HYDROMEL - A European Project for future hybrid Assembly

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1 Introduction

1.1 Core Approach

Today, emerging highly complex micro-devices with applications in mechanics, electronics, biological engineering, microfluidics and IT request ultra precision manufacturing processes. A need becomes apparent to develop tomorrow's high precision flexible and cost-effective manufacturing processes for complex micro-products. This includes emerging products that cannot be synthesized through one-shot processes.

Hybrid assembly has been identified as promising, innovative production technology. It is defined as the combination of two production approaches: (i) *positional assembly* where objects are mechanically manipulated and positioned one by one; and (ii) *self-assembly* where objects arrange themselves into ordered structures by physical or chemical interactions. Such hybrid assembly has not yet been achieved at the industrial scale. It will build a production paradigm permitting the development of a fully innovative hybrid automated tool for assembly of a variety of microproducts.

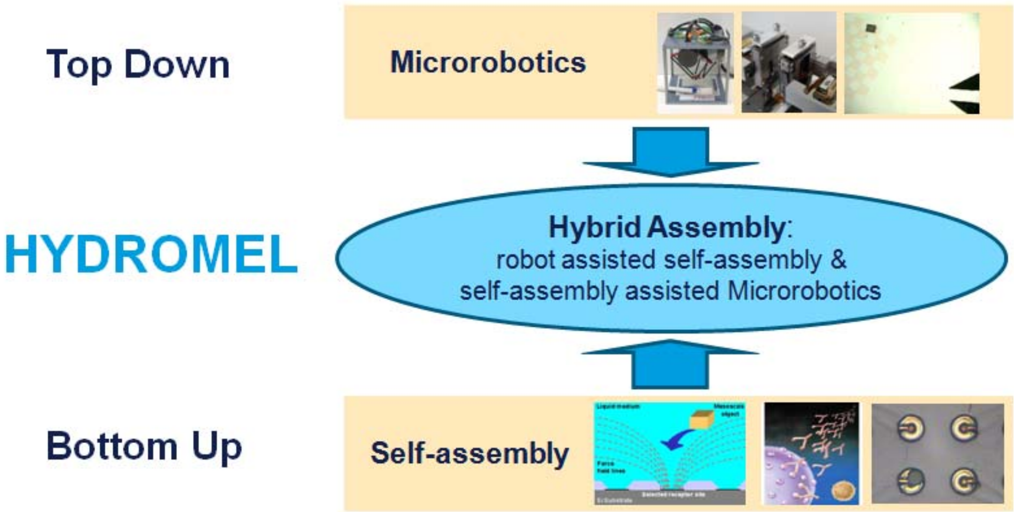

Figure 1: The HYDROMEL project targets at combining positional and self-assembly and thus offering a hybrid production approach.

1.2 Implementation

A European project has been started in order to address the ambitious goal of implementing hybrid assembly at the industrial scale: the HYDROMEL project has been implemented as integrated project in the *Sixth European Framework Programme.* The project started October 2006 and will finish September 2010. It brings together experts from academia, R&D and industry. Currently 23 partners are involved. Selected industrial partners (highlighted in the figure below) will act as endusers demonstrating various applications generated by the project.

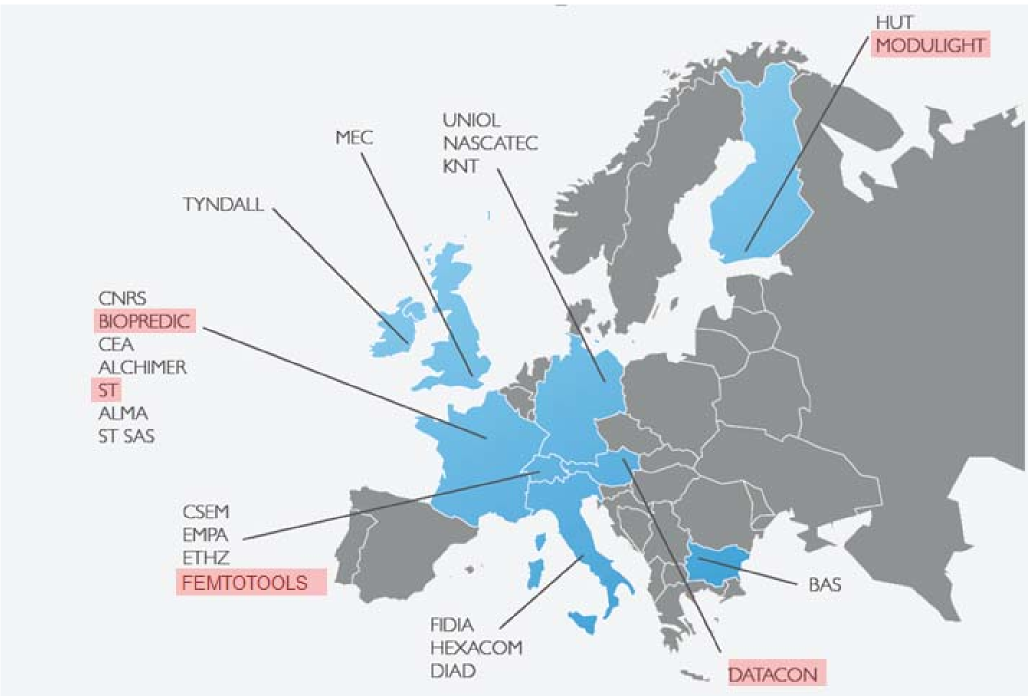

Figure 2: Partners that are involved in the HYDROMEL project. Selected industry partners demonstrating application cases are highlighted.

1.3 Development Goals

The goals of the activities are related to the two disciplines (i) *microrobotics*, (ii) *self-assembly* and finally the combination of both the (iii) *hybrid assembly* methods. Hybrid assembly relies on a methodology to combine common principles derived from robotics and self-alignment. Two hybridization scenarios will be studied: first robotics assisted by self-assembly where a primary pure robotic process is supported and optimized by self-assembly; and second self-assembly assisted robotics, where a self-assembly or self-alignment process is supported by robotics.

Hybrid assembly is aimed to be introduced for a range of applications on the industrial scale with very different demands in terms of component size, accuracy

and throughput. In the following five cases are listed: (i) hybrid assembly of delicate MEMS parts; (ii) hybrid assembly for high-throughput production of electrical devices; (iii) self-alignment assisted manipulation of biological cells; (iv) hybrid assembly of nano-structures such as nanowires or nanotubes for photonic applications; (v) self-alignment in high-throughput quality inspection.

The industrial exploitation and implementation is assured by core partners inside the consortium and supported by an external highly qualified industrial advisory board.

2 Concept Technologies

The overall structure of the project is show in the figure below. HYDROMEL is organized in several subprojects (SPs). The concpet of robotics, self-assembly and their hybridization is developed in SPs 2-4; these activites are focus of the current section. The validation of the concept and industrial demonstration is core of SPs 5-7 and will briefly be described in the following section. The project is supported by benchmarking and roadmapping activities (SP1) and by accompanying measures (SP 8).

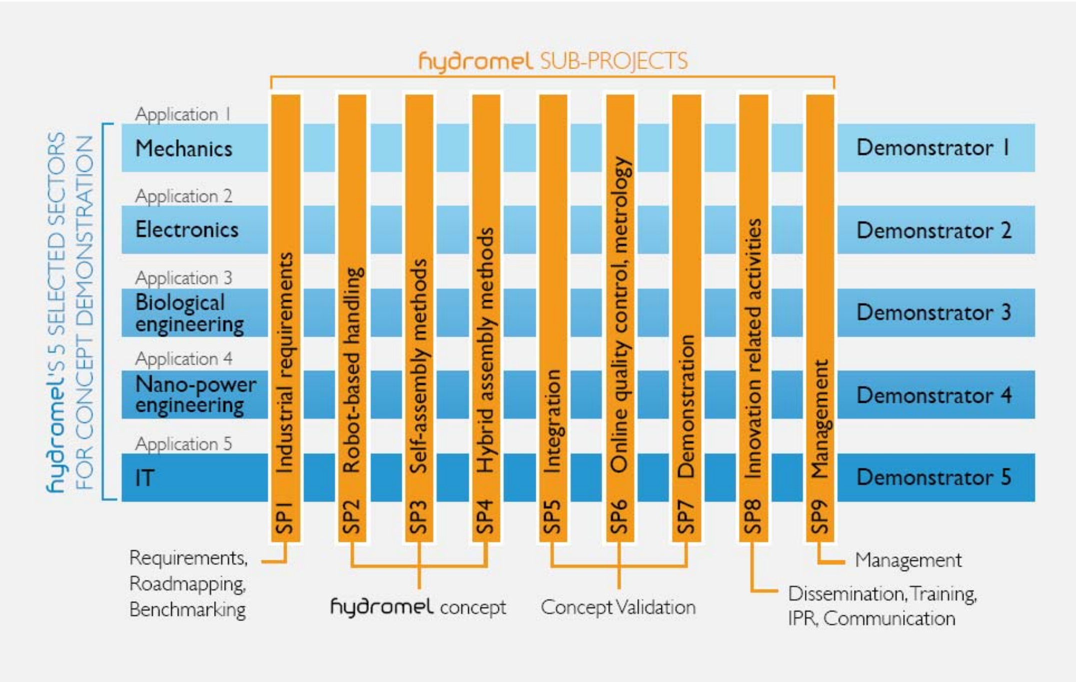

Figure 3: Structure of the project. Vertical organization in subprojects (SPs), horizontal demonstrator activities for selected application areas.

2.1 Robotics

Robotics is a well established industrial technology. Nevertheless if high throughput and high accuracy are aimed - especially in the microrobotic area - several bottlenecks have been identified that are addressed: (i) High-speed nano-manipulators by combining long range fast conventional robots and precise nano-robots. (ii) Tools and handling strategies for microhandling. (iii) Control and sensor fusion for microrobotics.

In the current development phase progress has been made towards the realization of improved components for reliable microhandling: combination of nanorobots and innovative multidimensional vision sensing for closed-loop Robot operation at nanometer precision (in the scanning electron microscope); development of tools (gripper, feeder) for microcomponents.

2.2 Self-assembly

Self-assembly can be considered as a new strategy for nano- and microfabrication. It offers a bottom-up production technique with massive parallel throughput. This way is a model for bio-inspired assembly in manufacturing. Self-assembly methods based on programmable forces for self-assembly of a range of mesoscale (length scale of parts in the micro- to millimeter-range) components are under development including the following topics: (i) Surface treatment and patterning for different self-assembly cases - cells, chips, nanowires - (ii) chemical and physical switching of surface properties for controlled adhesion; (iii) directed self-assembly by application of external fields; (iv) modeling and measuring of bonding forces in self-alignment.

Important goals in the development of self-assembly technologies have been achieved in the first project period. The feasibility of various techniques (local surface treatment, global switching of surface properties) could be proven for selected model systems. Furthermore important progress has been made in hierarchical self-assembly of nanowires.

2.3 Hybrid assembly

Hybrid assembly is the core technology bringing together robotics and self-assembly. Two ways to interpret hybrid assembly are investigated. Both ways implement the hybrid approach. Several examples of hybrid assembly scenarios are given below:

Improvement of robotics by using self-assembly techniques
Classical robotics can be improved by means of self-assembly in different ways. Structuring techniques can be applied to grippers in order to improve picking, reliable positioning and releasing of micro-objects. Feeding - a classical robotics task - can also benefit from controlled and switchable self-assembly by concentrating objects in desired position and thus facilitate an efficient pick- and place process.

Improvement of self-assembly by using robotics

Using robotics to assist or improve self-assembly is useful in various application scenarios. Micro- or nanorobots can be used in processes where the result of a self-assembly process has to be error corrected or characterized. Robust and fast coarse robotics will be used to place meso-scale objects close to self-alignment attractors. The final alignment in position and/or orientation that extends the targeted accuracy by an order of a magnitude is carried out by unsupervised self-alignment. Therefore parallelization can be achieved as well as a reduction of investment of equipment.

The implementation of hybrid assembly and integration into dedicated systems is currently the main project activity. The functionality of modules and sub-systems has been proven for various application cases with industrial relevance.

3 Technology Demonstrators for Industrial Applications

The industrial integration of the core technologies that have been presented in the previous section is demonstrated in selected applications. Figure 3 above shows the horizontal integration of demonstrator activities in the project. Benchmarking of the economical benefit of the hybrid integration compared to conventional solutions is a key point of the demonstrators. The technology demonstrators are addressing complementary assembly cases with very different system specifications and application areas.

3.1 Advanced Micromechanics: Hybrid assembly of fragile MEMS parts

MEMS parts for measuring micro forces and for force controlled microgripping have to be assembled into a package. A mechanical and electrical connection between MEMS and a printed circuit board (PCB) has to be realized. The MEMS components consist of fine mechanical structures and are very brittle. It is aimed to overcome tedious one-by-one processing by a parallel process. Coarse robotics will be combined with precise self-alignment to achieve high throughput and high alignment accuracy of the components with respect to the PCB.

The flexible integrated system will be cost effective, reduce assembly effort and increase the process yield targeting mid- to high-production rates.

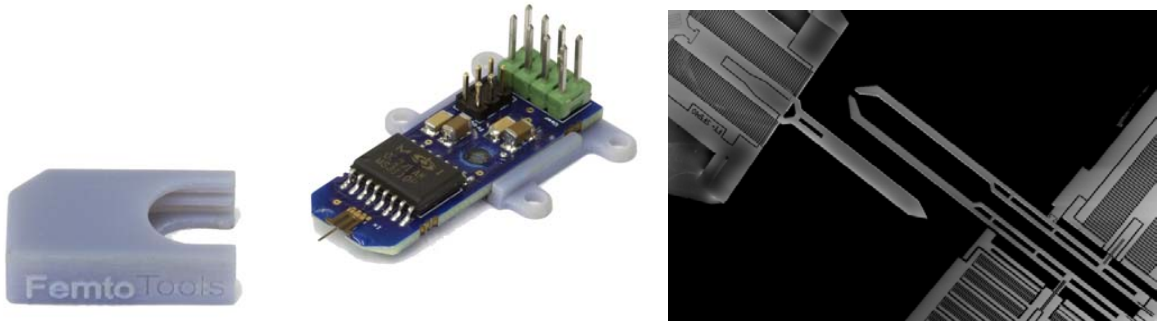

Figure 4: Force sensor. System overview (left) and close-up view (courtesey of FemtoTools).

3.2 Electronics: Hybrid assembly of RFID tags

A hybrid assembly solution for high-precision and high-speed assembly of RFID chips on an antenna web will be developed. The state-of art production process for RFID tags is a pick-and-place procedure with dedicated and highly optimized die bonding equipment. An alternative industry compatible approach will be implemented offering the opportunity for parallelization and cost reduction by an optimum combination of coarse placement and fine self-alignment. High-speed and high-throughput processes are targeted.

3.3 Bio- and life sciences: Self-alignment assisted handling of cells

A system is being integrated that combines several aspects of cell handling. It will include automated cell selection, immobilization, and a microinjection process by combining microfluidics for prior cell sorting and individualization, self-assembly for reversible immobilization of the cell, and microrobotics for cell injection and automation of the complete process by feedback loops. The complete system will be an automated, high throughput cell injection system. Cells with sizes between 1 and 0.02 mm are targeted.

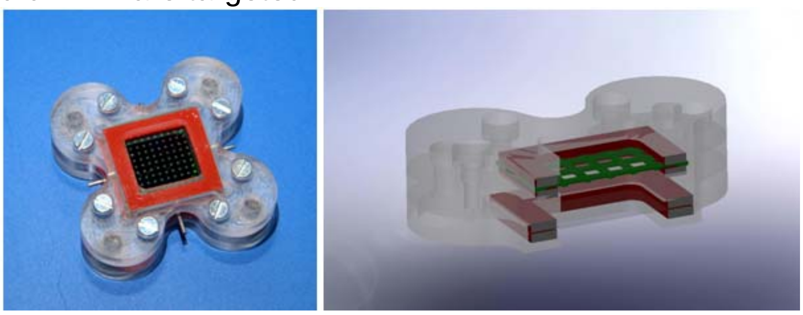

Figure 5: Device (left, right design) for reversible parallel cell immobilization used as sub-system in a robotic set-up for automated micro-injection (courtesey of CSEM).

3.4 Future Technologies: Self-assembly for emerging nanophotonics and -electronics

To address the current limitations associated with top-down fabrication approaches, a palette of self-assembly techniques will be developed and applied to the configurable assembly of a variety of nanostructures that will be selected so as to enable demonstration of not only the assembly methodology but also of resulting nanoscale functionality. Self-assembly of nano-objects will allow the organization of nanoscopic objects much smaller than those that can be defined with classical top-down approaches. This approach is mandatory for Systems on Chip or even in future 3D circuits.

Hybrid approaches are under investigation involving production and characterization of self-assembled nanostructures combined with robotic quality control and error-correction measures.

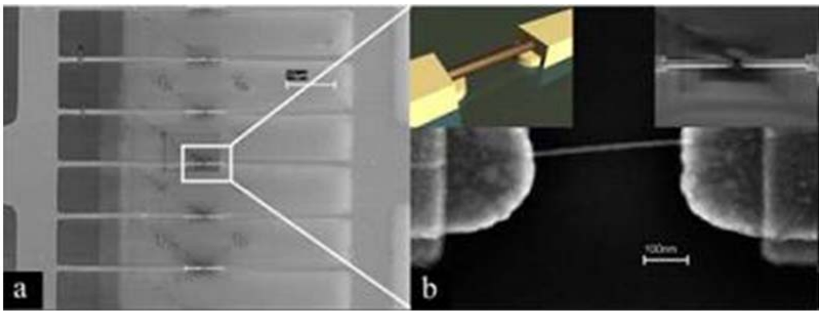

Figure 6: Hybrid nanofabrication approach to realize integrated nano-systems (a) Nanoarray design, (b) multi-walled nanotube on a nanostructure with schematic and a scanning electron microscope image shown in insets (courtesy of ETHZ).

3.5 Opto-electronics: Hybrid self-alignment in optical inspection

A high-speed handling and inspection solution for laser diodes will be developed that overcomes precise pure robotic pick-and-place approaches. A hybrid inspection system will be implemented that can handle diode chips with sizes down to 0.1 mm. The system will combine coarse handling robotics with high precision self-alignment and self-positioning of the chips.

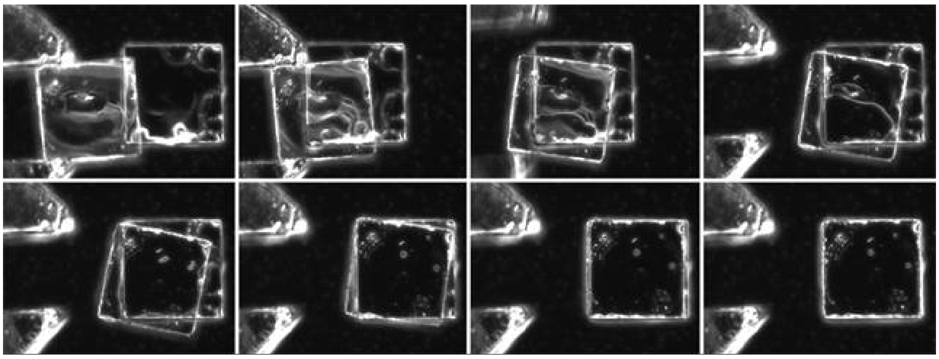

Figure 7: Study of self-alignment of sub-millimeter microparts(courtesy of HUT).

4 Outlook

A set of technologies for hybrid assembly has been developed. The proof of feasibility for hybrid assembly of selected systems has been given. In the upcoming phase the focus of activities will be the industrial exploitation of the technologies. This exploitation will proof industrial compatibility of selected processes, economic benchmark of integrated assembly solutions and a life cycle analysis for production cases. Advisory support by external industrial experts is guaranteed.

5 Acknowledgements

The HYDROMEL project is partially funded by the EC, contract number 026622-2. The support is gratefully acknowledged.
For information see also the project web site http://www.hydromel-project.eu.