Executive Summary

EU FP7 project "Process Intensification methodologies applied to Liquid-Liquid Systems in structured equipment" (PILLS)

PILLS is a FP7 funded project which ran from January 2009 to March 2012. The project aimed to develop and validate a design methodology and criteria for dealing with two-phase liquid-liquid reactions in chemical production processes. Leading to a new generation of flexible and high-performance process equipment (micro- through to meso-structured) for continuous manufacturing, this generic approach involved practical, theoretical and modelling aspects. The micro- and meso-scale reactors developed were to be applied to both bulk and fine chemical reactions. A state-of-the-art experimental research facility (ERF) and multipurpose plant (MP) were to be designed and constructed at Coimbra, Portugal and Lausanne, Switzerland respectively. Within the timeframe of the PILLS project these facilities were to be operated at scales relevant to commercial production to demonstrate improved selectivity, yield and specific performance. A pictorial summary of the work packages involved is shown in figure 1.

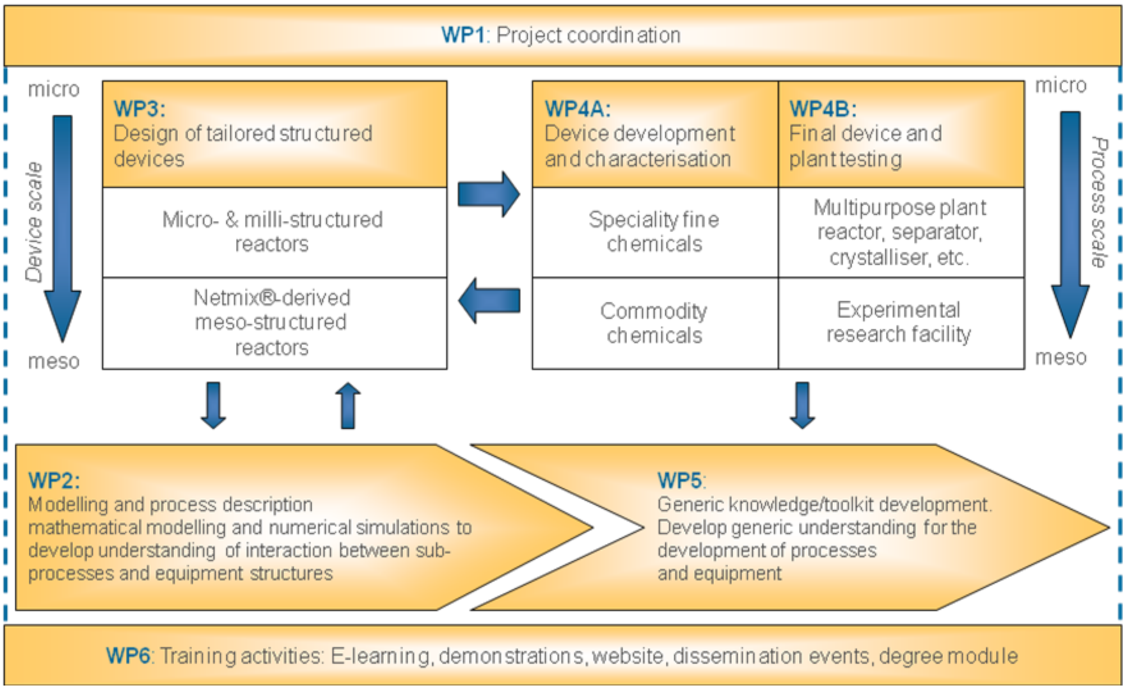

Figure 1: Schematic summary of Work Package contributions

Over the course of the project the consortium worked well as a team, engaging in regular dialogue through face-to-face and teleconference meetings. The collaboration between industry and corresponding academic groups for the two model reactions was especially strong with knowledge exchange strengthened through regular discussions and training of researchers in an industrial environment.

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° NMP2-SL-2008-214599

For more information about the PILLS project contact Rebecca Farnell, Chemistry Innovation (rebecca.farnell@ciktn.co.uk).

In the most part, the project progressed on-track, however, a number of unforeseen circumstances, including a change in Health Safety & Environment (HSE) legislation did significantly extend the time required for establishing the Experimental Research Facility ready for chemical reactions. Despite this, all 4 structured reactors realised within the project were evaluated, albeit for a shorter period of time.

Over the project a total of 11 scientific publications and 19 technical presentations were provided at relevant conferences, acknowledging the funding and support from the commission for the PILLS project. In addition, two dissemination events of the project being held in Coimbra, Portugal in December 2010 and Brussels, Belgium in March 2012. A full list of dissemination activities and further information on the events can be found on the project website.

The final outputs from the project include

- Development of a novel model to simulate effects of equipment choice and process conditions on selectivity of complex reactions in liquid-liquid systems
- Fabrication and testing of six new micro- or meso- structured reactors (for 0.1 to 250 kg/h flow rates) and two flow separators
- Operation of pilot scale flexible facility demonstrating an increase in specialty chemical model reaction yield from 80 to 98%
- Demonstration of continuous operability of micro- and meso- structured reactors at high temperature and flow rates for commodity chemical production
- Publication of training materials for generic lessons of design of liquid-liquid reactions are available to download from the project website (www.fp7pills.eu)

SEVENTH FRAMEWORK PROGRAMME

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Summary Description of project context and objectives

The European chemical industry is Europe's third largest manufacturing industry, generating 1.7 million jobs directly and more than 3 million jobs indirectly.

Many chemical processes are multiphase (often liquid-liquid), and despite their importance, the operation and control of such systems can be problematic. The traditional response is a continued reliance on old batch or semi batch processing - sub-optimal operation of processes, in order to maintain plant flexibility. Effectively, operators have become accustomed to running processes to the limitations of their existing equipment, rather than selecting the optimal reactor to run that process. Liquid-liquid systems present particular problems, and while continuous processes (i.e. micro-reactors) have successfully been used at research-scale level, there are few, if any, compelling examples of processes run at manufacturing scale.

The PILLS project has the objective to develop and validate a design methodology and criteria for dealing with two-phase liquid-liquid reactions in linkage with the development of a **new generation of flexible and high-performance process equipment** (micro through to meso structured) for continuous manufacturing. It will address the issues of mixing, mass and heat transfer in such equipment and the physical chemistry effects on reaction yield and quality that the achievable mixing, mass and heat transfer may cause. This generic approach will be developed by the project members and will involve practical, theoretical and modelling aspects. The output from the project will be demonstrated on 2 different industrial systems to show the wide applicability at **development stage**, **scale up** and **high-tonnage** chemical production.

The project will take two commercially significant processes, a commodity chemical and specialty chemical example, that present significant issues of control (both are substantially exothermic). Through a variety of modelling approaches, we will seek to understand the complex behaviour of these systems, and apply this to the design of micro- and meso-scale reactors. We will operate the micro- and meso-scale reactors at scales relevant to commercial production to demonstrate improved selectivity, yield and improvements of at least one order of magnitude for specific performance (kg/m^3/time). The specialty chemical example is representative of an exothermic processes for a multipurpose plant and for the commodity chemical example the intention is to design a first stage reactor to limit by-product formation to the extent that it may ultimately open the tempting prospect **to replace costly, energy-intensive separation processes** at commercial scale. Key to this objective is the design and realisation of a state-of-the-art **experimental research facility** (ERF) and a **multipurpose plant** which will be modular, flexible and expandable.

Our objective is to provide the evidence base that will encourage much greater take-up of continuous processing among the chemical industry. Having developed an **improved fundamental understanding** of these multiphase processes and **the design and operation** of appropriate micro/mesostructured reactors, we will **codify this learning**, in the form of a "toolkit", designed to identify the most suitable continuous processing methods for any liquid-liquid system. We will develop **whole process design** approaches tailored to continuous liquid-liquid processes to allow the application **of dedicated, small, continuous processes at reduced cost** in a wide range of manufacturing environments. We thus intend to provide the evidence that liquid-liquid systems are amenable to continuous processing at significant scale, and the tools to ensure the wider

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application of process intensification approaches in the European chemical industry. This will be supported by a programme of education activities; an **e-learning programme**, and a **practical demonstration** on an educational micro system to train process technologists in the toolkit of methodologies developed during the PILLS project.

State of art

Whole system design approach: the FP6 project IMPULSE worked on developing methodologies for whole process design, equipment selection and design and assessment of processes for safety, environmental sustainability and business optimisation. However, the case of liquid-liquid reactions has not studied in this project.

The **use of microreactors** (single or multiphase) for research purposes (discovery, small scale manufacture for assays) is established, particularly in the pharmaceutical sector. Furthermore, some companies have adopted microreactors for production purposes, typically in relatively small to medium scale. A number of large scale process intensive facilities have been established for reactions involving single phase but there are **no comparable examples at multi-ton scale** for liquid-liquid systems. This project takes two demanding exothermic processes, which represent considerable control and safety issues when run in batch mode, with the objective to manufacture **at scale** and to make products of **higher quality** than may be obtained in batch. By exemplifying such demanding processes (requiring the highest heat and mass transfer characteristics as well as materials of construction) we hope to show continuous processing in micro/mesostructured devices not only **is a viable method** at scale, but should be regarded as **the method of choice** for the European chemical industry for liquid-liquid systems.

Progress beyond the state of the art

As a result of this project, the following progress beyond this state of the art is expected:

Modelling & whole system design approach

- **Determination of flow patterns** in micro reactors; description of different flow regimes allowing an *a priori* prediction of the different patterns for specific geometries
- **Analysis of mass transfer** for different devices and flow pattern; determination of mass transfer characteristics as a function of device geometry; relation to CFD simulations and modelling of micro mixing
- **Generation of CFD models** for flow pattern and mixing for devices applied in the project: computational meshes for the tailored structured devices, simulation of multiphase integrated with mechanistic mixing models and two-phase mass transfer models
- **Multiphase reactor model**s for commodity and specialty chemical processes; integration of predictive models that include the flow, heat and mass transfer and reaction kinetics for laminar and turbulent flow reactors using CFD and hybrid modelling methods
- **Application of hybrid type models** combining CFD modeling of the multiphase flow with multi-zone or network of zones models and population balance modeling and models based on implementation of reaction kinetics and population balances to the CFD environment to model coupling effects at all scales between the macroscale down to the microscale defined by local concentration gradients

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- **Universal modelling methodology for multiphase reactive mixing.** A new, general methodology will be proposed that based on population balances and CFD will be used to model new problems in multiphase reactive mixing.
- **Extension of the IMPULSE methodologies** to processes that use reactions involving two immiscible liquid phases, refinement of tools and methodologies for:
    - moving from batch to continuous production,
    - changing the conditions for reaction and separation processes to give a more efficient process overall,
    - moving from a single liquid phase to two liquid phases, and changing solvents and additives to manipulate the phase equilibrium to improve process outcome.

Continuous processing of liquid-liquid systems

Generically applicable engineering systems for process intensification of liquid-liquid systems are not currently available. This project will develop an understanding of the key performance criteria for implementation of such systems and create a pilot scale experimental research facility (the ERF) and a multipurpose plant to demonstrate their applicability.

- Realisation of basic functional units with systematic variation of geometry and dimensions and experimental investigation of dispersion performance and dispersion stability in the reactor
- Development of pilot-scale microreactors for liquid-liquid control, incorporating fully flexible process control
- A selection of dispersion structures also suited for higher throughputs or as base unit for numbering-up
- A sufficient understanding of the impact of structure dimension on dispersion performance allowing predictions of required sizes for new applications
- Proven scale-up concept for the developed dispersion structures including also proof of sufficient equal distribution of flows in the reactors
- In total it is expected that the barrier for implementing structured devices also for two-phase liquid-liquid-reactions will be lowered
- Concepts for dispersing structures also capable for high throughput
- Availability of tailored reactors
- For the specialty chemical process: reduction of reactor volume and in specific performance (kg/m^3/time) of one order of magnitude compared with batch / semi-batch processes

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Description of the main scientific and technical results / foregrounds

Modelling and process description

This work aimed to develop and use mathematical modelling and numerical simulations to understand the interactions in liquid-liquid two-phase reactions in structured equipment. The programme of work undertook explored aspects relating to kinetics, flow pattern and mass transfer to generate CFD and multiphase reactor models which could finally be validated. This work was led by Prof. Jerzy Baldyga of Warsaw University of Technology.

The main results are summarised below:

- An initial whole process design analysis was completed for both the specialty and commodity chemical processes. It was identified that the specialty chemical reaction can in fact be performed in single or two-liquid phases.
- Kinetic studies for both processes were undertaken. Mechanisms and kinetics of biphasic and homogeneous specialty chemical reactions were identified experimentally and interpreted using mathematical models.
- Flow patterns of the micro-reactors were studied and analysed theoretically allowing for the flow stability models to be validated and future predictive CFD models to be developed and verified.
- Experiments were performed to investigate mass transfer performance in different types of micro-structured reactors (MSR) in slug flow regime. The experimental results were compared with developed theoretical models and very good agreement was observed. It shows that such a complex fluid flow in MSR can be interrelated using theoretical models which are useful for a priori judgment of flow regime and prediction of mass transfer rates.
- Models able to interpret effects of process conditions and reactor geometry on the flow pattern and mixing were developed. Modelling results were based on application of the CFD codes for single-phase flows and two-phase liquid-liquid flows.
- A new phenomenological model for mass transfer with chemical reaction was proposed. The model is able to predict influences of process conditions such as volume fraction and drop size, initial temperature and composition of the continuous and dispersed phase, hydrodynamic conditions in the reactor, mean residence time and residence time distribution, on the course of chemical reaction and related selectivity. Results related to multiphase reactor models are shown in figure 2.
- Droplet dispersion was modelled using VOF and MUSIG models. It has been shown that for conditions considered in PILLS project the VOF model requires too long computational times, making this approach not practical. Computations with the MUSIG model with a proper breakage kernel are faster, and after fitting model parameters it is possible to predict the drop size distribution.
- Integration of the process models and data was performed and incorporated in the context of a larger processing setup, suitable for industrial implementation of a liquid-liquid chemical reaction was presented using the commodity chemical process as a model.

Figure 2: Multiphase Reactor Models

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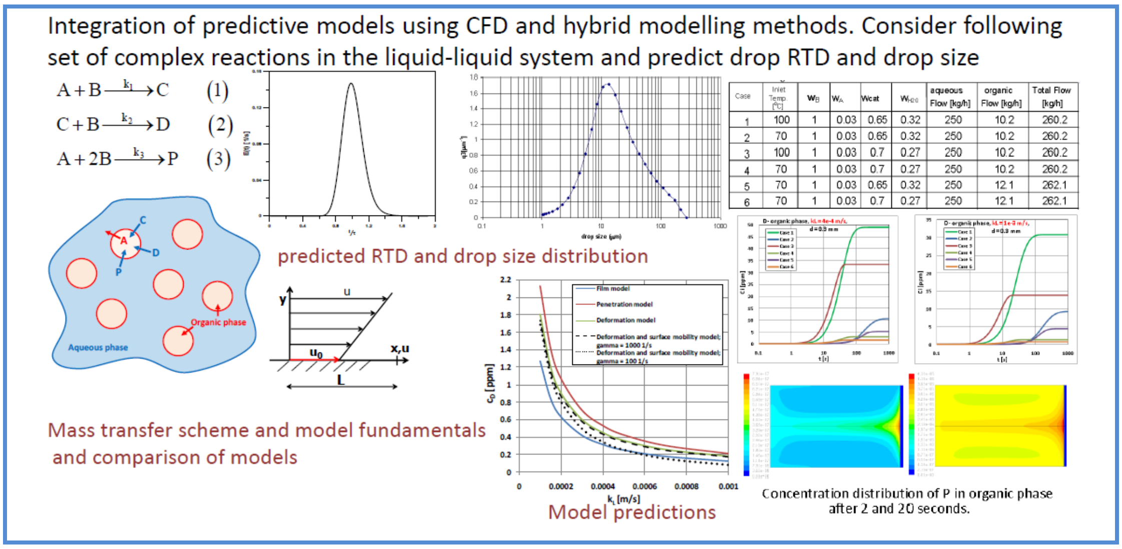

Case	Inlet Temp. [°C]	W_B	W_A	Wcat	W_{H2O}	aqueous Flow [kg/h]	organic Flow [kg/h]	Total Flow [kg/h]
1	100	1	0.03	0.65	0.32	250	10.2	260.2
2	70	1	0.03	0.65	0.32	250	10.2	260.2
3	100	1	0.03	0.7	0.27	250	10.2	260.2
4	70	1	0.03	0.7	0.27	250	10.2	260.2
5	70	1	0.03	0.65	0.32	250	12.1	262.1
6	70	1	0.03	0.7	0.27	250	12.1	262.1

Development of tailored structured devices

The aim of this work was to develop, realise and test tailored micro- and meso-structured devices up to pilot scale with throughputs ranging from several litres to several hundred litres per hour. This work was led by Dr Patrick Lob, IMM with significant input from Fluidinova.

A summary of the achievements is provided below:

- An analysis of the two example chemical process with regard to their requirements and limitations from the perspective mainly of equipment manufacture was completed along with evaluation of existing reactor designs in the area of meso- and micro-structured equipment for potential application in liquid-liquid processes with regard to the specific requirements of the two example processes.
- Development and realisation of meso- and microstructured lab-scale reactors for experimentation at academic groups FCTUC and EPFL for the commodity and specialty chemical processes
- Experimental work studying structure/(dispersion) performance relationship for microreactors was completed and used to derive pilot-scale reactor concepts.
- Development work on a combination of three different reactors for the cyclisation process has been completed by the design of a microstructured reactor.
- A multi-injection microreactor and microstructured reactor was developed and realised for the specialty chemical model reaction and embedded into the multi-purpose installation.
- Two 1st generation pilot reactor assemblies for the commodity chemical process were realised and implementation into the ERF. The meso-structured reactor was adapted and for the first time coated by Tantalum to resist the corrosive reaction conditions. A microsturctured reactor assembly with a micromixer (Caterpillar) followed by a foam-filled tubular reactor as core elements was also provided.
- Two 2nd gen. pilot reactor assemblies for the commodity chemical process were also realised. The meso-structured reactor supplied is characterised by a doubled reactor volume giving access to doubled residence time for the reaction. The micro-structured reactor supplied was another type of micromixer (StarLam) offering better potential for further scale-up and a larger tubular reactor. This was supplied with a larger foam filled tube which could be integrated with the 1st generation reactor in a modular set-up.

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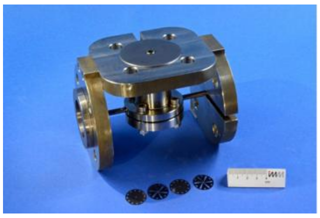
- Followed scale-up approaches from lab to pilot scale have been compiled and first thoughts for further increase to industrial scale throughputs considered.
- Finally the reactor concepts have been reinvestigated in view of a broader applicability to other reactions.

Figure 3 shows photographs of some of the reactors developed.

Figure 3: Micro- and meso-structured devices for two-phase liquid-liquid reactions

Micro-structured reactor (IMM)



Pilot-scale StarLam micromixer made from tantalum

Meso-structured reactor (FLU)

Machining of the Stainless Steel plates (top) and one of the reactor plates after machining (right)

Reactor plate coated with tantalum to prevent corrosion issues (below)

Development and evaluation of multipurpose plant for fine chemical production

The aim of this work was to develop a multipurpose installation for fine chemicals that would consist of plug-in microstructured mixers, reactors and separators for different liquid-liquid systems. As a model reaction, the highly exothermic cyclisation of pseudoionone (PI) to β-ionone was chosen. The first generation of reactors were developed based on reaction kinetics as detailed above. This work was led by Prof Albert Renken, EPFL with significant contribution from industrial partners Givaudan.

Development and characterisation of multipurpose devices:

- The general criteria was based on knowledge obtained from lab experimental and computational studies for different modules for the multipurpose plant
- The heat and mass transfer, reactor performance and product yield and selectivity was investigated for different systems
- A number of experiments and simulations were performed for different liquid-liquid systems
- Flow splitters for different liquid-liquid systems were developed.

The final characteristics of the multipurpose plant include:

- Continuously operating high precision piston pumps
- Equipment placed on a base plate
- Provision to fix equipment at any place on the plate
- Movable camera
- Easy to expand for multistep synthesis
- Supply of heating / cooling fluid
- Variable throughput

Study of model reaction within multipurpose plant

- Process analysis and product control

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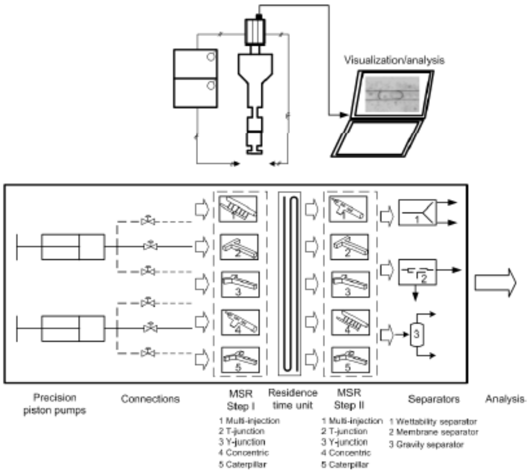
- Optimisation of the multipurpose plant
- Investigation of heat and mass transfer, reactor performance and product yield and selectivity for cyclisation reaction.

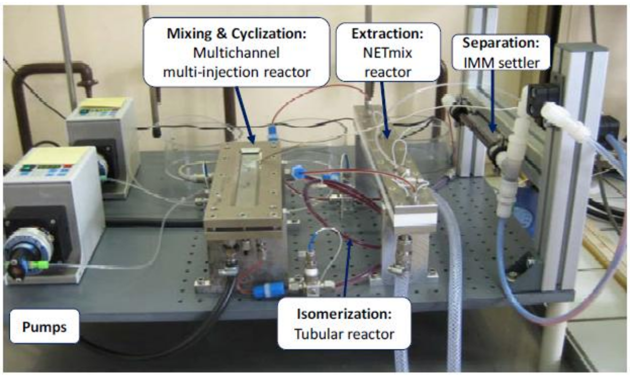
The process showed a step change improvement in yield (80 to > 97%) at total flow rates in the region of $1Lh^{-1}$. A schematic and photograph of the multipurpose plant is shown in figure 4.

Figure 4: Multipurpose plant for fine chemical production

Schematic overview of multipurpose plant



Photograph of multipurpose plant



Development of experimental research facility (ERF) for bulk chemical production

The objectives of this work were to produce a detailed design of the ERF unit considering materials of construction, requirements of an automated control system for continuous operation and HSE (Health, Safety and Environment) factors. The ERF was to be operated at steady state covering a wide range of operating conditions texting the performance of the different micro- and meso-structured reactors. This work was led by Prof Cristina Gaudencio, University of Coimbra with significant input from industrial partners CUF and Huntsman.

The facility was successfully installed and commissioned and during evaluation of the structured reactors steady state operation was achieved covering a range of operating conditions including flow rate and temperature changes. A good separation of the two phases was achieved at the outlet of the structured reactors.

Results have shown that several parameters including feed composition, flow rates and temperature influence the performance observed and similar impurity levels over existing commercial processes. Considering the limited evaluation time of the reactors in comparison to well optimised commercial processes, this warrants further investigation. A schematic of the ERF design is shown in figure 5 and figure 6 shows a comparison of main product concentration vs. impurity concentration for the 3 mixers evaluated.

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Figure 5: Experimental Research Facility for bulk chemical production

Schematic of Basic Design of ERF

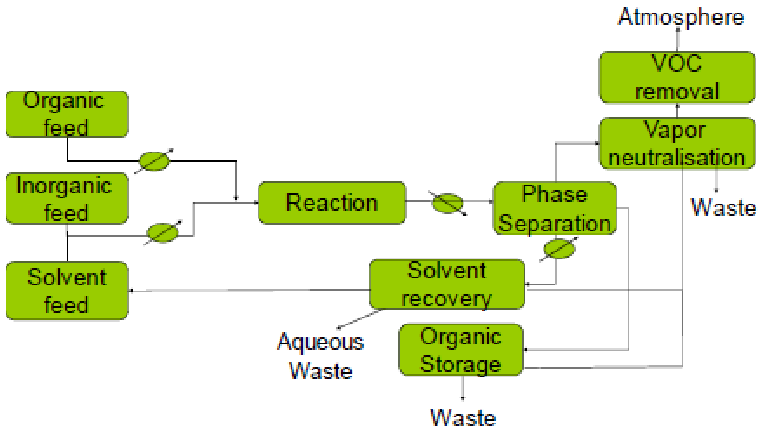
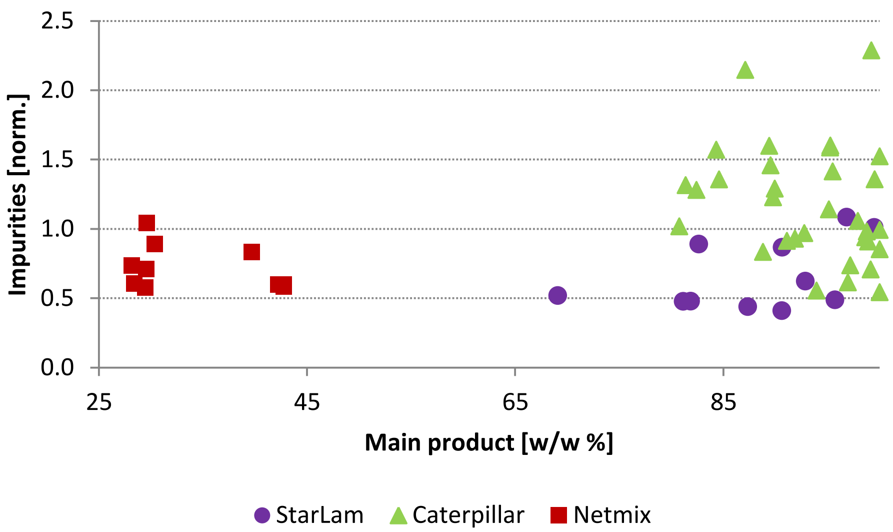


Figure 6: Comparison of main product concentration and impurity levels for structured reactors



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Generic knowledge collection & analysis and toolkit development

To enable the application of the results of the PILLS project, generic learnings about the design and development of liquid-liquid reactions were undertaken along with a systematic methodology for phase strategy selection as part of Whole Process Design. This work was led by Dr Jeremy Double, Britest with input from all partners.

This work done was done in the context of a framework for whole process design that was developed based on the previous work on whole process design done in the FP6 IMPULSE project. This framework is intended to be compatible with related work in the parallel FP7 projects F3 Factory and SYNFLOW.

Phase strategy is an important part of Whole Process Design as it answers the questions:

1. Can a two-liquid-phase reaction be run in a single liquid phase (*e.g.* by finding a suitable solvent) and would this be better?
2. Are there other feasible strategies, such as vapour phase process with a solid catalyst?
3. For single-liquid-phase processes, would there be advantages to moving to a two liquid phases?

In all cases, the aim is to choose the phase strategy that best meets the business needs *i.e.* that which results in the greatest profit for the process operator. A checklist-based methodology has been developed to help a process development team systematically choose the best phase strategy for their process. These training materials can be downloaded from the PILLS project website (www.fp7pills.eu).

Generic lessons from the model reaction processes was collected and codified as answers to 4 important questions:

1. What type of processes would benefit from the use of intensified, structure equipment?
2. What information should be collected to decide whether the use of intensified, structured equipment would be advantageous for a particular process?
3. What process development work is needed to implement the use of intensified, structured equipment for a particular process?
4. When is it not appropriate to use this type of intense, structured equipment?

The answers to these questions are presented in the form of training material available to access from the project website www.fp7pills.eu. As an example, figure 7 shows some situation where processes are likely to benefit from intensified structure equipment.

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Figure 7: Generic Knowledge Codification

Processes likely to benefit from Intensified Structured Equipment

- ✓ **Reaction is fast / mixing sensitive**
- ✓ **Undesired side reactions or consecutive reactions**
- ✓ **Highly exothermic or endothermic reaction**
- ✓ **Difficult separation after reaction**
- ✓ **Intractable emulsion generated**
- ✓ **Business benefits such as distributed production**

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Potential Impact and main dissemination activities and exploitation results

Dissemination

Through-out the project a total of 11 scientific publications have been prepared and accepted. These are listed in Table 1. 19 presentations were also provided at a number of conferences, most notably CHISA 2010 (Prague) and EPIC 2011 (Manchester), a full list of the presentation can be found in table 2.

Table 1. Peer Reviewed Publications

Title	Main Author	Title of the periodical or the series	Date of publication	Relevant pages
Influence of flow regime on mass transfer in different types of microchannels	Madhvanand N. Kashid	Industrial and Engineering Chemistry Research	21/12/2011	6906-6914
Cyclization of Pseudoionone to β-Ionone: Reaction Mechanism and Kinetics	Madhvanand N. Kashid	Industrial and Engineering Chemistry Research	21/12/2011	7920-7926
Gas-liquid and liquid-liquid mass transfer in microstructured reactors	Madhvanand N. Kashid	Chemical Engineering Science	01/12/2011	3876-3897
Analytical method to predict two-phase flow pattern in microstructured reactors	Madhvanand N. Kashid	Chemical Engineering Science	01/12/2011	219-232
Mixing efficiency and energy consumption for five generic microchannel designs	Madhvanand N. Kashid	Chemical Engineering Journal	01/12/2011	436-443
EFFECT OF MODEL STRUCTURE ON COMPLEX LIQUID-LIQUID HETEROGENEOUS REACTIONS	Jerzy Baldyga	SYMPOSIUM SERIES NO. 157, EPIC 2011	01/10/2011	175-181
Analytical method to predict two-phase flow pattern in horizontal capillaries	M.N.Kashid and J Baldyga	Chemical Engineering Science	28/05/2012	219-232
Effect of model structure on complex liquid-liquid heterogeneous reactions	J Baldyga	Symposium Series IChemE	20/06/2011	175-181
Effect of multiphase flow on mass transfer and chemical reactions	W Kowalinski	PhD Thesis at Warsaw University of Technology	01/03/2012	1-220
Nowy model wnikania masy do kropli fazy rozproszonej New model of mass transfer to dispersed phase	J Baldyga	Proceedings of XIIth Polish Seminar on Mixing	06/06/2011	22-27
Wnikanie masy w ukladach dwudazowych ciecz-ciecz w mikroreaktorach. Mass transfer in two-phase flows in microreactors	W Kowalinski	Proceedings of XIIth Polish Seminar on Mixing	06/06/2011	103-109

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Table 2: Dissemination activities of PILLS at conferences and events

Type of activities	Main leader	Title	Date	Place
Conference	IMM	CHISA 2010 - 19th International Congress of Chemical and Process Engineering	28/08/2010	Prague
Conference	EPFL	Two-phase micro-structured reactors for intensification of instantaneous exothermic cyclization	28/08/2010	Prague
Conference	FCTUC	Insights in heterogeneous liquid-liquid reactions against the background of bulk chemical production	01/09/2010	Prague
Conference	WUT	Modelling of complex liquid-liquid heterogeneous reactions	06/09/2010	Prague
Presentations	CIN	PILLS Mid-term Dissemination Event	09/12/2010	Coimbra
Workshops	FCTUC	Open days for ERF	23/02/2011	University of Coimbra
Conference	WUT	New model of mass transfer to dispersed phase	06/06/2011	11th Polish Seminar on Mixing - Szczecin-Miedzyzdroje
Conference	WUT	Mass transfer in two-phase flows in microreactors	06/06/2011	11th Polish Seminar on Mixing - Szczecin-Miedzyzdroje
Conference	EPFL	Intensification of catalytic reactors (keynote)	20/06/2011	International Scientific Conference, Manchester
Conference	EPFL	Process intensification via continuously operated microstructured reactors	20/06/2011	International Scientific Conference, Manchester
Conference	WUT	EPIC 2011: Application of test reactions to study micromixing in the rotor-stator mixer	20/06/2011	Manchester
Conference	WUT	EPIC 2011: Effect of model structure on complex liquid-liquid heterogeneous	20/06/2011	Manchester
Conference	FCTUC	ENBIS Conference	06/09/2011	Coimbra
Conference	WUT	Effect of mass transfer on complex liquid-liquid heterogeneous reactions	22/09/2011	8th European Congress of Chemical Engineering - Berlin
Presentations	WUT	Effect of mass transfer on complex liquid-liquid heterogeneous	25/09/2011	8th European Congress of Chemical Engineering, Berlin
Conference	EPFL	Microsstructured Reactor	27/12/2011	Bangalore
Conference	IMM	IMRET 2012	20/02/2012	Lyon
Presentations	CIN	PILLS End of Project Dissemination Event	22/03/2012	Brussels
Workshops	WUT	Mass transfer in PILLS Project	03/04/2012	Warsaw Poland

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In addition, two dissemination events of the project were held in Coimbra, Portugal in December 2010 and Brussels, Belgium in March 2012. The event programmes can be found below and the posters presented at the events can be found on the project website (www.fp7pills.eu).

Mid-term dissemination event – 10th December 2010, Coimbra, Portugal

14:00	Registration
14:30	Steve Fletcher, Chemistry Innovation & Patrick Löb, IMM *"Process Intensification methodologies applied to Liquid-Liquid Systems in structured equipment – concept, objectives and status of the EU project PILLS"*
15:00	Jeremy Double, Britest *"Whole process design for liquid-liquid reaction systems"*
15:30	Jerzy Baldyga, Warsaw University of Technology *"Description and Modelling of complex liquid-liquid heterogeneous reactions"*
16:00	Coffee
16:30	Albert Renken, Ecole Polytechnique Fédérale Lausanne *"Intensification of instantaneous exothermic cyclisation of pseudoionone: process development, two phase meso- and micro-structured reactors and derived concept of a multipurpose plant for fine chemical synthesis"*
17:10	Cristina Gaudêncio, University of Coimbra *"Insights in heterogeneous liquid-liquid reactions against the background of bulk chemical production: process development, two phase meso- and micro-structured reactors and introduction to the Experimental Research Facility as pilot installation"*
17:45	Posters & Networking
19:00	Close of day 1
	Day 2
09:00	Rebecca Farnell, Chemistry Innovation *Welcome and Introduction to the day*
09:20	University of Coimbra, Huntsman, CUF & Ecole Polytechnique Fédérale Lausanne **Tour of the Experimental Research Facility and model demonstration of Multipurpose Plant*
10:25	IMM & Warsaw University of Technology **Laptop simulations and model micro-reactors*
12:00	Fluidinova **Demonstration and simulation of NETmix® reactor*
13:00	Chemistry Innovation *Summary*
13:15	Lunch and networking
14:00	Event Close

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Final dissemination event – 22nd March 2012, Brussels, Belgium

10:00	Registration
10:30	Steve Fletcher, Chemistry Innovation & Patrick Löb, IMM *Process Intensification methodologies applied to Liquid-Liquid Systems in structured equipment – concept, objectives and results of the EU project PILLS*
11:15	Albert Renken, Ecole Polytechnique Fédérale de Lausanne & Petra Prechtl, Givaudan *Process Intensification of Liquid-Liquid Systems for specialty chemical production: overview of the pilot scale multipurpose facility and capability and its application to ß-ionone production*
12:00	Cristina Gaudêncio, University of Coimbra; Paulo Araújo, CUF & Asier Rodriguez, Huntsman *Process Intensification of Liquid-Liquid Systems for bulk chemical production: learnings from demonstrator scale testing of structured reactors*
12:30	Lunch and Networking
13:10	Patrick Löb, IMM & Paulo Quadros, Fluidinova *Introduction to micro– and meso-structured reactors developed within the PILLS project*
13:30	Madhav Kashid, Ecole Polytechnique Fédérale de Lausanne *An overview of the PILLS training material for higher educational institutes*
13:45	Jeremy Double, Britest *Generic lessons for the development and design of liquid-liquid processes*
14:00	Demonstration & Poster Exhibition (with coffee) Warsaw University of Technology - *Exhibit of modelling animations* Fluidinova and IMM - *Exhibit of micro– and meso–structured reactors and animations* Ecole Polytechnique Fédérale de Lausanne - *Demonstration of educational training manuals and animations* Britest - *Demonstration of e-learning content*
15:30	Close

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For more information about the PILLS project contact Rebecca Farnell, Chemistry Innovation (rebecca.farnell@ciktn.co.uk).

Project Team & Dissemination Activities
PILLS project team and some delegates at the final dissemination event 

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