Industrial applications of hybrid assembly for smart micro- and nano systems

Dr. Alexander Steinecker, CSEM, Central Switzerland Centre, Alpnach, Switzerland

1 Introduction

Hybrid assembly is the combination of robotics and self-assembly. The combination of positional assembly - where objects are mechanically manipulated and positioned one by one - and self-assembly (autonomous organisation of components into patterns or structures without human intervention) – where objects arrange themselves into ordered structures by physical or chemical interactions- offers a new and flexible production concept permitting the development of a fully innovating hybrid automated assembly process of micro-products at an industrial scale.
The European integrated project HYDROMEL has been presented at *SmartSystemsIntegration 2009* and is now close to finalization. Within this project the potential of this innovative production paradigm has been investigated and furthermore industrial assembly solutions have been realized for a broad area of application scenarios.
An overview of the hybrid assembly technology platform and of the innovations and results will be given. The focus is put on the domains (i) robotics, (ii) self-assembly and (iii) methodologies for their combination. Finally industrial application cases for the manufacturing and assembly of smart integrated systems of various devices will be shown. This covers applications in packaging of MEMS components, efficient technologies for next generation RFID tag assembly and reliable assembly of nanowires and nanotubes.

2 Hybrid technology platform

The fundament of the hybrid technology platform are the following domains: (i) *microrobotics*; (ii) *self-assembly;* and (iii) the combination of both microrobotics and self-assembly to form *hybrid assembly*.
Two hybridization scenarios are applied. The first scenario focuses on *robotics assisted by self-assembly* in which a robotic process is supported and optimized through self-assembly. For example, the use of self-directing capillary effects and low-adhesion functionalized surfaces is uesed for reliable part handling. The complementary scenario will also be applied in which a self-assembly or *self-alignment process is supported by robotics*. The massively parallel, unassisted positioning of parts (e.g. nanowires) on a substrate and the complementary use of robots to individually correct or manipulate specific target objects is one example of this approach. Another example of this second scenario is the combination of coarse robotics and precise self-assembly. Here the robot initiates the self-assembly process

by roughly positioning the part near the attractor allowing the self-assembly process to complete the precise positioning of the part.
Hybrid assembly is aimed to be introduced for a broad range of applications on the industrial scale with very different demands in terms of component size, accuracy and throughput. In the following, four scenarios are briefly sketched: (i) hybrid assembly of fragile MEMS parts; (ii) hybrid assembly for high-throughput production of electrical devices; (iii) self-alignment assisted manipulation of biological cells and finally (iv) hybrid assembly of nano-structures such as nanowires or nanotubes for photonic applications.

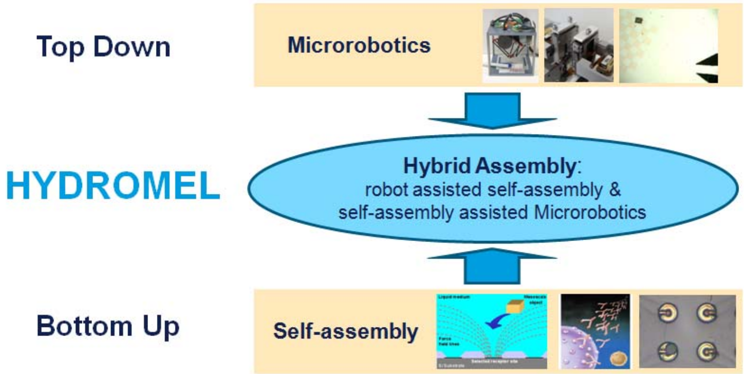

Figure 1: Hybrid assembly is the combination of robotics and self-assembly to develop a hybrid production approach.

3 Industrial applications

3.1 Advanced Micromechanics: Hybrid Assembly of fragile MEMS parts

MEMS parts for measuring micro forces and for force controlled microgripping must be assembled into a package. It is important to obtain a mechanical and electrical connection between the fragile MEMS component and a printed circuit board (PCB). The MEMS parts consist of fine mechanical structures and are very brittle. A parallel handling process is implemented with the aim of overcoming tedious one-by-one processing. Coarse robotics will be combined with precise self-alignment to achieve high throughput and high alignment accuracy of the package. The self-alignment of the MEMS part on the board is achieved by capillary forces of liquid solder dispensed on the contact pads.
The production equipment will be cost effective, reduce assembly effort and increase the process yield targeting mid- to high-production rates.

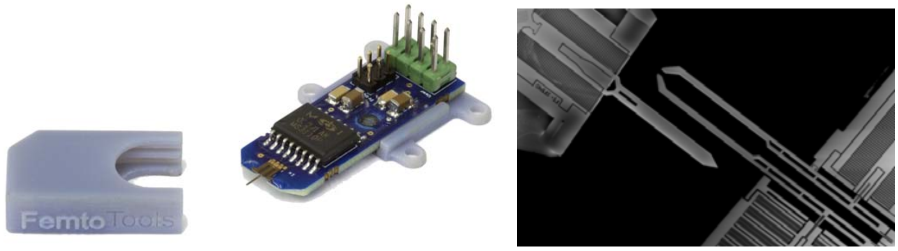

Figure 2: **Force sensor. System overview (left) and close-up view (courtesey of FemtoTools).**

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 is under development. 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 robotic placement and fine capillary self-alignment of the RFID chip. High-speed and high-throughput processes are targeted.

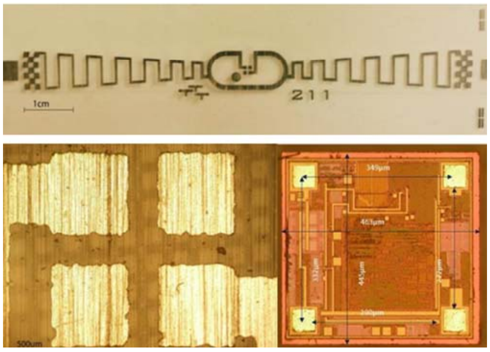

Figure 3: Antenna web (top) and RFID chip with contact pads (bottom, courtsey of DATACON).

3.3 Bio- and Life-Sciences: Self-alignment assisted Handling of Cells

A lab-automation system is being integrated that combines several aspects of cell handling. It offers automated procedures for cell selection, immobilization, and a microinjection process. The system combines microfluidics for prior cell sorting and separation, fluidic self-assembly for reversible immobilization of the cell, and microrobotics for force-controlled cell injection. The complete system will be an automated, high throughput cell processing system. Specifically, cells with sizes between 1 and 0.02 mm are targeted.

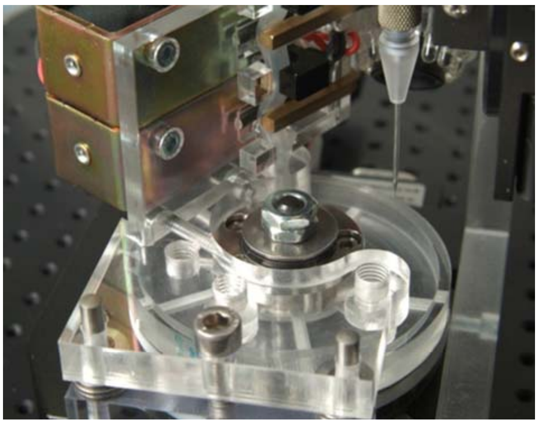

Figure 4: System for hybrid cell-sorting and micro-injection (courtesey of CSEM).

3.4 Future Technologies: Self-assembly for emerging Nanophotonics and Nanoelectronics

A palette of hybrid robotic / self-assembly techniques for nanowires or nanotubes will be developed and applied to a variety of nanostructures. The assembly methodology will be demonstrated but also the function of resulting nanoscale devices. 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 investigated addressing production and characterization of self-assembled nanostructures combined with robotic quality control and error-correction measures. Key technologies are: field-induced, guided assembly of nanowires; self-alignment of large areas of nanowires; and, individual robotic manipulation of nano-components for selective processing.

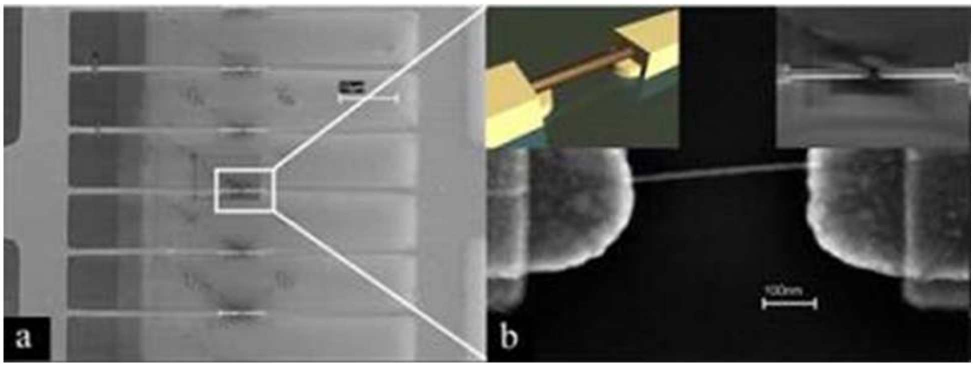

Figure 5: Hybrid nanofabrication approach to realize integrated nano-systems (a) Nanoarray design, (b) multi-walled nanotube on a nanostructure with schematic and a scanning electron microscope image shown in insets (courtesy of ETHZ).

4 Acknowledgements

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