage-Meetings in Leuven (1 person) and in Graz (3 persons), GA-Meeting in Leuven (3 persons)
TOTAL DIRECT COSTS (as in FormC)		**385.976,00**	

Table 5: Use of resources partner SEZ

ELS

Work package(s)	Cost items	Amount (in €)	Explanations
1,2,4,6	Personnel	165.260,88	11,5 MM Gert Nelissen, 12 MM Bart Van den Bossche
2	Legal/IP Advise	2.101,00	Prepation of patent on controllable anode structure
2,6	Travel	2.300,00	Kick-off meeting (1 person, Villach), WP meetings (Regensburg, Leuvenx2)
2	Equipment	4.042,50	Calculation computer
2	Patent office	8.657,00	Preparation and submission of patent on controllable anode structure
TOTAL DIRECT COSTS (as in FormC)		**182.361,38**	

Table 6: Use of resources partner ELS

KUL

Work package(s)	Cost items	Amount (in €)	Explanations
1,3	Personnel	44.190,25	Salary of researcher for 8 months
1,3	Equipment	14.177,48	PC, Glove box, pumpsystem
6	Travels	972,24	kick-off meeting, KM-vergoeding binnenland, congres Leuven 11/2008
1,3	Remaining direct costs	28.587,43	chemicals, spare-parts, etc...
TOTAL DIRECT COSTS (as in FormC)		**87.927,40**	

Table 7: Use of resources partner KUL

IFX

Work package(s)	Cost items	Amount (in €)	Explanations
1, 4, 5	Personnel	29.072,60	3,64 PMs
TOTAL DIRECT COSTS (as in FormC)		**29.072,60**	

Table 8: Use of resources partner IFX

FELMI TU Graz

Work package(s)	Cost items	Amount (in €)	Explanations
1,3,4,5,6	Personnel	56.271,74	incl. Project PhD, as well as FELMI stuff (professor and coworkers)
5	Equipment	23.000,00	Sample holder to implement electrn tomography
6	Travel	2.627,25	Travel to Kick-off, GA meeting and to Dresden workshop on CS-DFD
1,3,4,5	Remaining direct costs	39.826,34	Costs for the usage of TU instrumentation (microscopes)
TOTAL DIRECT COSTS (as in FormC)		**121.725,33**	

Table 9: Use of resources partner FELMI TU Graz

TEC

Work package(s)	Cost items	Amount (in €)	Explanations
4,6	Personnel	58.162,90	Salaries of staff employed by Technikon (1 project leader + 2 research engineers), plus 2 master students
4,6	Travels	3.118,78	General Assembly meeting in Leuven (2 people) Presentation of Copper in Vienna 2x (Open Space and ICT4you); Meetings organized by the Austrian Ministry for Innovation (1 person); Workshop in Villach (1 person); Research travels 4x (1 person)
6	Remaining direct costs	787,20	Postage fees (sending contracts to partners, deliverables to EC); Printing and layout fees (project brochure, poster); Project website domain fee
TOTAL DIRECT COSTS (as in FormC)		**62.068,88**	

Table 10: Use of resources partner TEC

VUB

Work package(s)	Cost items	Amount (in €)	Explanations
2, 3, 6	Personnel	38.237,08	Salaries of VUB staff employed within the CopPeR project
6	Travel	1.630,90	Kick-off meeting; GA-Meeting
6	Remaining direct costs	812,50	Organisational expenses of the General Assembly Meeting
TOTAL DIRECT COSTS (as in FormC)		**40.680,48**	

Table 11: Use of resources partner VUB

COR

Work package(s)	Cost items	Amount (in €)	Explanations
2, 4, 6	Personnel	46.207,70	According to Cormet's working hour record
2	Technical meetings	3.028,47	Internal meeting in Finland (1 person), technical meeting in Villach (2 persons)
6	Project meetings	1.195,71	Kick-off meeting (1 person), GA meeting (1 person)
TOTAL DIRECT COSTS (as in FormC)		**50.431,88**	

Table 12: Use of resources partner COR

7 Financial statements

The following table gives an overview of the EC contribution requested by the CopPeR partners for the first project year.

Beneficiary	Organisation short name	EC contribution requested for the first project year	Partner's total funding budget as planned in Annex 1
1	TEC	95.280.-	251.015,50
2	SEZ	286.974.-	779.351,50
3	ELS	220.234.-	359.502,25
4	KUL	105.512.-	641.929,75
5	FELMI	147.697.-	525.452,50
6	IFX	26.416.-	245.917,50
7	COR	60.518.-	187.990,00
8	VUB	48.816.-	158.841,00
Total requested funding		**991.447.-**	**3.150.000,00**

Table 13: Overview of requested contribution for year 1

On the next few pages you can find the separate financial statements from all CopPeR beneficiaries:

FP7 - Grant Agreement - Annex VI - Collaborative project

Form C - Financial Statement (to be filled in by each beneficiary)

Project Number	216474	Funding scheme	Collaborative project
Project Acronym	CopPeR		
Period from	01/01/2008	Is this an adjustment to a previous statement ?	No
To	31/12/2008		
Legal Name	TECHNIKON FORSCHUNGS- UND PLANUNGSGESELLSCHAFT MBH	Participant Identity Code	999761735
Organisation short Name	TECHNIKON	Beneficiary nr	1
Funding % for RTD activities (A)	75	If flate rate for indirect costs, specify %	60

1. Declaration of eligible costs/lump sum/flate-rate/scale of unit (in €)

	Type of Activity				
	RTD (A)	Demonstration (B)	Management (C)	Other (D)	Total (A+B+C+D)
Personnel costs	9,213	0	48,950	0	58,163
Subcontracting	0	0	0	0	0
Other direct costs	860	0	3,046	0	3,906
Indirect costs	6,043	0	31,197	0	37,240
Total costs	16,116	0	83,193	0	99,309
Maximum EC contribution	12,087	0	83,193	0	95,280
Requested EC contribution					95,280

2. Declaration of receipts

Did you receive any financial transfers or contributions in kind, free of charge from third parties or did the project generate any income which could be considered a receipt according to Art.II.17 of the grant agreement ?	No
If yes, please mention the amount (in €)	

3. Declaration of interest yielded by the pre-financing (to be completed only by the coordinator)

Did the pre-financing you received generate any interest according to Art.II.19 ?	Yes
If yes, please mention the amount (in €)	8,127

4. Certificate on the methodology

Do you declare average personnel costs according to Art.II.14.1 ?			No
Is there a certificate on the methodology provided by an independent auditor and accepted by the Commission according to Art.II.4.4 ?			No
Name of the auditor		Cost of the certificate (in €), if charged under this project	

5. Certificate on the financial statements

Is there a certificate on the financial statements provided by an independent auditor attached to this financial statement according to Art.II.4.4 ?			No
Name of the auditor		Cost of the certificate (in €)	

6. Beneficiary's declaration on its honour

We declare on our honour that:

- the costs declared above are directly related to the resources used to attain the objectives of the project and fall within the definition of eligble costs specified in Articles II.14 and II.15 of the grant agreement, and, if relevant, Annex III and Article 7 (special clauses) of the grant agreement;

- the receipts declared above are the only financial transfers or contributions in kind, free of charge, from third parties and the only income generated by the project which could be considered as receipts according to Art.II.17 of the grant agreement;

- the interest declared above is the only interest yielded by the pre-financing which falls whithin the definition of Art.II.19 of the grant agreement;

- there is full supporting documentation to justify the information hereby declared. It will be made available at the request of the Commission and in the event of an audit by the Commission and/or by the Court of Auditors and/or their authorised representatives.

Figure 6: FormC of TEC

FP7 - Grant Agreement - Annex VI - Collaborative project

Form C - Financial Statement (to be filled in by each beneficiary)

Project Number	216474	Funding scheme	Collaborative project
Project Acronym	CopPeR		
Period from	01/01/2008	Is this an adjustment to a previous statement ?	No
To	31/12/2008		
Legal Name	SEZ AG	Participant Identity Code	999762511
Organisation short Name	SEZ	Beneficiary nr	2
Funding % for RTD activities (A)	50	If flate rate for indirect costs, specify %	N/A

1. Declaration of eligible costs/lump sum/flate-rate/scale of unit (in €)

	Type of Activity				
	RTD (A)	Demonstration (B)	Management (C)	Other (D)	Total (A+B+C+D)
Personnel costs	284,851	0	22,773	0	307,624
Subcontracting	0	0	0	0	0
Other direct costs	78,352	0	0	0	78,352
Indirect costs	142,425	0	11,387	0	153,812
Total costs	505,628	0	34,160	0	539,788
Maximum EC contribution	252,814	0	34,160	0	286,974
Requested EC contribution					286,974

2. Declaration of receipts

Did you receive any financial transfers or contributions in kind, free of charge from third parties or did the project generate any income which could be considered a receipt according to Art.II.17 of the grant agreement ?	No
If yes, please mention the amount (in €)	

4. Certificate on the methodology

Do you declare average personnel costs according to Art.II.14.1 ?			Yes
Is there a certificate on the methodology provided by an independent auditor and accepted by the Commission according to Art.II.4.4 ?			No
Name of the auditor		Cost of the certificate (in €), if charged under this project	

5. Certificate on the financial statements

Is there a certificate on the financial statements provided by an independent auditor attached to this financial statement according to Art.II.4.4 ?			No
Name of the auditor		Cost of the certificate (in €)	

6. Beneficiary's declaration on its honour

We declare on our honour that:

- the costs declared above are directly related to the resources used to attain the objectives of the project and fall within the definition of eligble costs specified in Articles II.14 and II.15 of the grant agreement, and, if relevant, Annex III and Article 7 (special clauses) of the grant agreement;

- the receipts declared above are the only financial transfers or contributions in kind, free of charge, from third parties and the only income generated by the project which could be considered as receipts according to Art.II.17 of the grant agreement;

- the interest declared above is the only interest yielded by the pre-financing which falls whithin the definition of Art.II.19 of the grant agreement;

- there is full supporting documentation to justify the information hereby declared. It will be made available at the request of the Commission and in the event of an audit by the Commission and/or by the Court of Auditors and/or their authorised representatives.

Figure 7: FormC of SEZ

FP7 - Grant Agreement - Annex VI - Collaborative project

Form C - Financial Statement (to be filled in by each beneficiary)

Project Number	216474	Funding scheme	Collaborative project
Project Acronym	CopPeR		
Period from	01/01/2008	Is this an adjustment to a previous statement ?	No
To	31/12/2008		
Legal Name	ELSYCA NV	Participant Identity Code	999721286
Organisation short Name	ELSYCA SA	Beneficiary nr	3
Funding % for RTD activities (A)	75	If flate rate for indirect costs, specify %	60

1. Declaration of eligible costs/lump sum/flate-rate/scale of unit (in €)

	Type of Activity				
	RTD (A)	Demonstration (B)	Management (C)	Other (D)	Total (A+B+C+D)
Personnel costs	161,761	0	3,500	0	165,261
Subcontracting	0	0	0	0	0
Other direct costs	17,101	0	0	0	17,101
Indirect costs	107,317	0	2,100	0	109,417
Total costs	286,179	0	5,600	0	291,779
Maximum EC contribution	214,634	0	5,600	0	220,234
Requested EC contribution					220,234

2. Declaration of receipts

Did you receive any financial transfers or contributions in kind, free of charge from third parties or did the project generate any income which could be considered a receipt according to Art.II.17 of the grant agreement ?	No
If yes, please mention the amount (in €)	

4. Certificate on the methodology

Do you declare average personnel costs according to Art.II.14.1 ?			No
Is there a certificate on the methodology provided by an independent auditor and accepted by the Commission according to Art.II.4.4 ?			No
Name of the auditor		Cost of the certificate (in €), if charged under this project	

5. Certificate on the financial statements

Is there a certificate on the financial statements provided by an independent auditor attached to this financial statement according to Art.II.4.4 ?			No
Name of the auditor		Cost of the certificate (in €)	

6. Beneficiary's declaration on its honour

We declare on our honour that:

- the costs declared above are directly related to the resources used to attain the objectives of the project and fall within the definition of eligble costs specified in Articles II.14 and II.15 of the grant agreement, and, if relevant, Annex III and Article 7 (special clauses) of the grant agreement;

- the receipts declared above are the only financial transfers or contributions in kind, free of charge, from third parties and the only income generated by the project which could be considered as receipts according to Art.II.17 of the grant agreement;

- the interest declared above is the only interest yielded by the pre-financing which falls whithin the definition of Art.II.19 of the grant agreement;

- there is full supporting documentation to justify the information hereby declared. It will be made available at the request of the Commission and in the event of an audit by the Commission and/or by the Court of Auditors and/or their authorised representatives.

Figure 8: FormC of ELS

FP7 - Grant Agreement - Annex VI - Collaborative project

Form C - Financial Statement (to be filled in by each beneficiary)

Project Number	216474	Funding scheme	Collaborative project
Project Acronym	CopPeR		
Period from	01/01/2008	Is this an adjustment to a previous statement ?	No
To	31/12/2008		
Legal Name	KATHOLIEKE UNIVERSITEIT LEUVEN	Participant Identity Code	999991334
Organisation short Name	KUL	Beneficiary nr	4
Funding % for RTD activities (A)	75	If flate rate for indirect costs, specify %	60

1. Declaration of eligible costs/lump sum/flate-rate/scale of unit (in €)

	Type of Activity				
	RTD (A)	Demonstration (B)	Management (C)	Other (D)	Total (A+B+C+D)
Personnel costs	44,190	0	0	0	44,190
Subcontracting	0	0	0	0	0
Other direct costs	43,737	0	0	0	43,737
Indirect costs	52,756	0	0	0	52,756
Total costs	140,683	0	0	0	140,683
Maximum EC contribution	105,512	0	0	0	105,512
Requested EC contribution					105,512

2. Declaration of receipts

Did you receive any financial transfers or contributions in kind, free of charge from third parties or did the project generate any income which could be considered a receipt according to Art.II.17 of the grant agreement ?	No
If yes, please mention the amount (in €)	

4. Certificate on the methodology

Do you declare average personnel costs according to Art.II.14.1 ?			No
Is there a certificate on the methodology provided by an independent auditor and accepted by the Commission according to Art.II.4.4 ?			No
Name of the auditor		Cost of the certificate (in €), if charged under this project	

5. Certificate on the financial statements

Is there a certificate on the financial statements provided by an independent auditor attached to this financial statement according to Art.II.4.4 ?			No
Name of the auditor		Cost of the certificate (in €)	

6. Beneficiary's declaration on its honour

We declare on our honour that:

- the costs declared above are directly related to the resources used to attain the objectives of the project and fall within the definition of eligble costs specified in Articles II.14 and II.15 of the grant agreement, and, if relevant, Annex III and Article 7 (special clauses) of the grant agreement;

- the receipts declared above are the only financial transfers or contributions in kind, free of charge, from third parties and the only income generated by the project which could be considered as receipts according to Art.II.17 of the grant agreement;

- the interest declared above is the only interest yielded by the pre-financing which falls whithin the definition of Art.II.19 of the grant agreement;

- there is full supporting documentation to justify the information hereby declared. It will be made available at the request of the Commission and in the event of an audit by the Commission and/or by the Court of Auditors and/or their authorised representatives.

Figure 9: FormC of KUL

FP7 - Grant Agreement - Annex VI - Collaborative project

Form C - Financial Statement (to be filled in by each beneficiary)

Project Number	216474	Funding scheme	Collaborative project
Project Acronym	CopPeR		
Period from	01/01/2008	Is this an adjustment to a previous statement ?	No
To	31/12/2008		

Legal Name	TECHNISCHE UNIVERSITAET GRAZ	Participant Identity Code	999977948
Organisation short Name	TU GRAZ	Beneficiary nr	5

Funding % for RTD activities (A)	75	If flate rate for indirect costs, specify %	60

1. Declaration of eligible costs/lump sum/flate-rate/scale of unit (in €)

	Type of Activity				
	RTD (A)	Demonstration (B)	Management (C)	Other (D)	Total (A+B+C+D)
Personnel costs	52,205	0	4,067	0	56,272
Subcontracting	0	0	0	0	0
Other direct costs	65,454	0	0	0	65,454
Indirect costs	70,595	0	2,440	0	73,035
Total costs	188,254	0	6,507	0	194,761
Maximum EC contribution	141,190	0	6,507	0	147,697
Requested EC contribution					147,697

2. Declaration of receipts

Did you receive any financial transfers or contributions in kind, free of charge from third parties or did the project generate any income which could be considered a receipt according to Art.II.17 of the grant agreement ?	No
If yes, please mention the amount (in €)	

4. Certificate on the methodology

Do you declare average personnel costs according to Art.II.14.1 ?			No
Is there a certificate on the methodology provided by an independent auditor and accepted by the Commission according to Art.II.4.4 ?			No
Name of the auditor		Cost of the certificate (in €), if charged under this project	

5. Certificate on the financial statements

Is there a certificate on the financial statements provided by an independent auditor attached to this financial statement according to Art.II.4.4 ?			No
Name of the auditor		Cost of the certificate (in €)	

6. Beneficiary's declaration on its honour

We declare on our honour that:

- the costs declared above are directly related to the resources used to attain the objectives of the project and fall within the definition of eligble costs specified in Articles II.14 and II.15 of the grant agreement, and, if relevant, Annex III and Article 7 (special clauses) of the grant agreement;

- the receipts declared above are the only financial transfers or contributions in kind, free of charge, from third parties and the only income generated by the project which could be considered as receipts according to Art.II.17 of the grant agreement;

- the interest declared above is the only interest yielded by the pre-financing which falls whithin the definition of Art.II.19 of the grant agreement;

- there is full supporting documentation to justify the information hereby declared. It will be made available at the request of the Commission and in the event of an audit by the Commission and/or by the Court of Auditors and/or their authorised representatives.

Figure 10: FormC of FELMI

FP7 - Grant Agreement - Annex VI - Collaborative project

Form C - Financial Statement (to be filled in by each beneficiary)

Project Number	216474	Funding scheme	Collaborative project
Project Acronym	CopPeR		
Period from	01/01/2008	Is this an adjustment to a previous statement ?	No
To	31/12/2008		
Legal Name	INFINEON TECHNOLOGIES AG	Participant Identity Code	999978918
Organisation short Name	INFINEON	Beneficiary nr	6
Funding % for RTD activities (A)	50	If flate rate for indirect costs, specify %	N/A

1. Declaration of eligible costs/lump sum/flate-rate/scale of unit (in €)

	Type of Activity				
	RTD (A)	Demonstration (B)	Management (C)	Other (D)	Total (A+B+C+D)
Personnel costs	29,073	0	0	0	29,073
Subcontracting	0	0	0	0	0
Other direct costs	0	0	0	0	0
Indirect costs	23,760	0	0	0	23,760
Total costs	52,833	0	0	0	52,833
Maximum EC contribution	26,416	0	0	0	26,416
Requested EC contribution					26,416

2. Declaration of receipts

Did you receive any financial transfers or contributions in kind, free of charge from third parties or did the project generate any income which could be considered a receipt according to Art.II.17 of the grant agreement ?	No
If yes, please mention the amount (in €)	

4. Certificate on the methodology

Do you declare average personnel costs according to Art.II.14.1 ?			No
Is there a certificate on the methodology provided by an independent auditor and accepted by the Commission according to Art.II.4.4 ?			No
Name of the auditor		Cost of the certificate (in €), if charged under this project	

5. Certificate on the financial statements

Is there a certificate on the financial statements provided by an independent auditor attached to this financial statement according to Art.II.4.4 ?			No
Name of the auditor		Cost of the certificate (in €)	

6. Beneficiary's declaration on its honour

We declare on our honour that:

- the costs declared above are directly related to the resources used to attain the objectives of the project and fall within the definition of eligble costs specified in Articles II.14 and II.15 of the grant agreement, and, if relevant, Annex III and Article 7 (special clauses) of the grant agreement;

- the receipts declared above are the only financial transfers or contributions in kind, free of charge, from third parties and the only income generated by the project which could be considered as receipts according to Art.II.17 of the grant agreement;

- the interest declared above is the only interest yielded by the pre-financing which falls whithin the definition of Art.II.19 of the grant agreement;

- there is full supporting documentation to justify the information hereby declared. It will be made available at the request of the Commission and in the event of an audit by the Commission and/or by the Court of Auditors and/or their authorised representatives.

Figure 11: FormC of IFX

FP7 - Grant Agreement - Annex VI - Collaborative project

Form C - Financial Statement (to be filled in by each beneficiary)

Project Number	216474	Funding scheme	Collaborative project
Project Acronym	CopPeR		
Period from	01/01/2008	Is this an adjustment to a previous statement ?	No
To	31/12/2008		

Legal Name	CORMET OY	Participant Identity Code	999739134
Organisation short Name	COR	Beneficiary nr	7

Funding % for RTD activities (A)	75	If flate rate for indirect costs, specify %	60

1. Declaration of eligible costs/lump sum/flate-rate/scale of unit (in €)

	Type of Activity				
	RTD (A)	Demonstration (B)	Management (C)	Other (D)	Total (A+B+C+D)
Personnel costs	46,208	0	0	0	46,208
Subcontracting	0	0	0	0	0
Other direct costs	4,224	0	0	0	4,224
Indirect costs	30,259	0	0	0	30,259
Total costs	80,691	0	0	0	80,691
Maximum EC contribution	60,518	0	0	0	60,518
Requested EC contribution					60,518

2. Declaration of receipts

Did you receive any financial transfers or contributions in kind, free of charge from third parties or did the project generate any income which could be considered a receipt according to Art.II.17 of the grant agreement ?	No
If yes, please mention the amount (in €)	

4. Certificate on the methodology

Do you declare average personnel costs according to Art.II.14.1 ?			No
Is there a certificate on the methodology provided by an independent auditor and accepted by the Commission according to Art.II.4.4 ?			No
Name of the auditor		Cost of the certificate (in €), if charged under this project	

5. Certificate on the financial statements

Is there a certificate on the financial statements provided by an independent auditor attached to this financial statement according to Art.II.4.4 ?			No
Name of the auditor		Cost of the certificate (in €)	

6. Beneficiary's declaration on its honour

We declare on our honour that:

- the costs declared above are directly related to the resources used to attain the objectives of the project and fall within the definition of eligble costs specified in Articles II.14 and II.15 of the grant agreement, and, if relevant, Annex III and Article 7 (special clauses) of the grant agreement;

- the receipts declared above are the only financial transfers or contributions in kind, free of charge, from third parties and the only income generated by the project which could be considered as receipts according to Art.II.17 of the grant agreement;

- the interest declared above is the only interest yielded by the pre-financing which falls whithin the definition of Art.II.19 of the grant agreement;

- there is full supporting documentation to justify the information hereby declared. It will be made available at the request of the Commission and in the event of an audit by the Commission and/or by the Court of Auditors and/or their authorised representatives.

Figure 12: FormC of COR

FP7 - Grant Agreement - Annex VI - Collaborative project

Form C - Financial Statement (to be filled in by each beneficiary)

Project Number	216474	Funding scheme	Collaborative project
Project Acronym	CopPeR		
Period from	01/01/2008	Is this an adjustment to a previous statement ?	No
To	31/12/2008		
Legal Name	VRIJE UNIVERSITEIT BRUSSEL	Participant Identity Code	999902094
Organisation short Name	VUB	Beneficiary nr	8
Funding % for RTD activities (A)	75	If flate rate for indirect costs, specify %	60

1. Declaration of eligible costs/lump sum/flate-rate/scale of unit (in €)

	Type of Activity				
	RTD (A)	Demonstration (B)	Management (C)	Other (D)	Total (A+B+C+D)
Personnel costs	38,237	0	0	0	38,237
Subcontracting	0	0	0	0	0
Other direct costs	2,443	0	0	0	2,443
Indirect costs	24,408	0	0	0	24,408
Total costs	65,088	0	0	0	65,088
Maximum EC contribution	48,816	0	0	0	48,816
Requested EC contribution					48,816

2. Declaration of receipts

Did you receive any financial transfers or contributions in kind, free of charge from third parties or did the project generate any income which could be considered a receipt according to Art.II.17 of the grant agreement ?	No
If yes, please mention the amount (in €)	

4. Certificate on the methodology

Do you declare average personnel costs according to Art.II.14.1 ?			No
Is there a certificate on the methodology provided by an independent auditor and accepted by the Commission according to Art.II.4.4 ?			No
Name of the auditor		Cost of the certificate (in €), if charged under this project	

5. Certificate on the financial statements

Is there a certificate on the financial statements provided by an independent auditor attached to this financial statement according to Art.II.4.4 ?			No
Name of the auditor		Cost of the certificate (in €)	

6. Beneficiary's declaration on its honour

We declare on our honour that:

- the costs declared above are directly related to the resources used to attain the objectives of the project and fall within the definition of eligble costs specified in Articles II.14 and II.15 of the grant agreement, and, if relevant, Annex III and Article 7 (special clauses) of the grant agreement;

- the receipts declared above are the only financial transfers or contributions in kind, free of charge, from third parties and the only income generated by the project which could be considered as receipts according to Art.II.17 of the grant agreement;

- the interest declared above is the only interest yielded by the pre-financing which falls whithin the definition of Art.II.19 of the grant agreement;

- there is full supporting documentation to justify the information hereby declared. It will be made available at the request of the Commission and in the event of an audit by the Commission and/or by the Court of Auditors and/or their authorised representatives.

Figure 13: FormC of VUB

8 Certificates

Beneficiary	Organisation short name	Certificate on the financial statements provided? yes / no	Any useful comment, in particular if a certificate is not provided
1	TEC	no	Expenditure threshold not reached.
2	SEZ	no	Expenditure threshold not reached.
3	ELS	no	Expenditure threshold not reached.
4	KUL	no	Expenditure threshold not reached.
5	FELMI	no	Expenditure threshold not reached.
6	IFX	no	Expenditure threshold not reached.
7	COR	no	Expenditure threshold not reached.
8	VUB	no	Expenditure threshold not reached.

Table 14: Certificates overview table

As seen in the list of certificates above no certificates on the financial statements were necessary because no partner reached the expenditure threshold of 375.000.- Euro in the first project year. Nevertheless, SEZ has reported average personnel costs and therefore has to provide a certificate on the methodology which will be forwarded to the EC as soon as it is available.

9 List of Abbreviations

Abbreviation	Explanation
ADF	annular dark-field imaging
CBED	convergent beam electron diffraction
cf.	confer
CMP	chemical-mechanical planarization / chemical-mechanical polishing
CoO	Cost-of-Ownership
COR	Cormet Oy
CS-DFD	Circular Scanning Dark-field Diffraction
Cu	copper
CV	cyclic voltammetry
EBSD	electron backscattered diffraction
EELS	electron energy loss spectroscopy
EFTEM	energy-filtered transmission electron microscopy
ELS	ELSYCA NV
FELMI	Institute for Electron Microscopy
FP7	Seventh Framework Programme
GI-XRD	gracing incidence x-ray diffraction
HAADF	High Angle ADF
ICT	Information and Communications Technology
IFX	Infineon Technologies AG
KUL	Katholieke Universiteit Leuven
MSA	mean spherical approximation
PEG	polyethylene glycol
RBS	Rutherford backscattering spectrometry
SAED	selected area (electron) diffraction
SDEP	scanning diffraction electron precession
SEM	scanning electron microscope
SEZ	SEZ AG
SPS	bis(3-sulfopropyl)disulfide
STEM	scanning transmission electron microscope
STREP	Small or medium-scale focused research project
SVN	subversion
TEC	Technikon Forschungs- und Planungsgesellschaft mbH
TEM	transmission electron microscopy
TU	University of Technology
VUB	Vrije Universiteit Brussel
wrt.	with respect to