PROJECT FINAL REPORT

Grant Agreement number: 608698

Project acronym: SCAIL-UP

Project title: "Scaling- up of the aluminium plating process from ionic liquids"

Funding Scheme: Collaborative project

Period covered: from 01/11/2013 to 31/10/2016

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4.1 Final publishable summary report

The SCAIL-UP project ("**Scaling- up of the aluminium plating process from ionic liquids**") was launched the 1st of November of 2013 and finished 30th October of 2016.

This project is fully in accordance with the Topic FoF NMP.2013-10 Manufacturing processes for products made of composites or engineered metallic materials as its main aim is to develop a new manufacturing **industrial green process** based on the **electrodeposition of aluminium from ionic liquids and post-processed the aluminium pure coating** to obtain **high-tech engineered metallic materials for the automotive and aeronautic sectors.**

This new process will **replace conventional harmful techniques (Chromium VI electroplating and pack cementation)** and will be **more energy and material efficient,** at shows in specific objectives below. For achieving this goal, all barriers that difficult the industrialization of electrodeposition processes based on ionic liquid formulations will be overcome.

Two lists containing the requirements and specifications of the final products for automotive and aeronautic sectors have been provided by SCAIL-UP partners. Those lists contain the key criteria in order to qualify the final products for automotive and gas turbine applications, and will be the standard protocols which manufacturers must refer to for using the ionic liquid process for the previously described applications. Together with the specifications for the final products a list of suitable Ionic Liquids has been provided by IOLITEC. The list contains liquid media selected to act as universal compound family for different substrates. A specific ionic liquid has been selected as the most suitable for **larger-than-laboratory studies** task. Furthermore, MAIER and TUC have also selected real prototype components for automotive and aeronautic applications on which applying the electrodeposition by ionic liquids. MAIER and CIDETEC have been working in the definition of pre-treatment and post-treatments for the automotive application.

Regarding modelling and design of the progress, INSTM carried out some "in situ" control of the electroplating process based upon cyclic voltammetry and planned to do new electrochemical investigation coupling impedance measurements to voltammetry methods. Furthermore, CIDETEC carried out some work on the technical validation of the obtained coatings (thickness, composition and morphology) at laboratory scale. The mathematical model has been tested for aeronautic application and predicts correctly..

A pilot plant prototype (200L) has been built-up and tested. Other relevant related aspects as safety protocol and ionic liquid recycling process have been developed. Moreover a post-treatment full line for automotive prototype components have been developed and tested.

Process validation and some preliminary standardization tasks have been developed with real aeronautic and automotive components prototypes. Furthermore, ionic liquid recycling routes, environmental impact and cost assessment analysis have been performed.

Finally, it must be highlighted the strong impact achieved by SCAIL-UP project as all the partners obtained successful close-to-the market exploitable results. Furthermore, social impact achieved has been considered relevant, due to the creation of employment, doctorate thesis, post-graduate students and post doctorate students formation.

According the relevance of technological and exploitation results obtained in the SCAIL-UP project, a website of the project has been created for the dissemination of those results. The link to the website is the following: **www.scailup.eu**

The **factsheet** of the project can be summarized as follows:

- 7th Framework Programme
  - Call identifier: FP7-2013-NMP-ICT-FOF (RTD)
  - Project Contract Number: 2608698
- Estimated project duration 36 months: November 2013 - October 2016
- Project budget: € 4,215,147, EC funding: € 2,819,851
- Consortium with 6 participants
- Project co-ordinator: MAIER S.COOP
- Project Technical co-ordinator: Mónica Solay
- Official website is **www.scailup.eu**

Project context

In order to design new engineered metallic materials, **Aluminium (Al) is one of the most promising metals** as it is a **lightweight material** with a density of 2.7 g/cm^3 (0.1 $lb/in.^3$)**,** it has high mechanical strength achieved by suitable alloying and heat treatments and it has a relatively **high corrosion resistance** as pure metal. Other valuable properties include its high thermal and electrical conductance, its reflectivity, its high ductility, its magnetic neutrality and the non-poisonous and colorless nature of its corrosion products [2]. Thus, aluminium is a non-toxic metal that could be a cost-effective **alternative** for substituting conventional and harmful coatings like decorative chromium films.

The use of **ionic liquids** for depositing aluminium on different substrates has been studied for years within the scientific community due to the **unique properties** of these compounds: their wide electro-chemical window, which is a measure for their electrochemical stability against oxidation and reduction, high metallic salts solubility, low vapour pressure, negligible hydrogen enbrittlement, easy recovery of precipitated metals and low toxicity.

Nevertheless, although deposition of aluminium has been demonstrated at lab-scale, low efforts have been made for implementing the process parameters for achieving a proper up-scaling of the process. SCAIL-UP aims to transfer this technology (aluminium electrodeposition through ionic liquids) from the lab scale to the industrial scale. So, within the project **an industrial process for obtaining aluminium coatings will be implemented for the first time**. The new process will produce pure aluminium (> 99%) coatings with a high current efficiency (84-99 %) and energy consumption at least 29% lower than current electrodeposition processes.

[2] Sheasby, P.G.; Pinner, R. The surface treatment and finishing of aluminium and its alloys. 2001. ASM international

The obtained components will comprise metallic and plastics substrates covered with low weight and high corrosion resistance Al coatings. Moreover, **the coated products will be post-treated in order to provide them exceptional properties**. Thus, coated Plastic substrates will be post-treated in order to provide them high aesthetic properties and corrosion resistance, whereas heat treatment will be applied to coated nickel alloys to develop highly protective coatings based on nickel aluminide. Both post-treatment processes will be attained at industrial scale, and will lead to two innovative engineering materials:

- **Novel aesthetic and resistant automotive components:** The designed final product is a plastic base part metalized with Aluminum aesthetic, in a multilayer final structure which confers to the surface certain advantages as high resistance to wear and corrosion. The low weight of the final product would reduce energy demand by reducing vehicle weight (in accordance to up to date requirements of the automotive sector), and will allow the substitution of hazardous processes as nickel and chrome electroplating.

- **High performance gas turbine blades and vanes for the aeronautic sector.** These products will be obtained from nickel alloys that will be coated with aluminium and consequently will be submitted to a vacuum heat treatment process. As a consequence, an intermetallic (nickel aluminide) will be obtained, providing high temperature corrosion resistance to these components.

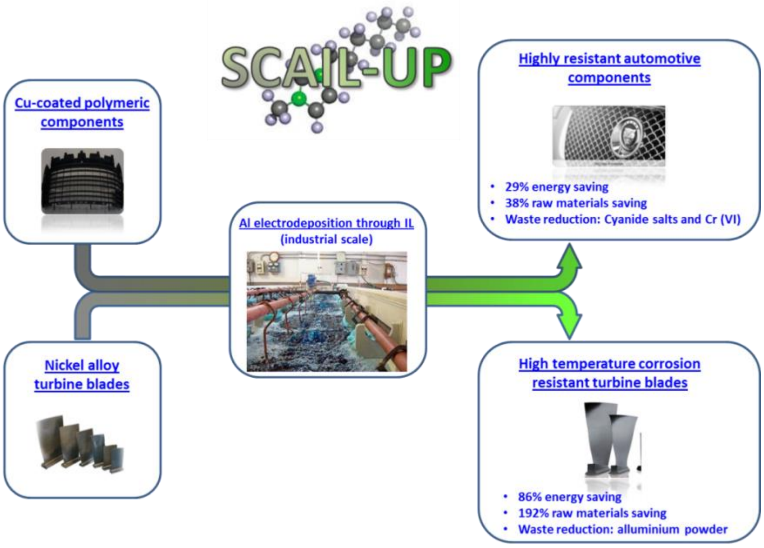

Figure 1: SCAIL-UP Concept

For attaining a reliable industrial process, **new protocols** to analyse, control and standardize the electrochemical bath will be developed. Due to the innovative nature of ionic liquids, **controlling and standardizing** deposition process will be critical, and a big effort will also be necessary. Complementarily to these protocols, **characterization technologies** will be implemented, in order to know the composition and thickness of coatings. Moreover, although it has been proved that is possible to control the deposit characteristics by controlling the electrochemical parameters at laboratory scale, this procedure will be adapted to large-scale productions. In addition, a deep characterization of coated components will be carried out for determining the extent of their good properties. The **new industrial processes will be validated by applying them to large series of products** (coating simultaneously between 4 and 8 3D pieces), analysing the incidence of malfunctions and the final quality of the final components.

Finally, a complete **study about sustainability**, which has never made with industrial scale processes, will be carried out within SCAIL-UP project. This study will involve developing **a new methodology for recovering and reusing ionic liquids**, as a way of reducing waste generation and improving the economic feasibility of the process. Moreover, a **Life Cycle Analysis** will be done for determining the environmental impact of the new process.

The main objective of this project is divided into the following **specific objectives**:

- To take advantage of **ionic liquids** properties to develop an electrodeposition process to obtain Al coatings.

- To obtain Al coatings on **plastic and metallic (nickel alloys) substrates** at industrial scale, optimizing the recent results obtained at laboratory scale.

- To produce **advanced engineering materials for the automotive and the aeronautic sector**, through application of different post-treatments to these aluminium coated substrates:

- **Automotive Component prototype with the specific characteristics of aluminium and polymers (**high corrosion resistance, light weight and aesthetic finishes) **to be used in the automotive industry,** that will be obtained through post-teatment of the aluminium coated plastic substrates.

- **Engineered metallic materials obtained after heat treatment of aluminium coated nickel alloys,** for having high-temperature corrosion resistant aeronautic components.

- **To increase the lifetime of electrodeposition baths** (ionic liquids) increasing the sustainability of electrodeposition processes.

- **To optimize the process laboratory-scale parameters** for the Al electrodeposition, in order to **be produced and post-processed at industrial scale**, achieving:

- **29 % energy reduction with respect to chrome plating** processes and **86% energy reduction against pack cementation** processes.

- **38 % raw material consumption decrease with respect to chrome plating, and a 192% raw material reduction** in comparison to pack cementation.

- A **high automation degree and a mass production approach** for coating simultaneously more than one piece.

- A substitution of harmful and pollutant raw materials **(cyanide baths, hexavalent chromium salts, aluminium powders)** by “greener” compounds (ionic liquids).

- To develop **new technologies of post-treatment at industrial scale to optimize the properties of the plated aluminium coating**To develop **new recycling technologies for the ionic liquids** that guarantee a minimal environmental impact of the process, replacing conventional and harmful electrodeposition processes.

- To achieve these objectives, this project proposes the following **operative objectives**:

- To define the working specifications required by ionic liquids for aluminium electrodeposition in both target applications, according the substrate properties and the coating technical requirements.

- To select a suitable ionic liquid electrolyte for the deposition of aluminium on nickel alloys and polymeric substrates, trying to find a universal formulation that could be used for platting both substrates.

- To simulate electrodeposition process at large scale in order to define optimal cell geometry and a good current distribution that lead to uniform and geometrically complex coatings. This cell geometry will be adapted to each target component, analyzing, among other parameters, current distribution, mixing effects.

- To test new cell geometries and process conditions at lab scale, in order to assess its validity before application in an industrial setting.

- To optimize existing control technologies for conventional (aqueous) electrolytes to ionic-liquid based electrolytes. Moreover, exploring alternative “in situ” and “ex situ” techniques for controlling process performance and electrolyte quality. New protocols to analyze and control the electrochemical bath based on ionic liquids will also be obtained.

- To design and build a large-scale pilot plant for the electrodeposition of aluminium with ionic liquid electrolytes, able to coat simultaneously 2000 cm2 and more than one 3D pieces (4-8) with an electrolyte (ionic liquid) working volume of at least 200L.

- To develop a feasible and reliable procedure for characterizing the Al electrodeposits at industrial scale from a morphological and structural (thickness) point of view.

- To implement post-treatment processes for providing high-tech properties to aluminium coated substrates, building specific large-scale demonstrators when necessary.

- To demonstrate the feasibility of the developed processes through long-term application of the processes in large series, and deep characterization of the obtained products.

- To develop new process for recycling big amounts of ionic liquids, in order to reduce the impact of this compound costs.

- To assess the technical, economic and environmental viability of the new process by means of applying an economical balance and a Life Cycle Analysis.

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The consortium consists of 4 industrial partners (1 SME), 1 research organization and 1 university, being the project led by a strong industrial partner (MAI). The industrial partners all have key, active and leading roles to guarantee industrial relevance and impact.

Project organization:

For the accomplishment of the objective of the project, the project has been organized into 7 different working packages as shown next:

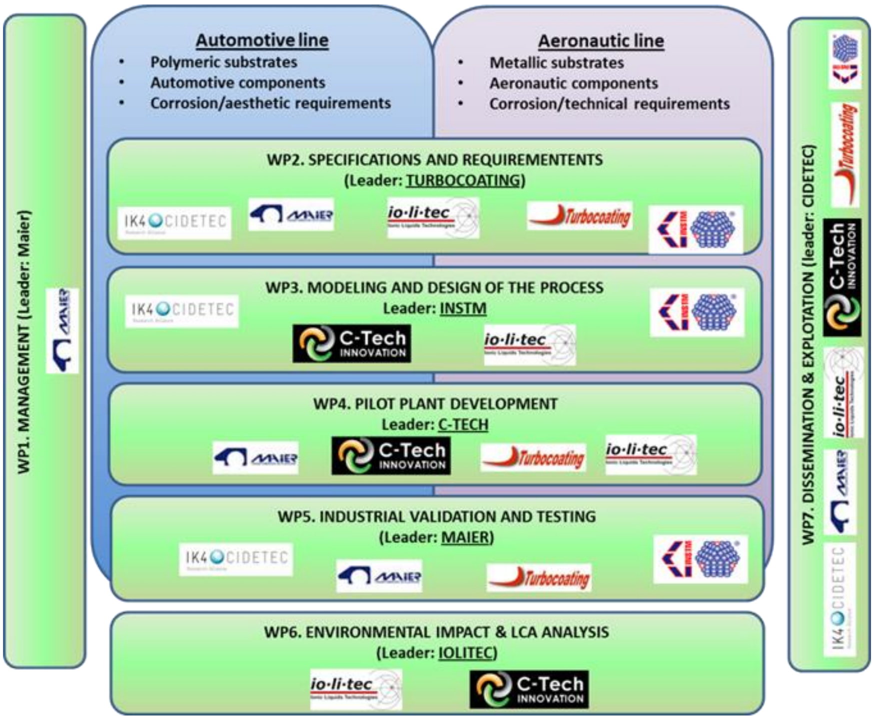

Figure 2: SCAIL-UP WPs Structure

Main S & T results/foregrounds

Relevant research activities have been carried out within all the project's technical Work packages fulfilling the objectives of the project:

- WP2 Specifications and requirements
- WP3 Modeling and design of the process
- WP4 Pilot plant development
- WP5 Industrial validation and testing
- WP6 Enviromental and economical impact. LCA Analysis

WP2 Specifications and requirements [Participants TUC, CIDETEC, MAI, INSTM, , IOLITEC]

The aim of the present WP the definition of specifications and the technical requirements in order to develop coatings for automotive and gas-turbine applications (***Task 2.1***). WP2 focused also on the selection of suitable electrodeposition baths: a "universal" compound family which could be adapted to both polymeric and metallic substrates (***Task 2.2***). Finally, in ***Task 2.3*** working conditions and preliminary larger-than-laboratory studies were defined and performed.

Task 2.1. Definition of the technical requirements of the electrodeposition process and of the final products to be developed (Coordinator: TUC; Participants: MAIER, CIDETEC, INSTM and IOLITEC).

MAIER, CIDETEC, INSTM, IOLITEC and TUC worked together to summarize all the information of the aluminium electrodeposition process to be provided to C-TECH for pilot plant construction. As a result, the following documents gathered together the generated technical information:

- In order to develop a robust and suitable process a summary of the state of the art concerning the IL processes were prepared by partners having previous experiences with Ionic Liquids. All the information was summarized in the titled document: **"*table of previous knowledge*" (Table 1 at *Deliverable D 2.4).***
- Technical requirements and specifications for the electrodeposition process and of the final products were defined by TURBOCOATING and MAIER. This was made taking into account the final applications of the coated components, *i.e.* gas-turbine and automotive fields respectively (***Deliverables D2.1*** and ***D2.2***).
- Suitable base materials for both automotive and gas turbine applications were chosen by MAIER and TUC respectively. MAIER selected an automotive component prototype for "larger than laboratory" studies.TUC selected a widely used Ni base superalloy as base material for flat samples and a 1st stage rotating blade as the target for final coating application.

TUC and INSTM focused on the possibility to apply ILs inside components cooling holes. Evidences of the unfeasibility of this option were showed in WP3 by INSTM. TUC investigated the new opportunity to apply an "Over-aluminizing" layer. This process purpose is the aluminization of an external metallic bond coat .

Task 2.2. Selection of the electrodeposition baths (Coordinator: IOLITEC; Participants: MAIER, CIDETEC, INSTM and TUC)

As far as **task 2.2** concerns, different Ionic Liquids (ILs) were examined and different solutions for the electrodeposition bath were discussed. All the inputs provided by partners were collected by IOLITEC within the ***Deliverable D2.3***, titled ***Preliminary list of suitable Ionic Liquids***. The document collects the most suitable electrolytes and Ionic Liquids for both gas turbine and automotive applications. In agreement with all partners an Imidazolium Chloride was selected as the most suitable Ionic Liquid for both applications (***Deliverable D2.3).***

CIDETEC and MAIER provided a document to IOLITEC named ***Ionic Liquids Specifications*** containing the parameters necessary to synthesize the most suitable formulations for the electrodeposition of aluminium over polymeric substrates.
Safety instructions for the selected Ionic Liquid were finally delivered for all partners by IOLITEC.

Task 2.3. Preliminary larger-than-laboratory studies (Coordinator : MAIER; Participants: CIDETEC, INSTM and TUC)
As far as the **task 2.3 is concerned**, all the working parameters for the entire process for each application were selected and tested at lab and larger than lab scale. All these information were collected in the ***Deliverable D 2.4.***
INSTM and CIDETEC worked on the optimization of the working conditions for the electrodepositon process in order to obtain the desired thickness or both applications. Pre and post-treatment processes differed from one application to the other.
MAIER performed a post-treatment stage to the plated specimens to obtain new aesthetics coatings (Figure 3). The last step of the automotive post-treatment process is the application of an organic layer on the top of the surface in order to increase corrosion protection of the automotive component prototypes.
On the other hand TURBOCOATING post-treatment have been carried out to induce the diffusion of aluminium into the base material in order to obtain a diffusion coating with a particular microstructure. This coating microstructure improves the corrosion and oxidation resistance of the component base material at high temperatures (Figure 4).

Figure 3: Top-coats tested on aluminium deposits from ionic liquids based electrolyte

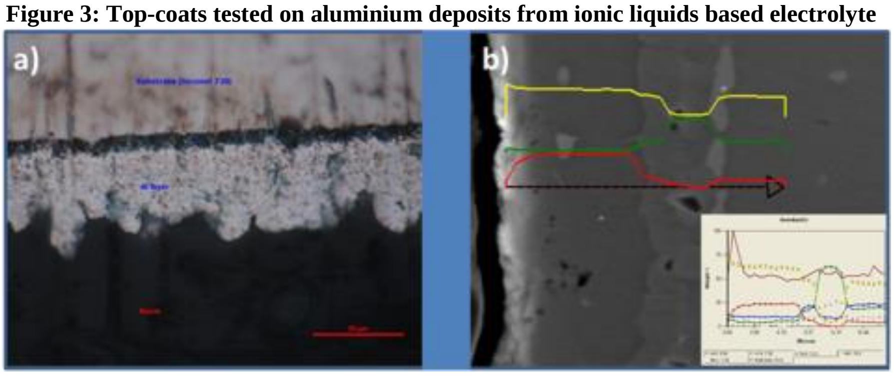

Figure 4: Semi microstructure of the diffusive coating after diffusion treatment

MAIER and CIDETEC have also developed a "**material compatibility test**" to select suitable materials to be used for the construction of the tank, tubes and ILs transport systems for the designed pilot plant. This test was started within this WP and continued during WP4 and WP5 until the end of the project.

MAIN S&T RESULTS OF WP2

- In agreement with all partners BMIMClan imidazolium chloride was selected as the electrolyte for both the "larger than lab" tests and the final pilot plant. This can in fact work at the optimal conditions for both processes.
- Polymeric materials were selected as the most suitable construction materials,

Deliverables submitted in WP2:

D2.1 – Technical requirements of decorative coatings for automotive applications–M2
D2.2 – Technical requirements of functional coatings for aeronautic applications– M2
D2.3 – Preliminary list of suitable Ionic Liquids– M6
D2.4 – Definition of working conditions for each substrate and final application of the coating–M12

WP3 MODELING AND DESIGN OF THE PROCESS [Participants: INSTM, CIDETEC C-TECH, IOLITEC]

The objective of this WP is to define, design and model a full-size Al electrodeposition process with ionic liquids, and develop and tune the control technologies that will be included in the global process in order to be the basis for the subsequent development of the electrodeposition pilot plant.

Task 3.1. Modelling of process at pilot plant scale (Coordinator: INSTM; Participants: CIDETEC, C-TECH and IOLITEC)

By using the finite element analysis (FEA) approach INSTM developed a mathematical model to obtain the current distribution, which constitutes the driving force for the electrodeposition process of Aluminium, from first generation ILs. Based upon the simulation program COMSOL Multiphysics® a model taking into account tertiary current distribution, chemical reactions coupled to electrochemical process and fluidodynamical conditions were developed. The robustness of the mathematical model were tested on both aqueous and ILs solutions by comparing experimentally measured thickness distribution with the values predicted by the model. The experimental data proved that the new model results more suitable to simulate edge effects respect to the state of the art in both aqueous and IL environments, even for complex shaped objects. That is dramatically important in the case of turbine vanes and blade which are characterized by sharp edges and complex geometry. This model can be considered as a main results and a very innovative approach since, to the best of our experience, the performances and the predictive capability of the model outnumbers the previously available models.

On the other side the use of a layer of organic solvent to seal the electrolyte from the environment has been tested by CIDETEC. From an experimental point of view, the organic solvent acts properly isolating the electrolyte from the environment (figure 5).

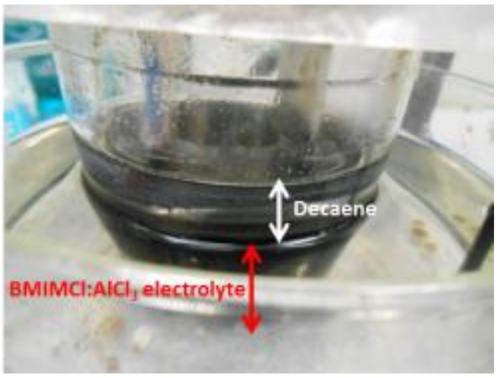

Figure 5: Electrolyte sealed with a dodecane layer

However, regarding the electrochemical performance it presents several problems. Thus, even though the organic solvent and ionic liquid are not miscible, some organic solvent is apparently dissolved into the ionic liquid hindering the electrodeposition process and leading to defective aluminium deposits. From a practical point of view, the greatest drawback is that this system does not allow stirring which is essential for a correct electrodeposition process. After analysing the results, it has been concluded that the use of an organic sealer to isolate the electrolyte from the environment is not suitable for the process.

Task 3.2. Definition and development of the tools for controlling the electrodeposition baths. (Coordinator: CIDETEC; Participants: INSTM, C-TECH and IOLITEC)

CIDETEC and INSTM focused on the characterization of the electroplating baths based on ionic liquids exploring two different approaches; physicochemical properties,such as conductivity, viscosity, density, water content and UV-Vis response, and, electrochemical methods, such as cyclic voltammetry, rotating Hull Cylinder (RHC) and electrochemical impedance spectroscopy (EIS), have been tested as tools for controlling the plating bath. It is worth mentioning that due to electrolyte´s corrosive nature and moisture sensitivity, most of the proposed techniques needed technical progresses and special configurations.

It was concluded that density and viscosity do not give us a clue for monitoring the operational conditions of the electrodeposition bath. Nevertheless, conductivity was found suitable for characterization of electrolytes.

CIDETEC also investigated the use of Karl-Fischer analysis (chemical analysis) to evaluate the water content of the electrolytes but conventional K-F analysis resulted not suitable to evaluate the water content of the BMIMCl:AlCl3 electrolytes due to side reactions between the IL and the analyte.
UV-Vis technique was employed by CIDETEC aiming to determine the aluminium complexes present in the electrolyte (Figure 6).

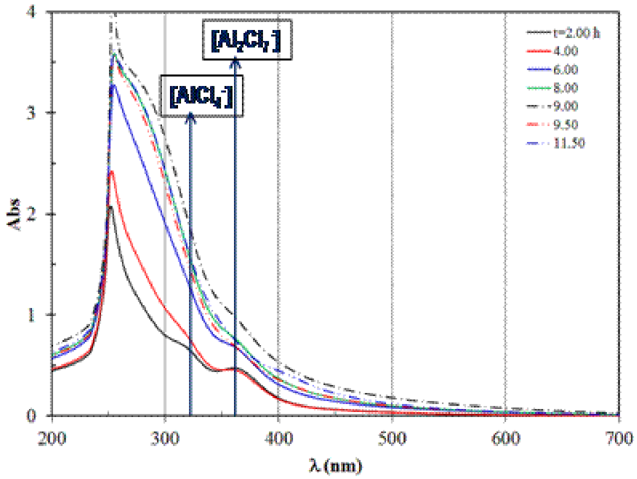

Figure 6: Evolution of UV-VIS signal under real working conditions

The second group of characterization tools that has been investigated are the electrochemical techniques. Among the others, cyclic voltammetry (CV) analysis has been carried out by CIDETEC and INSTM as function of plating time. Nevertheless is simplicity, CV does not seem to be suitable for plating control purposes.

Electrochemical Impedance Spectroscopy (EIS) a perturbative method for the study of electrochemical process dynamic, has revealed to be one of the most promising techniques for bath monitoring. Ranging from 1MHz to 5mHz, with 10 mV amplitude perturbation over the open circuit potential the technique was able to highlight differences for the as-received and the aged electrolytes allowing monitoring the electrochemical performances of the bath (figure 7).

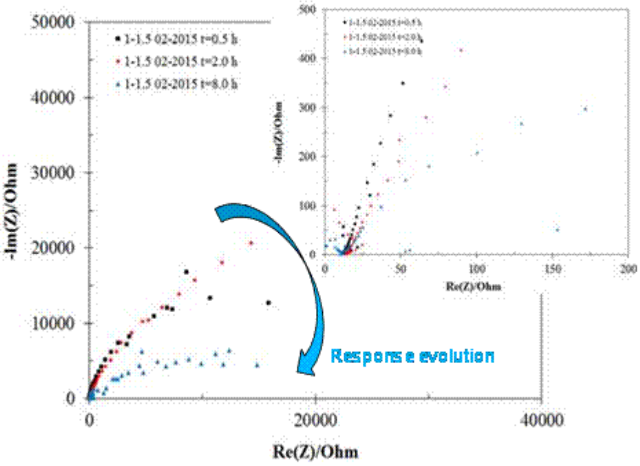

Figure 7: Nyquist diagrams of 1:1.5 electrolyte as function of working time.

EIS demonstrated to be more sensitive technique respect to CV, especially in case of foreign ions contamination. In case of addition of Ni ions, EIS returned a steeply increase of the polarization resistance. That was interpreted as increased difficulty in the reduction process. (figure 8).

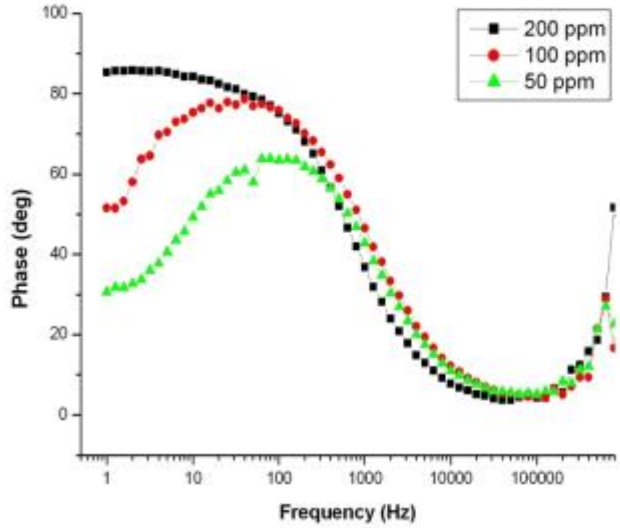

Figure 8: Eis Measurements (Bode Diagrams) Of 1:1.5 Electrolyte As Function Of The Ni2+ Content.

However, EIS experiments do not provide a traightforward investigation of the electrochemical properties and an accurate and time-consuming fitting by skilled operators is needed. Therefore its use as "in process control" method is a little cumbersome. In order to find an "easy to use" tool capable to qualitatively check the electrochemical properties of the galvanic bath, INSTM proposed the use of a newly designed Rotating Hull Cylinder. The peculiar characteristics of Ils (moisture sensitive, chemically aggressive towards the most commonly used plastic materials) do not allow the use of commercial device. Therefore, a totally new device has been designed in order to avoid the contact between the metallic/electric parts and the electrochemical bath.

As it stands it constitutes a main advantage respect to the traditional devices in which a portion of the electroplating solution is poured inside the cell. The scheme and sketch of the new device are depicted in figure 9.

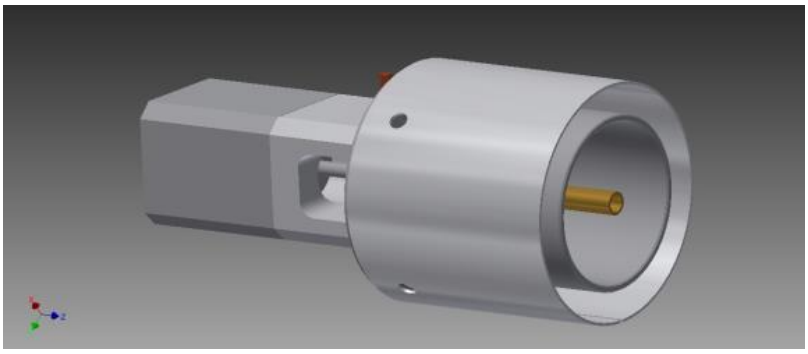

Figure 9: 3d representation of the new type of rotating hull cylinder.

Task 3.3. Technical validation of preliminary studies and designs (Coordinator: INSTM; Participants: CIDETEC, C-TECH and IOLITEC)

This task focuses on three different activities:

1. Check the effect of foreign metal ions to the Al-electrodeposition process.

2. Validation of the mathematical model by comparison of the evaluated and calculated thickness distribution across real industrial items (car bumper and turbine vane)
3. Validation of the newly designed Rotating Hull Cylinder as “in situ” controlling tool.

Regarding the effect of metallic ions on the electroplating bath ([BMIM]Cl AlCl3 1 to 1.5 molar ratio), cyclic voltammetry, potential-time curves, EIS and SEM-EDX, rugosimetry and optical microscopy were employed to characterize both the electrochemical baths and the obtained coatings as function of amount of Ni, Cu and Fe ions. Results evidenced that these elements are not noxious and amounts up to 50 ppm (for Fe and Ni) and 10 ppm for copper can be tolerated.

Regarding the mathematical model validation INSTM and CIDETEC worked on real 3D industrial items; an automotive component prototype for **automotive application** and a turbine vane for aerospace.

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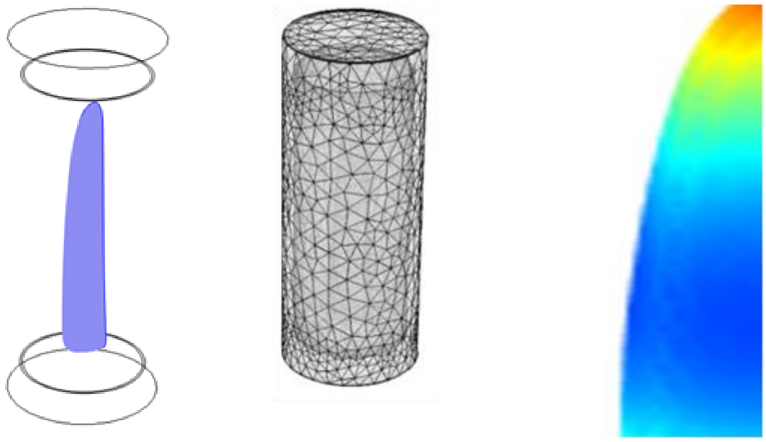

Figure 10: Geometrical setup (a) meshed geometry (b) and current distribution (c) for the automotive comoponent

. The theoretical model were compared with the experimentally determined (via XRF) data of a prototype plated in the same conditions finding very good agreement (fig 10).

The **same validation was carried out on a turbine vane**:

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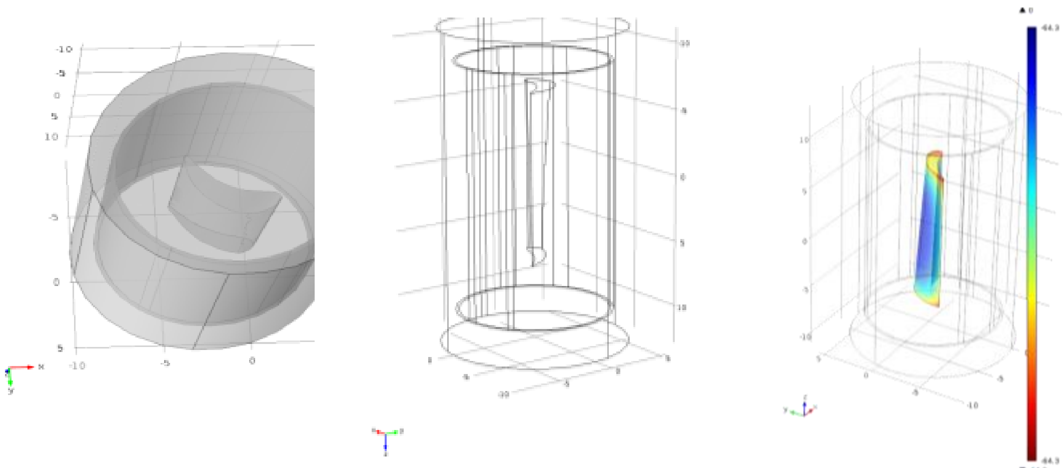


Figure 11: (a,b) geometry (c) thickness distribution on the turbine blade

Finally the newly designed controlling device (rotating Hull cylinder) was tested and their results validated on both aqueous (Ni-Watts type bath) and IL environments for different operating conditions (stirring and quiet).
Figure 12 depicts thickness distribution of Ni layer on the cylinder as function of distance from the tip, while figure 13 the same data regarding Al deposit from IL. In both cases there is a very good agreement between the experimental and theoretical data.

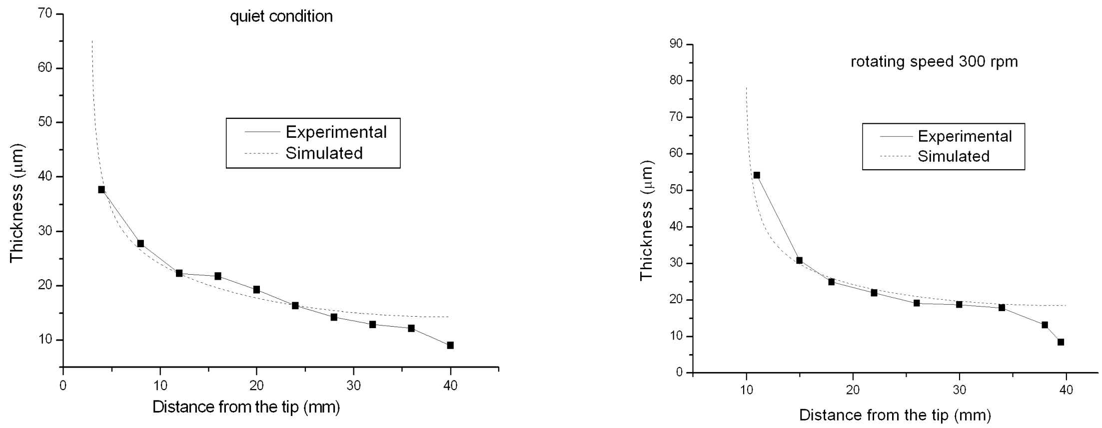


Figure 12: (Left) thickness of the Ni deposit obtained from a Watts-type Ni bath as function of the distance from the tip, experimentally determined (full squares) and simulated by mathematical model (dot line). (right) the same data measured and simulated for a cylinder rotating at 300 rpm.

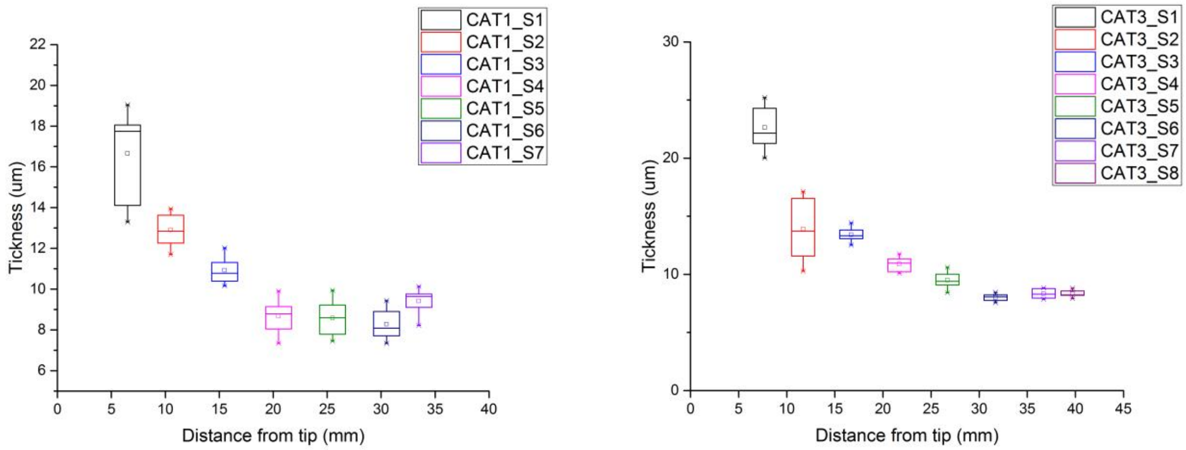


Figure 13: Thickness of the Al deposit as function of the distance from the tip in quiet (left) and rotating 300 rpm (right).

<u>MAIN S&T RESULTS OF WP3</u>

- Classical physicochemical characterization of the plating bath led to undesirable results due to IL corrosive nature. CV and EIS techniques give valuable information about the process but requires more in depth research.
- Mathematical model was validated for automotive application
  - A mathematical model capable of predicting the current distribution on complex-shaped 3D objects was built and optimized for Al-electrodeposition from ILs. It constitutes a completely

new, and powerful, tools for developing electrochemical process at lab as well as industrial scale.

- A new concept of rotating Hull Cylinder have been designed and realized. It is specifically designed to compel with chloroaluminated ionic liquids and constitute a viable and practical way to “in situ” monitoring of the electrochemical bath performances. On the ground of the new design and new operating principle, it constitute a tangible innovation in the field of IL electrochemistry.
- Copper have been identified as potentially noxious contaminant since even in tiny amounts (down to 10 ppm) negatively affects the electrodeposition of Al. However, being preferentially reduced at the cathode, a Cu-contaminants can be removed from the bath by simple electrodeposition. Ni and Fe are tolerable up to 50 ppm.
- Conductimetry can be used to check the status of the electroplating bath.
- Effect of Sonication and temperature were evaluated on the quality of the Al-deposits.

Deliverables submitted in WP3:
D3.1 – Process sequence and operation parameters for IL aluminium electrodeposition at industrial scale– M18
D3.2 – IL aluminium electrodeposition model development– M24

<u>WP4 PILOT PLANT DEVELOPMENT [Participants: C-TECH, TUC, MAI, IOLITEC]</u>
Work package 4 officially started in M12, but preparatory activity for this work package began early, with a particular focus on MoC testing and generating a design specification for task 4.1.
Objectives:

- This work package is focused on the development and construction of an industrial line for the electrodeposition of aluminium on polymeric and metallic substrates.
- It will be focused on the development of both pilot plants to be developed (for electrodeposition of Al and for post-treatment of the Al coatings)

Task 4.1. Development of electrodeposition pilot plant (Coordinator: C-TECH; Participants: MAIER, TUC and IOLITEC)
A specification for the pilot plant was developed between the partners, which was:

- Pre-treatment and post treatment beyond initial rinsing of any parts would take place outside of the pilot rig.
- Parts to be plated will be transported through the system on racks which can take up to 6 polymeric parts (Maier) and 4 metal aerofoils (TUC).
- The racks secure the parts in position during transport and act as cathode current collectors.
- Parts to be plated will be taken in wet on the rack into a combined drying and transfer / load lock chamber.
- The dryer unit should allow the moisture level of the parts to be reduced to a level where the enclosure moisture level does not affect the IL..
- Atmosphere control sufficient to keep the moisture content of the enclosure below 10 ppm.
- Ionic liquid for electroplating to be based on an Imidizolium salt plus aluminium chloride at requested temperature.

- Materials of construction such that the integrity of the pilot plant is not damaged by corrosion and that the ionic liquids are not contaminated.
- Controllable agitation and temperature control of the process tanks.
- One 200 liter plating tank and two 80 liter rinse tanks.
- Plating currents up to 30A.
- Automatically replaceable anodes.
- Automated safety systems including overpressure prevention, HCl detection, temperature limits, shutdown of automatic transport system if any manual operations are detected and air extraction.
- Fully automated transport of the racks through the whole process.
- PLC control of the process with a HMI screen for the operator.
- Window and glove ports to allow monitoring and minor maintenance tasks to be carried out.
- Remote support via an internet link.
- Transfer system for the ionic liquids and cleaning fluids from commercial transport containers into and out of the tanks ensuring operator safety and purity none contamination of the liquids.
- Suitable for transport between test locations.

The coating process can be summarized in the diagram below:

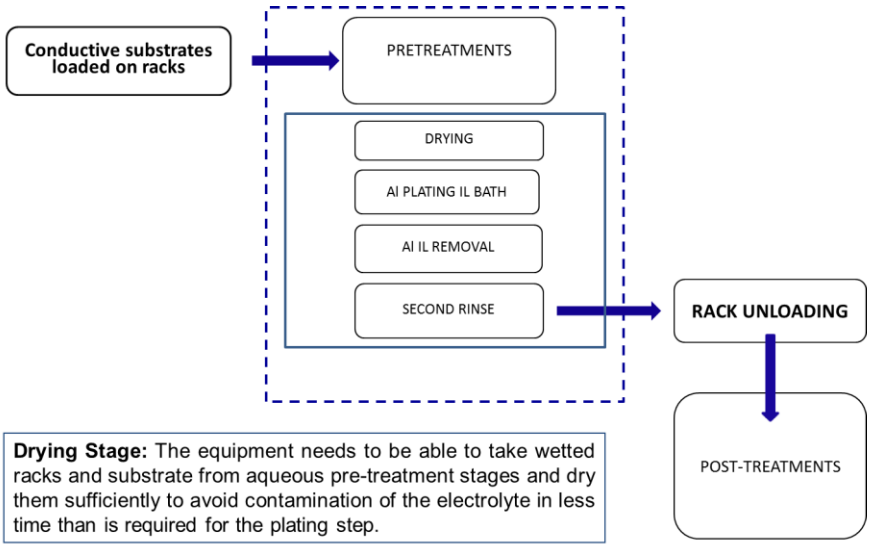


Figure 14: Diagram of the coating process

The specification is very challenging and all the simpler and smaller pilot plants constructed to date have failed within one month.

As part of the design process a full HAZOP and risk assessment was carried out on the design with input from all partners and a number of recommendations were implemented to enhance safety and operability.

The pilot rig was constructed in a number of sub-assemblies which were then individually commissioned prior to assembly of the full system, dry commissioning and then wet commissioning. The pilot plant was then thoroughly cleaned, partly disassembled into transportable units and shipped to be re-commissioned at CIDETEC.

The pilot plant was then recommissioned at CIDETEC. CIDETEC / MAIER personnel were fully trained in its operation and maintenance requirements. The commissioning work finished with the plating of a full rack of 6 automotive component prototypes.

The pilot plant is shown below in Figure 15:

Figure 15: The SCAIL-UP Pilot Plant. From Top left clockwise: Main rig section incorporating the process tanks in an enclosure plus the electrical control panel, samples being lowered automatically into the plating tank, another view of the plating tank, main HMI operating screen, initial HMI screen.

The pilot plant fully met the specification and operated successfully to produce Al coatings whilst maintaining the ionic liquid in an as received condition and suffering no integrity or corrosion issues. Minor operational lessons were learnt which will enable improved and larger plating plants to be constructed.

Task 4.2 Development of post-treatment pilot plant (Coordinator: MAIER; Participants: TUC)
<u>Automotive post-treatment (MAIER):</u>

According to process specifications, pre-treatment and post-treatment stages of the aluminium plated prototypes are multi-step procedures which take place in open-air conditions as the whole process is conducted using water-based electrolytes. **¡Error! No se encuentra el origen de la referencia.**16 shows the pilot plant designed and built including pre-treatment and post-treatment stages.

A 16 tanks long pilot plant was designed covering all the stages of post-treatment process, and the surface preparation and external rinsing of electrodepositing process.

Figure 16: Post-treatment Maier's pilot plant

Rack design was also performed to settle six 3D automotive parts for post-treatment. Deliverable D4.3 deals with design, development and commissioning of the post-treatment pilot plant as well as rack design and manufacturing.

Gas turbine posttreatment (TUC):

TUC worked on the development of the optimal post treatment parameters aimed to form the aluminide coatings after Al plating by Ionic Liquids.

The post-treatment parameters were selected with the main purpose to verify if the coating properties and performances met the specifications and technical requirements described in D2.2 (table 1).

REQUIREMENT	*DETERMINATION*	*CRITERIA*
Aluminum layer thickness	Metallography	20µm -30µm
Aluminum layer thickness distribution	Metallography	± 5µm
Aluminide diffusion coating thickness	Metallography	20µm -100µm
Aluminide diffusion coating structure	Metallography	3-layered diffusion coating
Aluminide diffusion coating phase	SEM, X-Ray	ß-NiAl
Aluminide diffusion coating composition	SEM	- 20-35wt% Al for IN738 aluminizing - 10-16 wt% Al for CoNiCrAlY over-aluminzing
Hardness	Metallography	600-750HV
Oxidation resistance	Oxidation at 1000°C	1000hours
Thermal cycling	1hr@1100°C + 15min to RT	OEM

Table 1: Specifications and technical requirements for gas turbine components

Two main systems, showed the most promising results:

- **IN 738 + 10 µm Al + post-treatment (diffusion heat treatment)**
- **IN 738 + MCrAlY bond coat + 20 µm Al + post-treatment (diffusion heat treatment)**

These two systems showed properties in compliance with the specification defined in WP2.
The amount of Al was in fact into the range specified as well as the microstructural composition for both systems.
Figure 17 and 18 shows the EDS results on the IN738 aluminized system via Ionic Liquid plating.

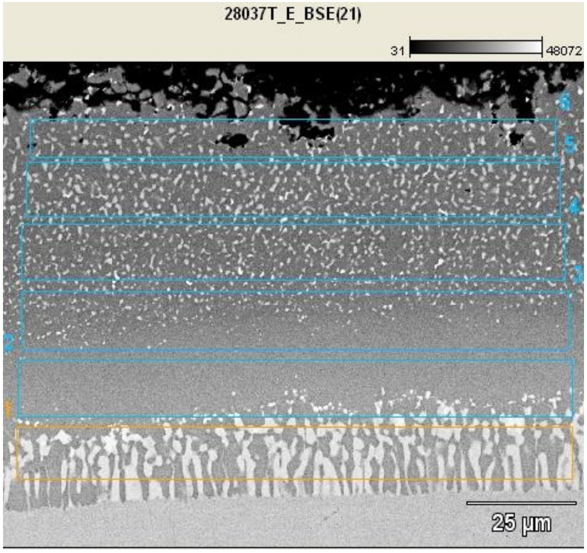


Figure 17: SEM micrograph of in738 aluminized

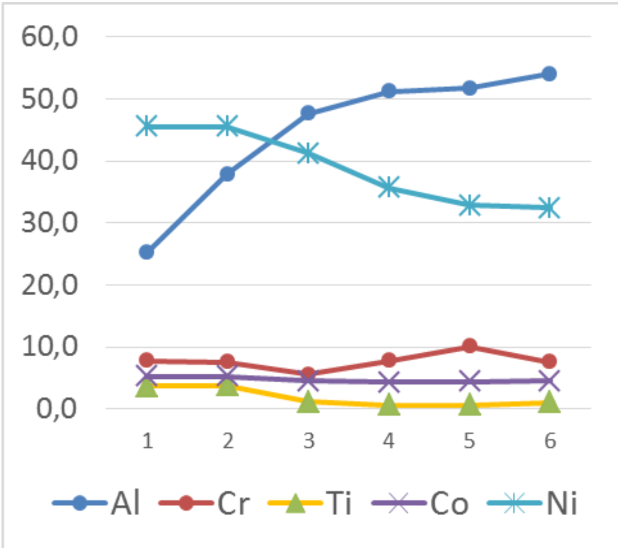


Figure 18:EDS analysis on in738 aluminized

Figures 19 and 20 shows the microstructure and elemental composition from SEM/EDS analysis of the IN738 + CoNiCrAlY over-aluminized via Ionic Liquids.

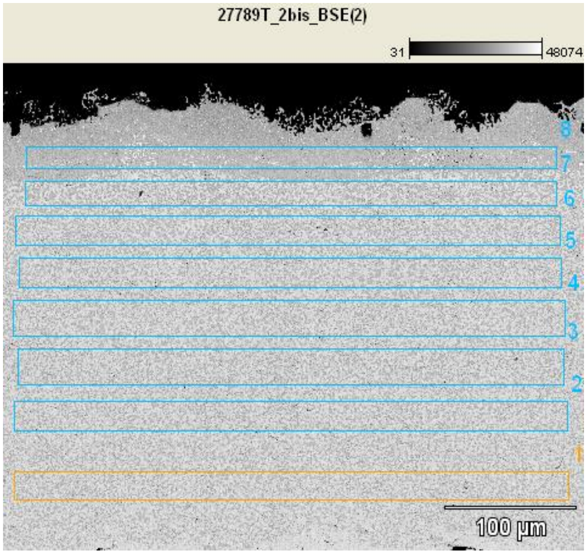


Figure 19:SEM micrograph od conicral overaluminized

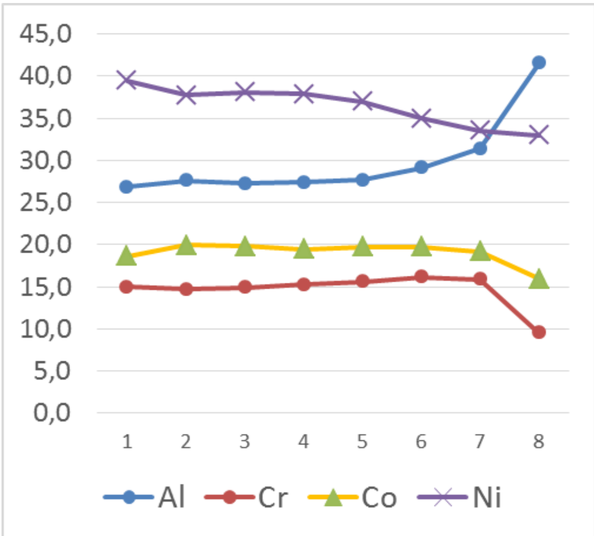


Figure 20:EDS profile of conicraly overaluminized

Moreover, TUC, together with INSTM developed the IL over-aluminizing process over real components. TUC designed and applied the specific thermal spray process and parameter for this

specific geometry. Low Pressure Plasma Spray (LPPS) process was selected to be applied over real components. This thermal spray process was selected instead of the High Velocity Oxygen Fuel (HVOF) due to the higher LPPS coating properties and performances than HVOF systems.
Coating (CoNiCrAlY) was applied on the whole component airfoil with thicknesses of 150±50 µm. No other surface treatments were applied on the bond coat after application: the roughness of the coating stays, in fact, between 4 and 5 Ra which gives an optimal anchoring system for the successive Al layer.
Al was then applied by INSTM after the component preparation. TUC, on the other side, performed the final post-treatment for Al inward diffusion and the formation of the over-aluminide coating. The heat treatment applied for this coated and plated componet was the one validated after the first part of WP4. The applied coating on real components met the specifications and technical requirements defined in WP2. For this reason the process developed for real component was considered suitable for further developments

MAIN S&T RESULTS FOR WP4

- Material resistance test using the real electrolyte identified the most reliable materials for the construction of the aluminium plating pilot plant.
- Design and construction of the post-process pilot plant for post-treatment of the aluminium coatings obtained from the electrodeposition of 3D plastic substrate from ionic liquids based electrolytes covering all the stages defined in WP2
- Designed and built post-process pilot plant allows pre-treatment of the automotive components prototypes and post –treatment of the aluminium coated 3D parts in the same pilot plant. The system is semi-automatic which facilitates the transports of the loaded racks along the line from one stage to another.
- Design and optimization of post treatment parameters for gas turbine applications
- Production of aluminium coated 3D parts in the 13 l tank. Neither the tank nor the components show any warning sign after being carefully reviewed after plating tests providing clear insights about the suitability of the constructions materials of the pilot plant.
- Application of the developed process over real gas turbine components with quality assurance in relation to the specifications defined in WP2
- Collaboration in the design and technical requirements of the aluminium plating pilot plant between C-TECH, MAIER and TUC
- Construction and validation of a robust and fully automated pilot plant for aluminium plating at the 200 l scale.
- Design of racks for 3D prototypes (MAIER) for the aluminum plating process.
- Design and development of racks for using in the post-treatment pilot plant.
- Design of the racks able to plate flat samples and real components for gas turbine application
- Post treatment was validated for real components in terms of parameters and tooling. This process phase is ready to be repeated for the rest of the components in WP5.

Collaboration for installation requirements of the aluminium plating pilot plant

Deliverables submitted in WP4:

D4.1 – Specifications of Aluminium electrodepostion and post-treatment pilot plants – M21

D4.2 – Industrial line for aluminium electrodeposition built and comissioned– M24
D4.3 –Pilot plant comissioned for aluminium coatings anodizing– M24

WP5 INDUSTRIAL VALIDATION AND TESTING [MAI, All partners]

The aim of task 5.1 is to validate and test the prototypes developed during WP4 and therefore establish scientific evidence that an industrial process is capable of consistently delivering quality product.

Task 5.1 – Technical validation (Coordinator: MAIER; Participants: All partners)

During the first stage of the SCAIL-UP, for the electrodeposition of aluminium, the 13L tank designed in the project was used to perform all the experiments with 3D automotive prototype components before commissioning of the 200 L pilot plant

MAIER worked on the definition and optimization of the experimental conditions on the 13L tank

CIDETEC was in charge of characterizing in depth the electrodeposits obtained in the 3D parts by MAIER at the 13 L tank scale. After these experiments in which main experimental parameters were scanned, the following conclusions were obtained:

- Al aluminium deposits were obtained in 3D parts
- Parameters definition: activation, shape and disposition of the anodes, the importance of applying a ramp for current density to avoid burned deposits. No homogeneous coatings.

During the optimizations of the experimental conditions at the 13 L scale one of the critical parameters detected was the variability of the Ionic Liquid batched performance. The main results obtained with the different batches were analyzed together with CIDETEC and IOLITEC.

Finally a common working protocol was defined and shared by the partners and no longer quality variation were found in the following IL batches.

Further modifications on the process were made for the purposes of increase aluminium coating homogeneity and electrolyte throwing power.

Even though inside face of the 3D parts were not enough coated so back face protection was needed for post-processing the automotive components prototypes, Post-treatment process allows four different finishes, red coloured prototypes were chosen for validation.

In addition, series of 3D polymeric substrates coated with aluminium from ionic liquids then post-treated were performed for coating validation following technical requirements of decorative coatings for automotive applications defined in D2.1. Validation Test of 3D parts was performed by CIDETEC.

Pilot plant experiments

The activities carried out by MAIER during the last stage of the project involve electrodeposition, pilot plant reception at final location, optimization of the experimental conditions for aluminium plating using the new pilot plant and production of short series of aluminium coated 3D automotive components prototypes for validation. Along with these activities, the post-treatment pilot plant developed during WP4 was used to complete the process on the aluminium coated 3D samples.

Before loading the electrolyte, CIDETEC characterized all the batches to be loaded into the pilot plant. The suitable quality of the IL was assured. Preliminary experiments performed during the setting up of the system revealed promising results for metalized plastic substrates.

Aluminium coating was clearly observed in the front side of all the coated parts. Back side of the parts showed no aluminium coating. These preliminary results showed a good performance of both the pilot plant itself and the ionic liquid electrolyte. Further test of the main electrolyte showed that no loose of performance of the ionic liquids could be detected; After these preliminary results, the first experiments were carried out, but these first series of aluminium coated 3D automotive prototypes lead to undesired results in terms of coverage of the coating, homogeneity of the deposit and thickness. These results led to the optimization of the plating conditions .At the same time, aluminium coated 3D prototypes for the automotive sector were obtained in the 13L tank in order to continue working in the anodizing pilot plant for validation.

Experimental parameters were optimised through different experimental configuration during the tests. After the different tests carried out a much better coverage of the sample with the aluminium coating as well as a more homogeneous layer but still dendritic growth and edge effect occurred.
Finally, adjustment of the anode distance allowed the deposition of aluminium on plastic substrates with the desired aspect, coverage and thickness as a result of the decreased ohmic drop.
After a short production period the crane breakage occurred making it impossible to continue plating in the pilot plant, so the expected time for aluminium coating automotive component prototypes production was minimised and compensated with the 13L tank production.
In parallel with the aluminium plating activity the optimizations of the post-treatment pilot plant was carried out to continue testing the complete process for the productions of aesthetic aluminium coated 3D prototypes for the automotive industry.
With the objective of validation in mind the required pieces for validating the process was produced specifically by MAIER and provided to CIDETEC to perform the tests.

Failure was detected on the crane, MAIER communicated it to C-TECH first and after realizing the severity of the damage the rest of the consortium was warned about the situation and the decision about the necessity of opening the rig was made. After several internal discussions among the consortium, an organic cleaner was chosen as the preferred solvent for cleaning up the pipework and the tanks to eliminate the remaining IL.

Previous to make the final decision, the consortium was asked for a proper cleaning solution in order to remove the remaining ionic liquid present in the pipework and on the main tank´s walls. In this sense different kind of solvents were proposed., CIDETEC and IOLITEC carried out several experiments in order to evaluate the suitability of some of the proposed solvents.

After the experiments carried out by other members of the consortium it was agreed to do the washing of the pilot plant with sequential washing steps using only Organic cleaner as cleaning solution.

Coatings validation

CIDETEC carried out the validation of the 2D and 3D component prototypes for the automotive sector. Validation tests for the automotive components prototypes are collected in deliverable D 2.1. The aluminum coating obtained from the electrodeposition from a BMIM:$AlCl_4$ ionic liquid electrolyte was done on 2D and 3D prototypes obtained by MAIER at the 13L tank firstly, and from the pilot pant developed during the project. Deliverable D5.1 covers in depth all the validation tests carried out so a summary of the obtained results will be shown in this report.

Table 2: Results of the validations tests

Test	Result
Color and aspect	Ok
Al layer thickness	Ok
Al_2O_3 layer thickness	Ok
oxidized layer homogeneity	Ok
Silted up of the anodized coating	Ok
Corrosion resistance (CASS)	Ok
Saline Mist Resistance (NSS)	Ok
Coloration resistance: UV by Xenotest 450	No OK
Chemical agents Resistance	Ok
Color resistance in water. Bac Ford 10 days and adherence after immersion.	Ok
Scratch Resistance	No Ok
Nivea cream Resistance	Ok
Adherence between layers	Ok

All the validation test were successfully accomplished except coloration resistance and scratch resistance. Use of Integral colour and electrolytic deposited lacquers, in the case of coloration resistance, and optimization of the oxidized layer in the case of scratch resistance were proposed to pass these tests.

Gas turbine process validation

The isothermal test was carried out with the purpose of evaluating the oxidation behavior of the aluminide and over aluminide coatings employ the new developed aluminizing process via Ionic Liquids and for comparing those processes with the concurrent pack aluminizing and pack over-aluminizing one.

Table 3 shows the list of systems selected for the isothermal test and parallel characterization.

Sample number	Target	Aluminizing	Test Temperature
1	base material (IN 738)	Ionic Liquids	1000°C, static air
2	MCrAlY (NiCoCrAlY)	Ionic Liquids	1000°C, static air
3	MCrAlY (CoNiCrAlY)	Ionic Liquids	1000°C, static air
4	base material (IN 738)	pack cementation	1000°C, static air

5	MCrAlY (NiCoCrAlY)	pack cementation	1000°C, static air
6	MCrAlY (CoNiCrAlY)	pack cementation	1000°C, static air
7	MCrAlY (NiCoCrAlY)	none	1000°C, static air
8	MCrAlY (CoNiCrAlY)	none	1000°C, static air

Table 3: systems tested under oxidative conditions at 1000°c for 1000 hours

Two different MCrAlY compositions were selected to be aluminized in order to detect the main differences in Al diffusion into two different oxidation protecting coatings.
The same systems were aluminized with the two competitor processes:

- IL aluminizing: composed by Al plating by Ionic Liquid and post-treatment (1100°C in vacuum)
- Pack aluminizing: pack treatment at 1000°c in Ar + 1100°c in vacuum

The following characterizations were performed over "as sprayed" samples (0 hours of test), 500h tested samples and 1000 hours tested samples:

- **Isothermal oxidation test**: **Optical microscope observation: SEM/EDS analysis XRD analysis Micro-hardness profile The main conclusions ca**n be summarized as follows:

- IL aluminizing over IN738 did not match the specifications described in the table 1. Al found difficulties in diffusing into the base material creating a thin aluminide layer. The cause of this un-expected results was the possible remaining of electrolyte residuals from the electroplating process onto the base material surface.
- IL over-aluminizing process created a well performing aluminide coating over CoNiCrAlY. The thickness of the over-aluminide coating was higher than the one formed by pack aluminizing process. Al content into the upper layers of the coatings was also higher for the IL aluminized coating with respect to the standard pack over-aluminizing process. IL over-aluminizing process created a well performing coating over NiCoCrAlY. The same considerations made for the CoNiCrAlY are valid also for NiCoCrAlY. However the increase in Al wt% after IL aluminizing process was less than in the case of CoNiCrAlY.

Task 5.1.2: Technical validation on different base materials

A further process development was the feasibility study for the application of the new developed IL aluminide coatings over two different base materials compositions.
MAR M247 and Hastelloy X were chosen for this feasibility study: they were selected due to their high employment as base materials for gas turbine components.
The developed and established Al electroplating process was applied over the two selected base materials in the same process conditions: 20 μm of coating was applied with the parameters studied and developed within WP2 and WP4
Figures 21 and 22 show the optical microscope cross sections of the electroplated Mar M247 and Hastelloy X respectively. The applied coating was homogeneus and no Dendritic microstructure was detected by optical microscope after Al plating at a lab scale.

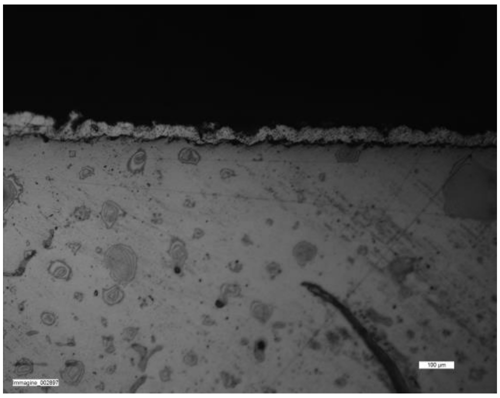


Figure 21. Al plated mar m 247

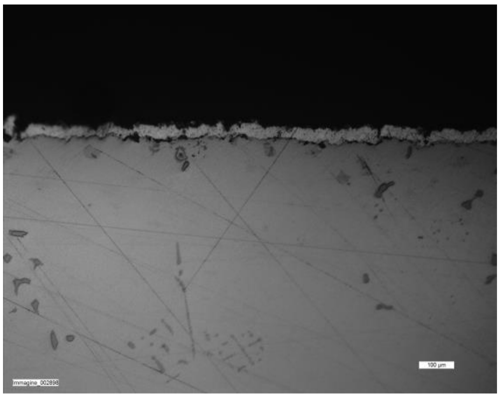


Figure 22. Al plated hastelloy x

New post treatment parameters had to be chosen for the two different applications. Heat treatment parameters strongly depends on the target to be treated and on its chemical composition indeed.
For this reason a Design of Experiments (DOE) was designed to find out the optimal parameters for the total diffusion of the plated Al layer. The main variables chosen for the DOE were:

- **TemperatureMaintenance at high temperature:**
- **Pressure**:

The DOE gave the optimal parameters for the final heat treatment selected for these base materials
The main results came out after heat treatment application are showed in Figures 23 and 24 related to IL aluminizing of Mar M 247 and Hastelloy X respectively.

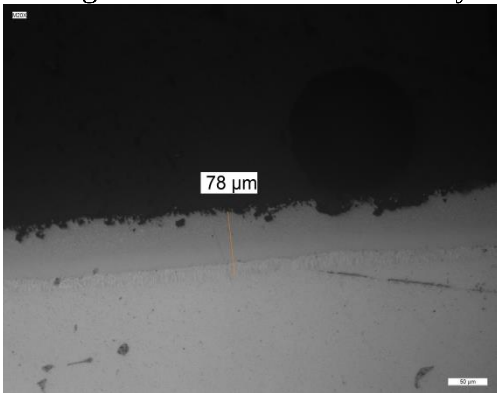


Figure 23. Plated and heat treated mar m247

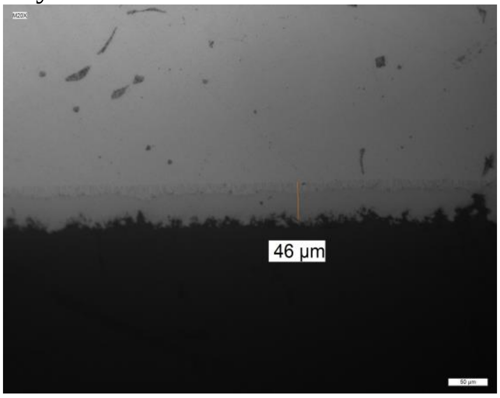


Figure 24. Plated and heat treated hastelloy x

Task 5.1.3: Technical validation of ionic liquid aluminizeng process within the installed pilot plant
The scailing up of the process from the lab scale to the pilot plant scale was carried out.
Both INCONEL 738 flat samples and real parts (1st stage rotating gas turbine blades) were chosen for the IL aluminizing process validation in the pilot plant. The samples were prepared considering the results achieved during the isothermal test (Deliverable 5.2):

- CoNiCrAlY was chosen as main target to be over aluminized via IL Al plating due to the good performance achieved after isothermal test
- 40 IN738 samples were purchased, machined and prepared (coated with CoNiCrAlY by LPPS and laser drilled) for the pilot plant trials

- 4 rotating blades were prepared and coated with CoNiCrAlY LPPS sprayed coating using the same robot program and plasma spray parameters developed in WP4.
- 1 whole week of trials was carried out testing different plating parameters

The process applied over the whole amount of samples and components followed the same steps developed within WP2 and WP4.
Seven sets of process parameters were tried on flat samples in order to understand the feasibility of the process with a larger electrolyte volume than the lab scale and to ensure the process was repeatable from the lab scale
The same main results occured for all sets of parametrs:

- the Al layer plated within the pilot plant was detected as not homogeneus and with Dendritic microstructure (un-desidered microstructure) (Fig 25). The same dendritic microstructure was observed over the whole amount of samples plated with sets from 1 to 7 unfortunately.
- Even if the coating dis-homogenity before heat treatment decreases after the heat treatment, the content of Al stays out from the range specified in technical requirements (D2.2): from 6 to 9 wt%. Aluminide coating microstructure is shown in figure 33 as an example of the same results detected for all the plated samples.
- A further period of time dedicated to more trials on the pilot plant is necessary in order to study new plating parameters able to give the right coating, microstructure and behaviour.

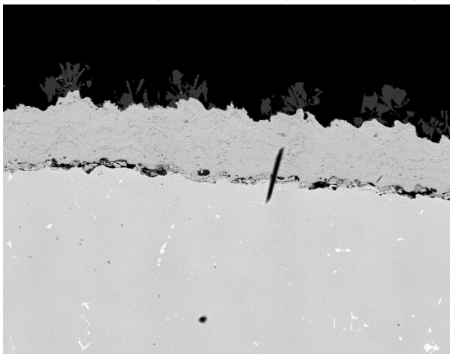


Figure 25: Al layer plated within the pilot plant before heat treatment. Sem micrograph shows the dendritic microstructure of the al layer

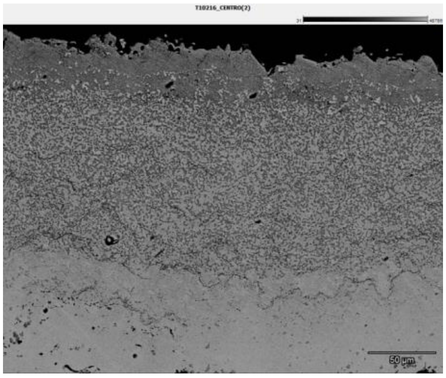


Figure 26: Aluminide layer plated and heat treated. Sem micrograph shows the coating microstructure of the coating

Validation of IONIC LIQUID ALUMINIZING process on real components:

4 real components were prepared, plated and heat treated in order to understand if the process developed within WP4 was repeatable by the installed Pilot Plant.

The same conditions and parameters developed within WP4 (surface preparation, CoNiCrAlY application by LPPS technique and post-treatment) were applied over 4 rotating blades.

Parts of the turbine blade airfoil were cutted for optical microscope observation and for SEM/EDS analysis.

Figure 27shows the Al layer plated over the complete section of the airfoil, from the leading edge to the trailing edge while figure 28 shows the same results of the coating after heat treatment

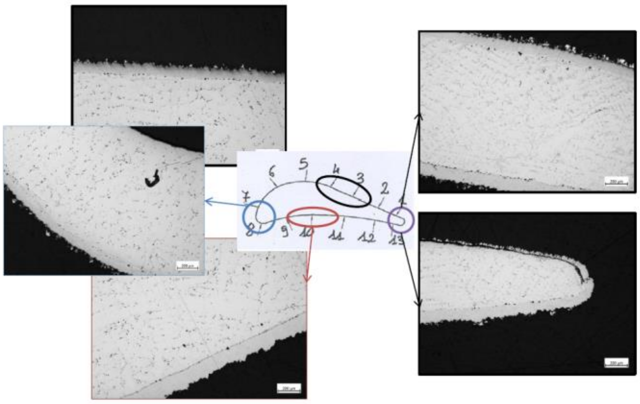


Figure 27: Al plated on the airfoild surface of a rotating gas turbine blade

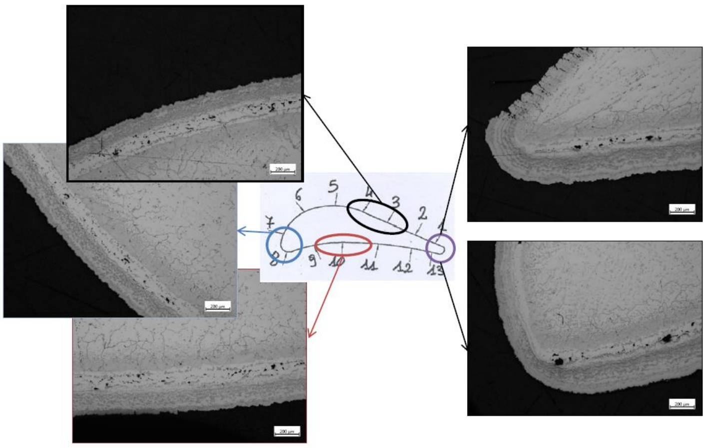


Figure 28: Al layer plated and diffused by heat treatment at 1100°c on the airfoil section of a gas turbine rotating blade.

Results achieved on the real components totally reflect those obtained on flat samples within the pilot plant.

The Al layer electroplated via Ionic Liquis is evidently not homogeneus, from optical microscope the microstructure detected is dendritic.

The over-aluminide coating formed after heat treatment is more homogeneus than prior to this post-treatment, however the content of Al is less than the specified range (Al wt% stays between 8 and 10 %).

These results confirm the need to carry out several other trials with different plating parameters in order to achieve the optimal coating in terms of microstructure and chemical composition and in terms of performances.

Task 5.2 – Process standardization (Coordinator: MAIER; Participants: TUC)
At this moment MAIER is waiting for the celebration of the next meeting of the CEN Technical Committee 262 on November 30th. At that meeting, David Michael (secretary) will collect all the comments about the future standardization possibilities of the process and send us the conclusions.

<u>MAIN S&T RESULTS FOR WP5</u>
Characterization of the obtained aluminium coatings (13L).

- Flat samples have been employed to evaluate the aluminum coatings on plastic substrates for the automotive application
- Aluminum coatings from ionic liquids fulfill all the requirements requested by the automotive industry, in 2D samples.

Aluminum coating on automotive components prototypes exhibit excellence adherence and chemical resistance.

Characterization of the obtained aluminium coatings (200L).

- Coatings passed all the specifications except Coloration resistance and Scratch Resistance. In order to pass these two tests further investigations on the post-treatment process are needed to be developed taking advantage of the broad technical knowledge available.

IL electrolyte characterization revealed the electrolyte had the expected quality for plating on plastic substrates for the automotive application.

Characterization of the IL inside the pilot plant revealed no loss of performance and the electrochemical features of the Il were preserved after 5 months inside the pilot plant.

An organic cleaner was selected as cleaning solution of the main tank as well as the pipework but further research needs to be carried out in order to improve the procedure diminishing the risks associated to those operations.

<u>Deliverables submitted in WP5</u>
D5.1 – Report on technical properties from industrial series of decorative coatings for the automotive sector– M36.
D5.2 – Report on technical properties from industrial series of intermetallic coatings for the aeronautic sector– M36.
D5.3 – Guidelines for electrodepositing aluminium on polymeric substrates– M36.
D5.4 – Guidelines for electrodepositing aluminium on nickel alloys– M36.

<u>WP6 ENVIRONMENTAL AND ECONOMICAL IMPACT. LCA ANALYSIS [IOLITEC, MAI, TUC and C-TECH]</u>
The implementation of a new technology on an industrial scale demands not only the successful delivery of a ready to use product, but also an effective treatment and recovery of the used materials and resulting waste beside an environmental and economical impact analysis. An effective recycling process of waste is not only an economical advantage concerning the total costs of a product, but also

saves resources and is environmentally friendly. Therefore, IOLITEC's intention was to develop a process to recover the used aluminium electrolyte after the end of its process lifetime has been reached and Aluminium depositions do not have the necessary quality anymore. Furthermore, data for the LCA were collected during synthesis of the electrolytes and recycling processes.

In literature no reaction data for the BMIM Cl with $AlCl_3$ were available, but a very familiar reaction of the EMIM Cl with the $AlCl_3$(**¡Error! No se encuentra el origen de la referencia.**) was found. There König et al. investigated the reaction enthalphy, which are very important parameters for scaling up the production of the electrolyte.

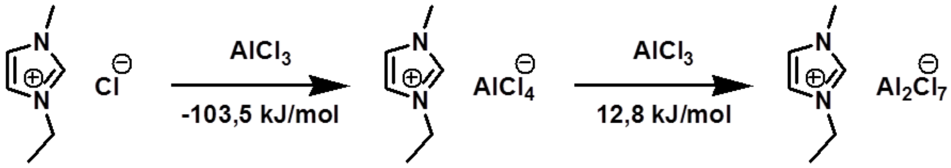


Figure 29: Reaction enthalphy for the synthesis of emim al$_2$cl$_7$ described by könig et al.[3]

Task 6.1. Waste treatment, recovering and recycling. Development of mitigation processes (Coordinator: IOLITEC; Participants: MAIER, TUC and C-TECH)

IOLITEC provided a detailed plan for extending the lifetime and of recovering the electrolyte (**Deliverable D6.1**.) and discussed the advantages and disadvantages of two different routes for quenching and recycling of the 1-butyl-3-methylimidazolium chloride from the aluminum electrolyte. With both methods it is possible to deactivate the highly corrosive and with water reactive material to proceed with the separation of different impurities and to recover good quality BMIM Cl after the life extending measures for the plating electrolyte are no longer sufficient. The majority of the 1-butyl-3-methylimidazolium chloride (BMIM Cl), can be recovered and reused in the production of new electrolyte. The successful recycling route involves 8 steps and allows easy heat control or control of other potential safety issues and involves no solid formation at any time during the work up, which allows use of simple industrial reactors. The recovery process minimizes the costs for new electrolyte and also saves resources and reduces the amount of waste. The solvents, water and organic ones, used for extraction during the recovery process can be distilled and reused as well.

But this recovery/recycling step is not needed for several months or even years, if the plating electrolyte is kept well maintained and treated in with the described on-side measures for extending the lifetime in the plant.

On an industrial scale with larger amounts of electrolyte to recycle the released waste or heat should be also reused instead of wasting it. The waste heat could be recovered by using a heat exchange unit, to be reused for cooling or heating of other processes.

In order to enhance the overall economic reasonability of the pilot plant plating process, it was considered to be useful to recover and to reuse the rinsing fluid, which is typically contaminated with BMIM $AlCl_4$ after its usage within the process. Unfortunately, the recovery and reconditioning of the chosen rinsing fluid was not possible. Taking into account that the rinsing solution was also not

[3] P. Keil, A. König, *Thermochimica Acta.* **2011**, *524*, 202-204.

suitable to act as cleaning solution for the pipework, it might be substituted in the production unit by another fluid.

Task 6.2. LCA and risk assessment. (Coordinator: C-TECH; Participants: MAIER, TUC and IOLITEC)

During the production of the electrolyte batches IOLITEC conducted the data acquisition for the Life Cycle Assessment (LCA) after the international norm ISO14040 (ISO 2006). Data for the energy and mass balance of the synthesis have been collected as well as for the environmental and economic assessment.

The material streams typically involved in the Ionic liquid production are summarized in Figure 30:

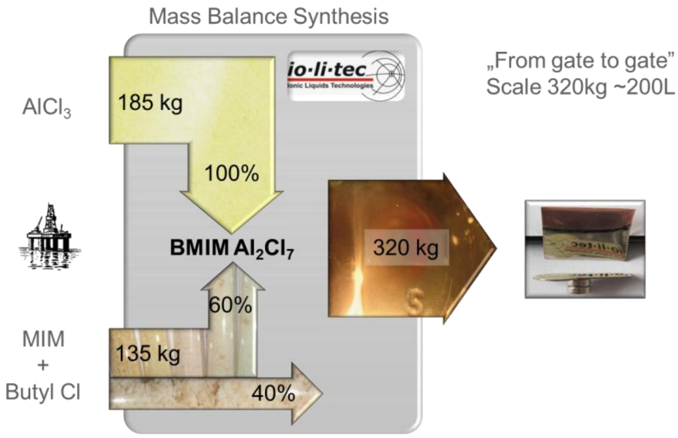


Figure 30: Material consumptions for electrolyte production at Iolitec

The costs for pilot plant electrolyte of 320 kg (~200 L) BMIM $AlCl_4$ are calculated at around 87.50 Euro/kg, leading to 28'000 Euro for the first fill. The costs for rinsing solution of 160 kg are calculated at 92.50 Euro/kg (14'800 Euro for one filling). Due to the recovery rate on the BMIM Cl, there are savings on starting materials (after reduction of costs for the recovery process, including solvents, reagents and waste disposal) of about 18.1 %.

The compiled data at IOLITEC for raw material streams, waste streams including local rates for waste disposal, energy consumption including local price for power on an individual big industrial customer rate, and hourly labour rate for chemistry-trained personnel were shared with the partners and used in the life-cycle (D6.2) and economical assessment (D6.3) done by the partners C-TECH and Turbocoating.

Note: The devices used in this project are handling currently batches on the kg-scale; the energy consumption per kg will go down significantly with larger equipment. (Estimation: approx. -75% on a ton's scale).

A complete Life Cycle Analysis has been carried for the developed process in accordance with the requirements of the International Organization of Standardization standards ISO 14040/44 with four main steps:

1. Goal and scope definition articulates the objectives, functional unit under consideration, and regional and temporal boundaries of the assessment.

2. Inventory analysis entails the quantification of energy, water, and material resource requirements, and emissions to air, land, and water for all unit processes within the life cycle.

3. Impact assessment evaluates the human and ecological effects of the resource consumption and emissions to the environment associated with the life cycle.

4. Interpretation of results includes an evaluation of the impact assessment results within the context of the limitations, uncertainty, and assumptions in the inventory data and scope.

In this study the **functional unit** of comparison is defined as **1 Batch of 1 m^2 coated.**

The whole cradle to grave analysis of a component being coated is beyond the scope of this analysis and would be dominated by factors irrelevant to the coating operation. Consequently the SCOPE has been defined quite tightly as the coating process and any pre 0r post treatments required to get a functionally equivalent coating (feedstock materials and energy).

More specifically, different analyses were carried out for the automotive and aerospace markets compared with current processes.

For Aerospace (TUC) the comparison was **Scail-up vs Current Aluminium Deposition comparison**, with two different processed developed by TUC have been use as baseline; **Pack Cementatio**n process and **Chemical Vapour Deposition (CVD)** process.

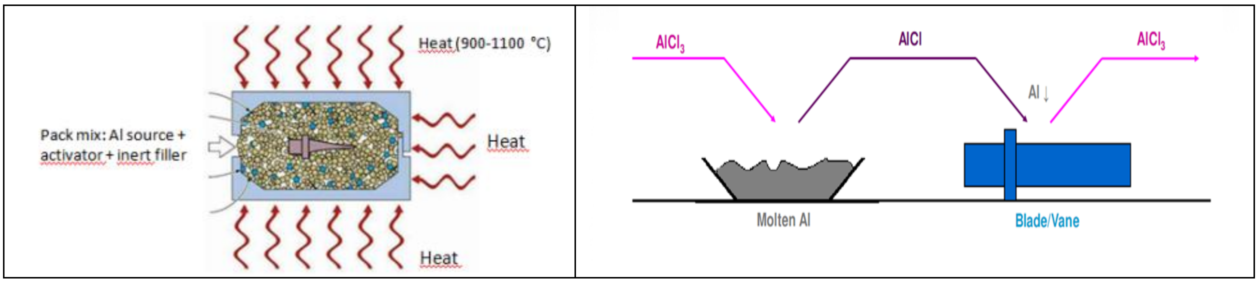


Figure 31: Pack Cementation (left) and CVD (right).

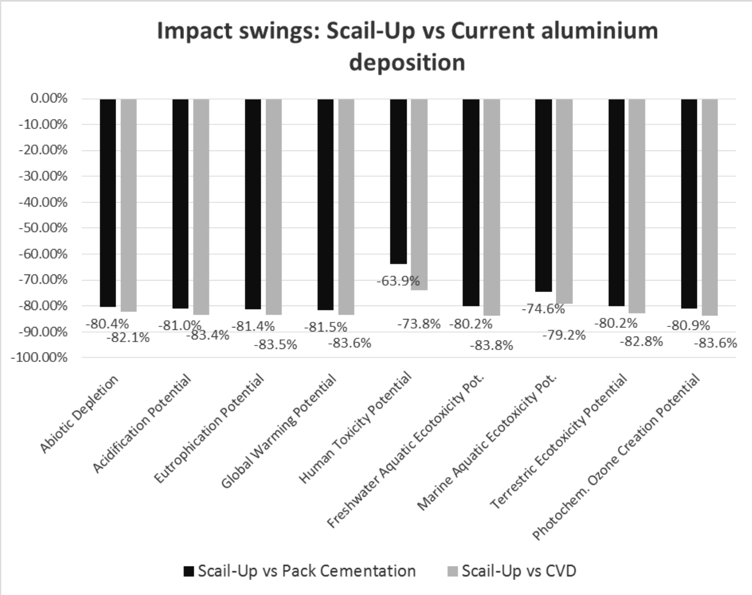
For Automotive applications within Maier the application is putting an aesthetic but corrosion resistant surface onto plastic components prototype. No current aluminium coating process is available for comparision and it is compared with conventional chrome electroplating. However the as plated aluminium does not have sufficient corrosion resistance to meet the functional specification, so an post treatment step is also included for the SCAIL UP process.

The performance indicators used in the LCA were the following impact assessment categories:

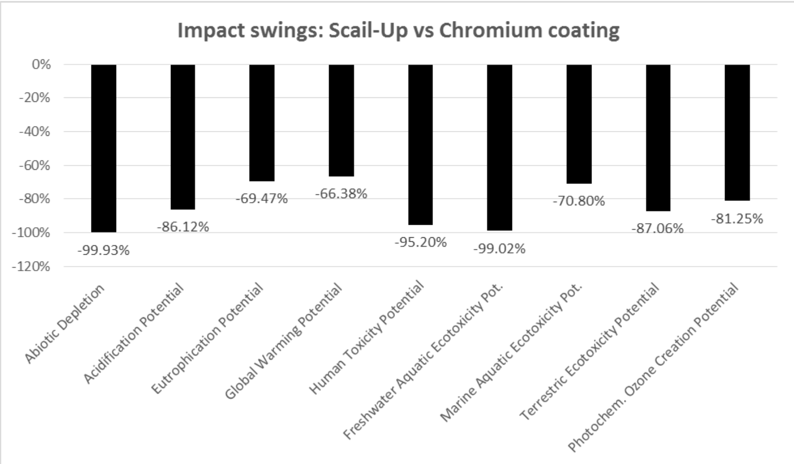
- Global Warming Potential (kg Co2 Equiv.)
- Acidification Potential (kg SO2 equiv.)
- Eutrophication Potential (kg Phosphate Equiv.)
- Abiotic depletion elements (kg Sb Equiv.)
- Freshwater Aquatic Ecotoxicity (kg DCB Equiv.)
- Terrestric Ecotoxicity Potential (kg DCB Equiv.)

- Human Toxicity Potential (kg DCB equiv.)
- Marine Aquatic Ecotoxicity (kg DCB equiv.)
- Photochemical Ozone Creation Potential (kg Ethene equiv.)

For both applications it can be seen below that the use of the ionic liquid electrodeposition process brings about very significant reductions (65 to 99%) in the environmental impacts in all categories. Detailed analysis shows that the reductions are mostly due to reductions in energy consumption from high temperature processes or inefficient processes and reduction in toxic material use. Consequently it can be concluded that the SCAIL-UP ionic liquid electroplating process has significant potential to reduce the environmental impact of these and similar processes.



Aerospace – Turbine Blade Coating Application



Automotive – Metallising of plastic automotive component prototype application

Task 6.3. Economical assessment (Coordinator : TUC; Participants: MAIER, C-TECH and IOLITEC)

An economical assessment was carried out based on the data coming from the pilot plant manufacturer and from the experience of the industrial partners achieved from the commissioning of the pilot plant itself.

The economical assessment data are reported in Deliverable D6.3, the document is divided in two main sections:

- CAPEX costs related to the design, manufacturing and commissioning of the pilot plant
- OPEX costs related to the actual operations for Al plating on the Pilot Plant

The OPEX costs of the developed Ionic Liquid process were also compared with the currently employed industrial processes for both applications:

- **Chromium plating process for automotive application**
- **Pack aluminizing for gas turbine applications**

The CAPEX costs repartition related to the design, manufacturing and commissioning of the pilot plant are reported in figure 32 while OPEX costs repartition are reported in figure 33:

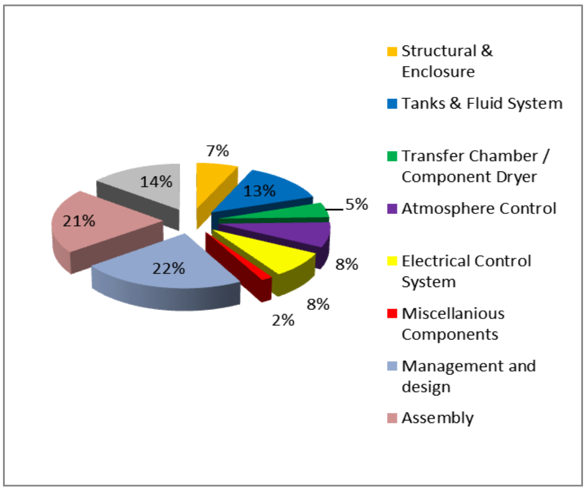


Figure 32: OPEX costs repartition

The main outcome is that the highest impact is given by the design and management of the manufacturing operations. This costs will be drecreased in future for new orders since the biggest piece of work was carried out during the current project.

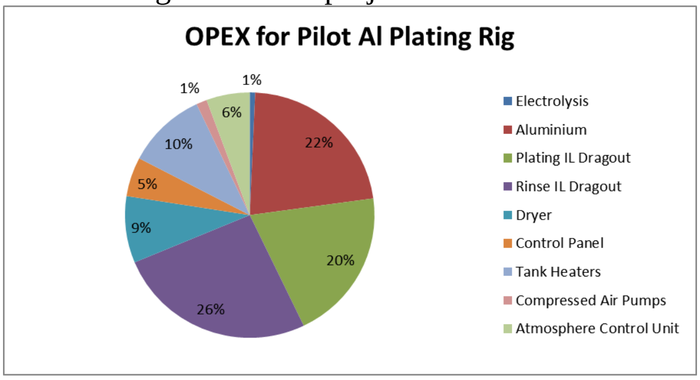


Figure 33: OPEX costs repartition

The main impact on OPEX costs is the cost of the Al anodes. The costs depicted in Figure 33 were elaborated considering the costs for Al anodes with 99,99 % purity material. Tests and trials were performed in the past with anodes made of Al 1050 alloy (99,90 % pure), results coming from the Al plating using these anodes gave great results in terms of homogeneity and microstructure quality.
Considering to substitute the 99,99% pure Al anodes with the 1050 Al alloy anodes a decrease of 16% of cost per part was estimated. Giving a final cost repartition showed in figure 34:

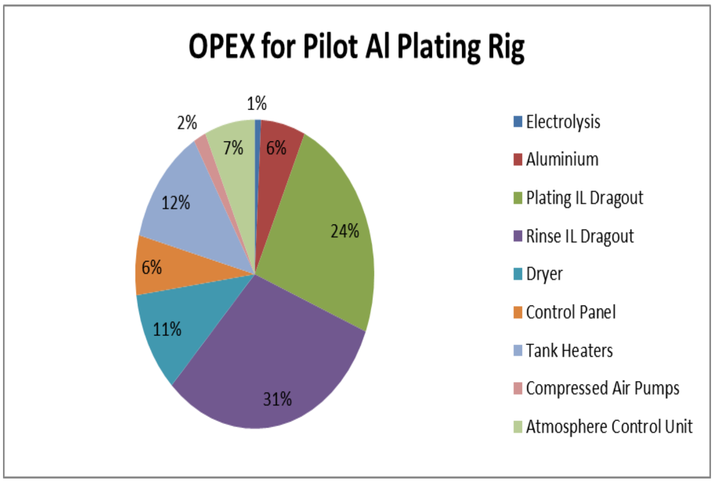


Figure 34: OPEX costs repartition considering al1050 as base material for anodes

The comparison between the new developed processed and the currenlty employed production processes for both applications gave the following conclusions:

- 52% energy reduction was estimated for the Al plating process in comparison with the Cr plating process for the automotive application. By making the same comparison, 50% material reduction was also estimated for automotive application.
- 76% energy reduction was estimated for the IL aluminizing process in comparison with the currently employed Pack aluminizing for gas turbine components. The same comparison showed a decrease of 86% in material consumption between the the developed process with respect to the standard one for gas turbine application.

<u>Deliverables submitted in WP6</u>

D6.1 – Specifications and defined working conditions of developed recovering/recycling process– M27.
D6.2 – Life Cycle Analysis and risk assessment of new process– M36.
D6.3 – Economical balance and roadmap for implementing electrodeposition through Ionic Liquids– M36.

DESCRIPTION OF POTENTIAL IMPACTS

The SCAIL-UP coordination team really believe that the project has been really successful according to exploitable results that have been achieved. Furthermore, it worthy be remark that some of the results are currently exploiting.

CIDETEC (RTD CENTER)

- Deep understanding of the aluminum electrodeposition process from Ionic liquids which could be exploited through new research projects (regional, national, European).
- Strength private funding incomes via developing new solutions based on IL technology for different sectors.
- Increase the workforce of CIDETEC as a result of new projects/contracts.
- Peer reviewed and open access scientific publications
- Close to market solutions for several industrial markets. New processes.
- Enhance the position of CIDETEC as research partner in the field of surface engineering

INSTM (University)

- Increasing and disseminate knowledge on both theoretical and practical aspects of material science and electrochemistry.
- Exploitation via publications and congress contributions.
- Modeling of Al plating process that can be used in other electrochemical processes being an innovative and useful instrument for galvanic industries as well as research institutes foe both theoretical and applicative purposes.
- Development of a new device (modified Rotating Hull Device) which can be used in aggressive environments (not only ILs).
- Consultancy on development & commercialization of IL electrodeposition for self and to support post SCAIL UP exploitation:
    - New substrate materials and pre-treatments
    - Alloy coatings e.g. Al-Cu
    - None Al coatings e.g. Be

IOLITEC (IONIC LIQUIDS SUPPLIERS)

- Sustainable and cost-effective new methods for ILs production, implementation of recycling processes marks a unique selling point

- IL production and purification cannot be patented; it will be kept as internal company knowhow at Iolitec, there are no licensing strategies.

- Electrolyte BMIM $AlCl_4$ is on the market in volumes far below one ton at Iolitec; if demand increases, Iolitec will invest in further upscaling.

(0.1 – 0.25 Mio. € might be needed, own investment)

- Competitors are: BASF (Germany), KOEI Chemicals (Japan)

Target Markets: Automotive, Aerospace, industries such as mechanical/engine construction, plating industry

The Market trend: replacing Chromium,

- the public acceptance is driven by the replacement throughout a novel

- environmentally benign technology

- IOLITEC is responsible for the market introduction of the electrolyte; (it could be beneficiary to implement the technology together with the partners, but also extend the technology towards other technologies)

-The product is directly marketable and will be marketed via a plating-product launch in Q1-2017. (EU, North America (US-subsidiary)

- REACH registration is required, but there are no ethical requirements
- Depended on the output volume of BMIM $AlCl_4$-Electrolyte numerous jobs for lab technicians at Iolitec might be newly created:
    - annual output: 10 tons => 2 jobs
    - annual output: 50 tons => 5 jobs
    - annual output: 100 tons => 8 jobs

(project SCAILUP itself created already one job at Iolitec during the lifetime of the project.)

- A joint company may be considered if pilot plant and electrolyte are sold as a combined package, which could be a good strategy for C-Tech and Iolitec

C-TECH (TECHNOLOGY SUPPLIER)

C_Tech expect there to be a commercial business in the supply of equipment for electroplating with ionic liquids, in particular for aluminium. While we don't have patents that will prevent copying of our designs, the considerable know-how inherent in the design will delay competitors allowing us to be first to market with the following advantages:

- Proven robust containment system
- Integrated dryer system
- Experience at building / operating at the World's largest scale with low running costs.

We would hope to extend sales to further than just pure aluminium plating, as the technical requirements of the equipment are identical or at least very similar. It will be primarily led by the research community but demand for scale up may be stimulated when it is publically known that this tye of equipment is now available at pilot scale or larger._Examples are: Al alloys, Si, other semiconductors, BiTe for Thermo-electrics, others as they become available

Customer Sectors

Pilot Plants for industrial and Universities, Industrial Gas Turbines (IGT), Aerofoils for aircraft engines, Cd replacement on components and fasteners.

Collaborations

There is a compelling case for a close collaboration between CTECH (equipment supplier) and IOLITEC (IL supplier) for exploitation. We have started discussions on the commercial basis of these collaborations on marketing / sales possibly including the option of a joint company. Both companies are planning on a product launch in 2017.

Any new applications of ionic liquid plating (new components, substrate materials or coating systems) are likely to require technical support from research organisations skilled in the application of these technologies. If the customers do not have their own technical expertise then INSTM and CIDETEC have these skills and will be introduced to the customers.

Time to market

- Pilot plant (similar size to Scail-Up): 6 months
- Production plant (Scail-Up x 2-3): 18 months

- Scale up of the pilot plant to production scale is very feasible given the learning from the project. We would expect a x2-3 increase in capacity to cost less than 50% extra with a reduction in the none consumable OPEX.

MAIER (END USER)

- New aluminum plating process based on a green alternative to conventional plating processes.which would open new bussines opportunity for MAIER in terms of:
  - **New trends**: satined metals and new metal effects in interior and exterior trims.
  - **Break the market** introducing Al coated products that nowadays are produced with Cr or just painted to simulate Al or even bulk aluminium.
  - These kind of coatings answer the needs of **Premium OEMs as the German Market**. MAIER is trying to open its business in German market (Mercedes/ audi/BMW –Premium).
- Time to market: MAIER foresee the timeframe outlined below for industrialization of the technology:
  - Dissemination activities. Optimization stage in the pilot plant (at C-TECH). Contact OEM design team for validation of the new finishing. (Year 1)
  - Peer reviewed specification tests by OEM´s technical labs. Field validation. Selection of the target car model in which components prototypes with Al finishing will be introduced. (Year 2)
  - New plating line for mass production at industrial scale (Year 6).
  - SOP of automotive parts (Year 8).

TURBOCOATING (END USER)

TUC aims to collect all the missing information in order to be sure to propose the process to IGT Customers:

TUC is also trying to enter into the aviation market: possibility to propose this process to interested Aereo engine customers

TUC is aiming to perform more trials on the pilot plant (that will be placed in C-Tech for next years) within 2017 in order to achieve the expected results and to optimize the process parameters for aluminizing and over-aluminizing technique by Ionic Liquids. Once the results are achieved, the idea is to exploit them to the customers during internal meeting and/or international conferences.

In a long term prospective, TUC might be able to install a pilot plant for the customer parts qualification for a successive mass production in a 5 years time frame.

MAIN CONCLUSIONS

While initial external customer interest can be satisfied with laboratory samples, a pilot plant capable of producing industrial sized samples is essential to drive the exploitation of the technology both internally and externally.

Short Term. The pilot plant will return to CTECH for minor modifications (modify for solvent operation and operability).

Longer term. We need to consider where to locate and fund the pilot plant going forward to allow further trials by the project partners and potential external customers. Potential locations:

- C-Tech where we can support it and have some post / pre treatment equipment.
- A host site convenient to C-Tech – likely to be a loan with proviso that the rig is available for external trials for X% of the time. Probably a university or manufacturing research centre.

- Extended trials on a potential customers site – loan fee to cover costs.

Other considerations:

- IOLITEC are an essential partner in this activity to supply the IL and be a credible long term supplier.
- CTECH as a small SME (<50 employees) has limited capacity to self fund these activities without equipment orders. We are currently discussing with the consortium and external organisations the best way forward. Models include: technology demonstration grant funding, pay per trial, loan with support fee and external hosting with access.
- Timescale to set up the pilot plant is about 6 months which fits well with Maier / TUC deciding upon their ongoing requirements and contacts firming up with external customers.

The strong relationships between the SCAIL UP partners will continue after the end of the project and are essential for successful exploitation

Equipment Build

Collaboration on selling systems (equipment + liquid) to customers both internal and external to the project primarily between CTECH and IOLITEC. But INSTM or CIDETEC partners may be involved to develop custom processes.

Aerospace

TUC would take the lead on aero-engine components and CTECH on Cd replacement. We jointly have a large number of high level contacts including: Rolls Royce, GE, Snecma, Airbus, plus equipment suppliers, coating companies and coating associations e.g. DGO, IMF.

CTECH are already collaborating with Airbus on Cd replacement coatings and wish to evaluate these Al coatings. We had hoped to produce samples for them on the pilot plant. This will now be done by INSTM at lab scale.

Support from INSTM & CIDETEC.

At a minimum we will develop a joint marketing & sales strategy.

Automotive

Led by Maier according to their requirements in the first instance as they need a period of exclusivity to develop a technological lead.

Research Activities.

Plentiful opportunities exist for future grant funded and direct commercial research activities to further IL electroplating.

SOCIO-ECONOMICAL IMPACT

During the project lifetime CIDETEC has created 2 new job positions, one lab technician and 1 junior researcher. Moreover, CIDETEC, the 2 created positions will become permanent position at CIDETEC.

It is expected that this positions will become permanent positions once the project finishes. In the case of INSTM, Within the project two (2) doctorate thesis have been started (the final dissertation will be discussed in 2017) and several grants have been signed allowing the formation of three post graduate students (two males and one female) and two post doctorate students (two female) that, thanks to the experience done within the project, eventually moved to industry.

C-TECH None currently but we will probably seek grant funding to further develop or demonstrate the technology. C-Tech will actively market the technology along with IOLITEC as a complete package of equipment + liquid.

C-TECH will safeguard 2 jobs. Beyond the project, we expect that with sales growth of 1 -2 systems per sold from the end of 2017 that we would safeguard 1 job and create 2 jobs over the next 3-4 years.
IOLITEC is confident to create a dialogue with numerous companies being interested in aluminium plating technologies. As a consequence, there's a potential to create 2 to 4 novel jobs within the next three years, and 4-8 with the next five years, respectively.
In the case of MAIER and TUC, it is expected to create 2 new jobs respectively related the project during next year (2017).

Project website:
According the relevance of the results obtained in the SCAIL-UP project, a website of SCAIL-UP project has been created for the dissemination of project results. The link to the website is the following: www.scailup.eu. The website includes an overall description of the project (objectives, structure, innovations, Consortium…), as well as planned events and articles carried out by the partners of the project.
The project coordinator has taken the responsibility for the development and maintenance of the project Webpage and will take the same responsibility for the period of one year after its completion to ensure maximum presence for the project, its concept, results and conclusions to as wide an audience as possible.

List of contacts:

Party	Person	Phone	Email
MAIER	Monica Solay	+34 946259265	monsol@maier.maier.es
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4.2 Use and dissemination of foreground

A plan for use and dissemination of foreground (including socio-economic impact and target groups for the results of the research) shall be established at the end of the project. It should, where appropriate, be an update of the initial plan in Annex I for use and dissemination of foreground and be consistent with the report on societal implications on the use and dissemination of foreground (section 4.3 – H).

The plan should consist of:

- Section A

This section should describe the dissemination measures, including any scientific publications relating to foreground. **Its content will be made available in the public domain** thus demonstrating the added-value and positive impact of the project on the European Union.

- Section B

This section should specify the exploitable foreground and provide the plans for exploitation. All these data can be public or confidential; the report must clearly mark non-publishable (confidential) parts that will be treated as such by the Commission. Information under Section B that is not marked as confidential **will be made available in the public domain** thus demonstrating the added-value and positive impact of the project on the European Union.

Section A (public)

This section includes two templates

- **Template A1:** List of all scientific (peer reviewed) publications relating to the foreground of the project.
- **Template A2**: List of all dissemination activities (publications, conferences, workshops, web sites/applications, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters).

These tables are cumulative, which means that they should always show all publications and activities from the beginning until after the end of the project. Updates are possible at any time.

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES

Nº	Title of the publication	Main author Name Organization	Journal or periodical or the series	Volume and Issue[4], or date[5] or frequency	Publisher	Year of Publication	Permanent Identifiers[6]	Is/will be open access[7] provided to the publication?
1.	Aluminium electrodeposition from ionic liquid: effect of deposition temperature and sonication	Enrico Berretti INSTM	Materials	9 (9) (2016) page 719	MDPI	2016	doi:10.3390/ma9090719	www.mdpi.com/1996-1944/9/9/719/pdf
2.	Effect of Metals Ions on the Aluminium Electrodeposition Finite elements Analysis of an Electrochemical Coating Process of an Irregulary Shaped Cathode with COMSOL Multiphysics®	A. Giaccherini INSTM	ECS Transactions	64 (35) (2015) pages 1-8	ECS	2015	doi:10.1149/06435.0001ecst	No
3.	Effect of Ni, Cu and Fe on the morphology of electrodeposited Al layers	S. Caporali INSTM	Journal of Materials	Accepted for publication	Springer US	Pending	To be confirmed	No

4 For publications in scientific journals

5 For conference proceedings publications

6 A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view or to the final manuscript accepted for publication (link to article in repository).

7 Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

			Engineering and Performance					
4.	Current Density Distribution for a Full Scale Industrial Aluminization Process	A. Giaccherini INSTM	Journal Material Processing and Technology	To be submitted	Elsevier			No

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES

Nº	Type of activity[8]	Main leader Name Organization	Title of the disseminated material	Place of the Dissemination Activity	Date	Type of Audience[9]	Size of audience	Geographic coverage
1.	**Workshop Presentation**	Ana Ortega MAIER	Area "3.2.5. Manufacturing processes for products made of composites or engineered metallic materials".	WORKSHOP on Impact of the Factories of the Future PPP Brussels (Belgium)	24-25 March 2014	All FoF projects funded in the first 3 calls (2010-2012)	150	European
2.	**Oral presentation**	Dr. Frank Stiemke IOLITEC	New Developments in the Use of Ionic Liquids (ILs) for Aluminum Plating and Life Cycle Assessment (LCA) of the Electrolyte	SUR/FIN 2014, Manufacturing & Technology Trade Show & Conference Cleveland (Ohio)	9-11 June 2014	Industry, Higher Education, Scientific Community	200	International
3.	**Conference poster**	Elena Guinea CIDETEC	Electrodeposition of Aluminium on metalized Plastic-substrates from Eutectic Based Ionic Liquids	EUCHEM 2014. Conference on Molten Salts & Ionic Liquids XXV Tallinn (Estonia)	6-11 July 2014	Industry, Higher Education, Scientific Community	400	European
4.	**Conference poster**	Stefano Caporali INSTM	Surface study of metal-containing ionic liquids by means of photoemission and absorption spectroscopies	EUCHEM 2014. Conference on Molten Salts & Ionic Liquids XXV Tallinn (Estonia)	6 -11 July 2014	Industry, Higher Education, Scientific Community	400	European

8 Conference presentation, workshop presentation, web based project information, press release, flyer distribution, articles published in press, videos, media briefings, presentations in other events, exhibitions, thesis, interviews, films, TV clips, poster display, Other.

9 Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias ('multiple choices' is possible).

5.	**Conference poster**	Stefano Caporali INSTM	Pd-In and Pd-Fe as new type of "Ni-free" top coatings for decorative applications	EUROCORR 2014, European Corrosion Congress Pisa (Italy)	8 -12 September 2014	Industry, Higher Education, Scientific Community	1000	National
6.	**Oral presentation**	Dr. Maria Ahrens IOLITEC	Ionische Flüssigkeiten und deren Anwendung als Elektrolyte für die Aluminiumabscheidung sowie erste LCA Ergebnisse der Aluminiumelektrolyten	ZVO Tagung, Düsseldorf (Germany)	17 -19 September 2014	Industry, Higher Education, Scientific Community	500	European
7.	**Oral presentation**	Dr. Bojan Iliev IOLITEC	Ionic Liquids for aluminum plating and LCA of the Electrolyte	APCIL 2014, Asia-Pacific Conference on Ionic Liquids & Green Processes Sydney (Australia)	28 September- 1 October 2014	Industry, Higher Education, Scientific Community	200	International
8.	**Oral & poster presentation**	Peter von Czarnecki IOLITEC	Aluminum deposition by using ionic liquids-based electrolytes: Facing the commercialization	COIL-6, 6th International Congress on Ionic Liquids Jeju City (South Korea)	16–20 June 2015	Industry, Higher Education, Scientific Community	500	international
9.	**Oral presentation**	Enrico Berretti INSTM	Electrodeposition of aluminium from ionic liquids: corrosion behavior and deposition parameters influence	XXV CONGRESSO DI CHIMICA ANALITICA Università di Trieste Trieste (Italy)	13-17 September 2015	Industry, Higher Education, Scientific Community	300	National
10.	**Oral presentation**	Andrea Giaccherini INSTM	FEA modelization of electrodeposition of Alluminium from ionic liquid	GEI 2015, Green Events & Innovations Università di Bologna Bertinoro (Italy)	20-24 September 2015	Industry, Higher Education, Scientific Community	100	National
11.	**Oral presentation**	Stefano Caporali INSTM	Effect of Ni, Cu and Fe on the morphology of electrodeposited Al layers	GEI 2015, Green Events & Innovations Università di Bologna Bertinoro (Italy)	20-24 September 2015	Industry, Higher Education, Scientific Community	100	National
12.	**Oral Presentation**	Enrico Berretti INSTM	Anti-corrosion properties of ultrasonic assisted electroplated Al layers	GEI 2015, Green Events & Innovations Università di Bologna Bertinoro (Italy)	20-24 September 2015	Industry, Higher Education, Scientific Community	100	National

13.	**Oral presentation**	Andrea Giaccherini INSTM	Current Density Distribution for a Full Scale Industrial Alluminization Process	COMSOL Conference 2015 World Trade Center Grenoble (France)	14-16 October 2015	Industry, Higher Education, Scientific Community	200	European
14.	**Poster presentation**	Enrico Berretti INSTM	Electrodeposition of aluminium for gas turbine applications: influence of the bond coat deposition parameters on the corrosion resistance	ENERCHEM–1 Florence (Italy)	18-20 February 2016	Industry, Higher Education, Scientific Community	100	National
15.	**Oral Presentation**	Peter von Czarnecki IOLiTEC	Aluminum coatings from Ionic liquids as corrosion protection layers	SMART COATINGS 2016 Orlando, Florida (USA)	24-26 February 2016	Industry, Higher Education, Scientific Community	200	International
16.	**Oral Presentation**	Dr. Boyan Iliev IOLITEC	Industrial Applications	ACS SPRING MEETING 2016, San Diego, CA (USA)	13-17 March 2016	Industry, Higher Education, Scientific Community	>200	International
17.	**Oral Presentation**	Luca Tagliaferri TUC	Aluminizing of IGT components after Al plating using Ionic Liquids	TURBINE FORUM 2016 Nice (France)	27-29 April 2016	Gas Turbine companies and reserach institutes linked with IGT and Aviation sectors	150	European
18.	**Oral presentation**	Stefano Caporali INSTM	Aluminium electrodeposition fron ionic liquid: effect of deposition temperature and sonication	ECM-2, 2nd International Electronic Conference on Materials Web Conference	2–16 May 2016	Industry, Higher Education, Scientific Community	500	International

19.	**Poster presentation**	Stefano Martinuzzi INSTM	Effect of metal ions on the Aluminum electrodeposition from Ionic Liquids	EUCHEM 2016, Conference on Molten Salts & Ionic Liquids Vienna (Austria)	3-8 July 2016	Industry, Higher Education, Scientific Community	400	European
20.	**Poster presentation**	Stefano Caporali INSTM	Electrodeposition of aluminium/ceramic metal matrix composite coatings from ionic liquid	EUCHEM 2016, Conference on Molten Salts & Ionic Liquids Vienna (Austria)	3-8 July 2016	Industry, Higher Education, Scientific Community	400	European
21.	**Oral Presentation**	S. Brewer C-Tech	Scale up of Aluminium Electroplating Processes from Ionic Liquids.	Electrochem 2016 Conference, Leicester UK	19/8/2016	Scientific community (Research)	50	Europe + S. America
22.	**Oral Presentation**	Andrea Giaccherini INSTM	Electrodeposition of Aluminium from ionic liquids: effects of the process parameters on morphology and corrosion resistance	MSE 2016. Materials Science and Engineering Darmstadt (Germany)	27- 29 September 2016	Industry, Higher Education, Scientific Community	1400	European
23.	**Oral Presentation**	Enrico Berretti INSTM	FEA study of the electrodeposition of Al from ILs: definition of a pilot plant model for an industrial scale-up	MSE 2016. Materials Science and Engineering Darmstadt (Germany)	27- 29 September 2016	Industry, Higher Education, Scientific Community	1400	European
24.	**Oral Presentation**	Andrea Giaccherini INSTM	Aluminization Process from Ionic Liquid in Operative Conditions: Validation and Perspective	COMSOL Conference 2016 Munich (Germany)	12-14 October 2016	Engineers, physics and chemists		European

<u>Section B (Confidential[10] or public: confidential information to be marked clearly)</u>

Part B1

The applications for patents, trademarks, registered designs, etc. shall be listed according to the template B1 provided hereafter.

The list should, specify at least one unique identifier e.g. European Patent application reference. For patent applications, only if applicable,contributions to standards should be specified. This table is cumulative, which means that it should always show all applications from the beginning until after the end of the project.

Part B2

In addition to the table, please provide a text to explain the exploitable foreground, in particular:

- Its purpose
- How the foreground might be exploited, when and by whom
- IPR exploitable measures taken or intended
- Further research necessary, if any
- Potential/expected impact (quantify where possible)

Section B (Confidential[11] or public: confidential information to be marked clearly)

Part B1

The applications for patents, trademarks, registered designs, etc. shall be listed according to the template B1 provided hereafter.

There is not any application for patent.

Part B2

[10] Note to be confused with the "EU CONFIDENTIAL" classification for some security research projects.

[11] Note to be confused with the "EU CONFIDENTIAL" classification for some security research projects.

Please complete the table hereafter:

Type of Exploitable Foreground[12]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[13]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Commercial exploitation of R&D results	*Process to produce coatings for automotive sector by electrodeposition of Aluminium from ionic liquids*	*YES*	*2018*	*Launch to market a competitive sustainable alternative for currently metallized automotive plastic parts*	*Automotive*	*Year 2 after the project (2017-2018)*	*Direct industrial use, patenting will be considered, and standards will be considered by MAIER.*	*MAIER (entire process)* *CIDETEC (some parts of process)* *C-TECH (equipment + al deposition process)* *IOLITEC (Liquid + recycle)*
Commercial exploitation of R&D results	*Process to produce coatings for aeronautic sector by electrodeposition of Aluminium from ionic liquids*	*YES*	*2017*	*Launch to market a competitive sustainable alternative for currently IGT aluminide coatings*	*Aeronautic*	*Year 2 after the project (2017-2018) (Assuming the technology proves to be successful and meet the coating specifications)*	*No patents will be made on this process due to the TUC policy to protect the IPR*	*TUC (electrodeposition process + pre- & post-treatment)* *C-TECH (equipment + al deposition process)* *INSTM (electrodeposition process + pre- & post-treatment)* *IOLITEC (Liquid + recycle)*
Commercial exploitation of R&D results	*Process for producing ionic liquids to be used for Aluminium electrodeposition*	*YES*	*2017*	*Sustainable and cost-effective new methods for ILs production.*	*IL using sectors: Catalysis industry. Chemical sector (synthesis). Pharmaceutical sector.*	*2015-2017*	*Trade secrets will be considered by IOLITEC*	*IOLITEC*

12 9 A drop down list allows choosing the type of foreground: General advancement of knowledge, Commercial exploitation of R&D results, Exploitation of R&D results via standards, exploitation of results through EU policies, exploitation of results through (social) innovation.
13 A drop down list allows choosing the type sector (NACE nomenclature) : http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

Type of Exploitable Foreground[12]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[13]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
					Metal extraction. *Biomass processing.* *Energy (Fuel cells, batteries and sorption cooling).* *Renewables (solar cells).* *Plating and finishing companies.* *Functional Fluids (lubricants, heat transfer fluids, phase changing materials)* *Analytical chemistry (GC materials, Karl-Fischer titration of nutritions like chocolate and nuts, sensors).*			
General advancement of knowledge	*Knowledge about the methodology to manage, characterize and control ionic liquid for electrodeposition in automotive sector*	*NO*	*2017*	*Nowadays, there is not a defined method to characterize chloroaluminate ionic liquids at the industrial level, neither for "as-received" ionic liquids nor for "in-use" ionic liquid.*	*In the case of plastic substrate: Automotive industry, OEMs*	*2-3 years after the project.*	*As most of the control and analytical methods that are going to be developed are based on conventional methods is very difficult to register them.*	*CIDETEC (Characterizing e.g. monitoring baths during process)* *MAIER (Characterizing e.g. monitoring baths during process)* *IOLITEC (Characterizing e.g. monitoring baths during process)*

Type of Exploitable Foreground[12]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[13]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
								INSTM (Characterizing e.g. monitoring baths during process) *C-TECH (if equipment changes required)*
General advancement of knowledge	*Knowledge about the methodology to manage, characterize and control ionic liquid for electrodeposition in aeronautic sector*	*NO*	*2017*	*At the moment the only innovation is the knowledge about the "in-situ" and "ex-situ" control measurement. In the next future the knowledge about the methodology for electroplating the external surfaces of real components with Ionic Liquids would be an innovation from the past.*	*Every companies that are interested in the deposition of Al layers over Ni/Co-based alloys. Industries operating in the field of electrodeposition of metals from ILs*	*The knowledge of this electroplating process will be available after 2-3 years from the end of the project (2018).*	*Direct industrial use, license agreement*	*CIDETEC (Characterizing e.g. monitoring baths during process)* *TUC (Characterizing e.g. monitoring baths during process)* *IOLITEC (Characterizing e.g. monitoring baths during process)* *INSTM (Characterizing e.g. monitoring baths during process)* *C-TECH (if equipment changes required)*
General advancement of knowledge	*Knowledge of modelling process of the pilot plant*	*NO*	*2017*	*Capability to model the electrochemical process finding via a mathematical model the optimal cell*	*Industries and companies operating in the field of metals electrodeposition.*	*Year 1-2 after the project.*	*Patent the software seems to be difficult. May be the application of COMSOL software.*	*INSTM* *CIDETEC (if required)*

Type of Exploitable Foreground[12]	Description of exploitable foreground	Confidenti al Click on YES/NO	Foreseen date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[13]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
				design and operating parameters				
Commercial exploitation of R&D results	*Schedule of technical specifications/con ditions of coatings for automotive sector*	*YES*	*2016*	*The specifications listed in the deliverable containing the coating requirements. The innovation is Al plating by ionic liquids for plastic substrates.*	*Automotive*	*Year 2 after the project*	*Possible technology transfer or license agreement*	*MAIER*
Commercial exploitation of R&D results	*Schedule of technical specifications/con ditions of coatings for aeronautic sector*	*YES*	*2016*	*The specifications listed in the deliverable containing the coating requirements are the state-of-the-art for validating gas-turbine coatings. Only the requirements for the plated layer are innovative.*	*Aeronautic*	*Year 2 after the project (2017-2018) (Assuming the technology proves to be successful and meet the coating specifications)*	*no patents, specifications should remain confidential within project partners. Also specifications could be updated depending on the interested customer*	*TUC*
Commercial exploitation of R&D results	*Schedule of technical specifications/con ditions of coatings for aeronautic sector*	*YES*	*2016*	*The specifications listed in the deliverable containing the coating requirements are the state-of-the-*	*Aeronautic*	*Year 2 after the project (2017-2018) (Assuming the technology proves to be successful and meet the coating*	*Possible technology transfer or license agreement*	*TUC*

Type of Exploitable Foreground[12]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[13]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
				art for validating gas-turbine coatings. Only the requirements for the plated layer are innovative.		*specifications)*		
Commercial exploitation of R&D results	*Range of ionic liquid that could be used for electrodeposition process*	*YES*	*2017*	*Sustainable and cost-effective new methods for electrodeposition of metals*	*IL using sectors: -Catalysis industry. -Chemical sector (synthesis). -Pharmaceutical sector. -Metal extraction. -Biomass processing. -Energy (Fuel cells, batteries and sorption cooling). -Renewables (solar cells). -Plating and finishing companies. -Functional Fluids (lubricants, heat transfer fluids, phase changing materials) Analytical chemistry (GC materials, Karl-Fischer titration of nutritions like*	*It is already at the market*	*Trade secrets will be considered by IOLITEC*	*IOLITEC*

Type of Exploitable Foreground[12]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[13]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
					chocolate and nuts, sensors).			
General advancement of knowledge	*Fundamental and industrial oriented knowledge about electrodeposition process for automotive sector*	*YES*	*2017*	*Aluminium plating process does not exist on an industrial scale so this technology could be a real alternative to other aluminium finishing methods which could be less competitive in terms of price or sustainability.*	*Companies of the automotive industry and OEMs.*	*2-3 years after the project. Probably not in terms of knowledge but as key part of the final product.*	*Difficult to register the knowledge. The knowledge, fundamental and industrial oriented, will be part of the direct industrial use of the technology.*	*MAIER C-TECH CIDETEC IOLITEC*
General advancement of knowledge	*Fundamental and industrial oriented knowledge about electrodeposition process for aeronautic sector*	*YES*	*2017*	*At the moment the only innovation is the knowledge about the "in-situ" and "ex-situ" control measurement. In the next future the knowledge about the methodology for electroplating the external surfaces of real components with Ionic Liquids would be an innovation from the past.*	*Every companies that are interested in the deposition of Al layers over Ni/Co-based alloys.*	*The knowledge of this electroplating process will be available after 2 years from the end of the project (2018). Assuming the technology proves to be successful and meeting the coating specifications 2-3 after the project.*	*Direct industrial use, license agreement.*	*TUC INSTM C-TECH CIDETEC IOLITEC*

Type of Exploitable Foreground[12]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[13]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Commercial exploitation of R&D results	*Demonstration Plant for Electrodeposition Design and hardware for an electrochemical electroplating process for Al based on IL electrolytes*	*YES*	*2017*	*No equipment is currently commercially available to purchase for the purpose of electroplating Al from ionic liquid electrolytes.*	*Initially Universities and Research Centres for pilot equipment then industrial electroplating and metal finishing companies and end-users for the finished coated products.*	*A product will be marketed from Q2 2017 aimed at pilot plant applications for R&D. Assuming demand exists then larger pilot and then production plants will be designed and marketed. Maier and Turbocoating could be among the first customers for this technology. Within 3 years C-Tech would start being able to provide guarantees on the performance of the equipment for production equipment.*	*A registered design is not suitable.. Patents would be difficult to obtain given the extensive known prior art in similar fields e.g. semiconductor processing we consider it to be generally not patentable. But we will review if key elements of the design which make the system more economic are patentable but we are not optimistic. To a large extend C-Tech will have to rely on knowhow and being first to market. The equipment once it is being sold commercially would be relatively easy to reverse engineer (although specialist knowledge and time*	*C-TECH with most interaction with IOLITEC. However the other partners may be involved: MAIER TUC INSTM CIDETEC*

Type of Exploitable Foreground[12]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[13]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
							would be required to sufficiently understand the process to offer anything other than direct copies), so C-Tech will be looking for key elements of the design to protect where possible.	

4.3 Report on societal implications

Replies to the following questions will assist the Commission to obtain statistics and indicators on societal and socio-economic issues addressed by projects. The questions are arranged in a number of key themes. As well as producing certain statistics, the replies will also help identify those projects that have shown a real engagement with wider societal issues, and thereby identify interesting approaches to these issues and best practices. The replies for individual projects will not be made public.

A General Information *(completed automatically when **Grant Agreement number** is entered.*	
Grant Agreement Number:	**608698**
Title of Project:	**SCALING-UP OF THE ALUMINIUM PLATING PROCESS**
Name and Title of Coordinator:	**PhD. Mónica Solay (Director of Chrome Plating Laboratory)**

B Ethics	
1. Did your project undergo an Ethics Review (and/or Screening)? • If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports? Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 *'Work Progress and Achievements'*	***NO***
2. Please indicate whether your project involved any of the following issues (tick box) :	***YES***
RESEARCH ON HUMANS	
• Did the project involve children?	
• Did the project involve patients?	
• Did the project involve persons not able to give consent?	
• Did the project involve adult healthy volunteers?	
• Did the project involve Human genetic material?	
• Did the project involve Human biological samples?	
• Did the project involve Human data collection?	
RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the project involve Human Embryos?	
• Did the project involve Human Foetal Tissue / Cells?	
• Did the project involve Human Embryonic Stem Cells (hESCs)?	
• Did the project on human Embryonic Stem Cells involve cells in culture?	
• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	
PRIVACY	
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	

• Did the project involve tracking the location or observation of people?	
RESEARCH ON ANIMALS	
• Did the project involve research on animals?	
• Were those animals transgenic small laboratory animals?	
• Were those animals transgenic farm animals?	
• Were those animals cloned farm animals?	
• Were those animals non-human primates?	
RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the project involve the use of local resources (genetic, animal, plant etc)?	
• Was the project of benefit to local community (capacity building, access to healthcare, education etc)?	
DUAL USE	
• Research having direct military use	0 Yes 0 No
• Research having the potential for terrorist abuse	

C Workforce Statistics

3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator	1	2
Work package leaders	2	3
Experienced researchers (i.e. PhD holders)	9	18
PhD Students	0	2
Other	10	38

How many additional researchers (in companies and universities) were recruited specifically for this project?	**6**
Of which, indicate the number of men:	**3**

D Gender Aspects

5.	**Did you carry out specific Gender Equality Actions under the project?**	○ X	Yes No

6. Which of the following actions did you carry out and how effective were they?

	Not at all effective				Very effective
❑ Design and implement an equal opportunity policy	○	○	○	○	○
❑ Set targets to achieve a gender balance in the workforce	○	○	○	○	○
❑ Organise conferences and workshops on gender	○	○	○	○	○
❑ Actions to improve work-life balance	○	○	○	○	○
○ Other:					

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

○ Yes- please specify

X No

E Synergies with Science Education

8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

○ Yes- please specify

X No

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

○ Yes- please specify:

X No

F Interdisciplinarity

10. Which disciplines (see list below) are involved in your project?

X Main discipline[14]:

○ Associated discipline[14]: | ○ Associated discipline[14]:

G Engaging with Civil society and policy makers

11a	**Did your project engage with societal actors beyond the research community?** *(if 'No', go to Question 14)*	○ X	Yes No

[14] Insert number from list below (Frascati Manual).

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

- ○ No
- ○ Yes- in determining what research should be performed
- ○ Yes - in implementing the research
- ○ Yes, in communicating /disseminating / using the results of the project

11c In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?	○ ○	Yes No

12. Did you engage with government / public bodies or policy makers (including international organisations)

- ○ No
- ○ Yes- in framing the research agenda
- ○ Yes - in implementing the research agenda
- ○ Yes, in communicating /disseminating / using the results of the project

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

- ○ Yes – as a **primary** objective (please indicate areas below- multiple answers possible)
- ○ Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)
- ○ No

13b If Yes, in which fields?

Agriculture Audiovisual and Media Budget Competition Consumers Culture Customs Development Economic and Monetary Affairs Education, Training, Youth Employment and Social Affairs		Energy Enlargement Enterprise Environment External Relations External Trade Fisheries and Maritime Affairs Food Safety Foreign and Security Policy Fraud Humanitarian aid		Human rights Information Society Institutional affairs Internal Market Justice, freedom and security Public Health Regional Policy Research and Innovation Space Taxation Transport	

13c If Yes, at which level?

- ○ Local / regional levels
- ○ National level
- ○ European level
- ○ International level

H Use and dissemination

14. How many Articles were published/accepted for publication in peer-reviewed journals?	**3**
To how many of these is open access[15] provided?	**1**
How many of these are published in open access journals?	**1**
How many of these are published in open repositories?	**0**
To how many of these is open access not provided?	**2**
Please check all applicable reasons for not providing open access:	
■ publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available ❑ no suitable open access journal available ❑ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access ■ other[16]: ……………	

15. How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*		
16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	
	Registered design	
	Other	

17. How many spin-off companies were created / are planned as a direct result of the project?	
Indicate the approximate number of additional jobs in these companies:	

18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

X	Increase in employment, or	**X**	In small & medium-sized enterprises

[15] Open Access is defined as free of charge access for anyone via Internet.
[16] For instance: classification for security project.

X	Safeguard employment, or	X	In large companies
❑	Decrease in employment,	❑	None of the above / not relevant to the project
❑	Difficult to estimate / not possible to quantify		

19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:

1-2 FTE

Indicate figure: 2

Difficult to estimate / not possible to quantify

I Media and Communication to the general public

20. As part of the project, were any of the beneficiaries professionals in communication or media relations?

○ Yes X No

21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

○ Yes X No

22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

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❑	Press Release	❑	Coverage in specialist press
❑	Media briefing	❑	Coverage in general (non-specialist) press
❑	TV coverage / report	❑	Coverage in national press
❑	Radio coverage / report	❑	Coverage in international press
X	Brochures /posters / flyers	X	Website for the general public / internet
❑	DVD /Film /Multimedia	X	Event targeting general public (festival, conference, exhibition, science café)

23 In which languages are the information products for the general public produced?

❑	Language of the coordinator	X	English
❑	Other language(s)		

***Question F-10*:** Classification of Scientific Disciplines according to the Frascati Manual 2002 (Proposed Standard Practice for Surveys on Research and Experimental Development, OECD 2002):

FIELDS OF SCIENCE AND TECHNOLOGY

1. NATURAL SCIENCES

1.1 Mathematics and computer sciences [mathematics and other allied fields: computer sciences and other allied subjects (software development only; hardware development should be classified in the engineering fields)]
1.2 Physical sciences (astronomy and space sciences, physics and other allied subjects)
1.3 Chemical sciences (chemistry, other allied subjects)
1.4 Earth and related environmental sciences (geology, geophysics, mineralogy, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, oceanography, vulcanology, palaeoecology, other allied sciences)
1.5 Biological sciences (biology, botany, bacteriology, microbiology, zoology, entomology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences)

2 ENGINEERING AND TECHNOLOGY
2.1 Civil engineering (architecture engineering, building science and engineering, construction engineering, municipal and structural engineering and other allied subjects)
2.2 Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]
2.3. Other engineering sciences (such as chemical, aeronautical and space, mechanical, metallurgical and materials engineering, and their specialised subdivisions; forest products; applied sciences such as geodesy, industrial chemistry, etc.; the science and technology of food production; specialised technologies of interdisciplinary fields, e.g. systems analysis, metallurgy, mining, textile technology and other applied subjects)

3. MEDICAL SCIENCES
3.1 Basic medicine (anatomy, cytology, physiology, genetics, pharmacy, pharmacology, toxicology, immunology and immunohaematology, clinical chemistry, clinical microbiology, pathology)
3.2 Clinical medicine (anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology)
3.3 Health sciences (public health services, social medicine, hygiene, nursing, epidemiology)

4. AGRICULTURAL SCIENCES
4.1 Agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects)
4.2 Veterinary medicine

5. SOCIAL SCIENCES
5.1 Psychology
5.2 Economics
5.3 Educational sciences (education and training and other allied subjects)
5.4 Other social sciences [anthropology (social and cultural) and ethnology, demography, geography (human, economic and social), town and country planning, management, law, linguistics, political sciences, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary , methodological and historical S1T activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences].

6. HUMANITIES
6.1 History (history, prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, genealogy, etc.)
6.2 Languages and literature (ancient and modern)
6.3 Other humanities [philosophy (including the history of science and technology) arts, history of art, art criticism, painting, sculpture, musicology, dramatic art excluding artistic "research" of any kind, religion, theology, other fields and subjects pertaining to the humanities, methodological, historical and other S1T activities relating to the subjects in this group]