Technologies and Applications for Industrial Hybrid Assembly

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Abstract

Hybrid assembly is the combination of robotics and self-assembly for ultra-precise, massively parallel assembly of microsystems. This presentation gives an overview of enabling technologies - robotics, self-assembly and their hybridization, that are the focus of a running research initiative [1]. Industrial scenarios are presented in different production domains, where robotics and self-assembly are combined. Robotics technologies include enhanced robot control by improved sensing and tools (vision, force, grippers with self-alignment properties). Complementary self-alignment technologies are involved such as substrate treatment for control or reduction of adhesion of components on the surface or development of field-induced assembly technologies (electrical, magnetical, fluidic fields for controlled self-positioning of micro or nano-objects).

The following applications are based on fast robotics and capillary self-alignment: a1) parallel assembly of MEMS sensor on a PCB, a2) high-speed assembly of RFID chips on an antenna web. Fluidic self-alignment combined with force controlled robotics is used for application b): automated processing and micro-injection of bio-substances into cells. A hierarchical self-alignment process stimulated by external, electrical fields in investigated for c): production of nanowires enabled sensing devices.

1 Hybrid Assembly

Manufacturing and assembly of complex products involving micro or even nano components is an increasing challenge in industrial manufacturing. Dimensions of the components are decreasing, tolerances are shrinking and production costs have to be reduced. Classical assembly approaches – including manual or robotized operations – are reaching their limits.

Use of *robotics* in combination with *self-assembly – hybrid assembly* – is the core of a new production paradigm for micro manufacturing. Several research activities are addressing this topic [1, 2, 3].

The benefits of *robotics* are: high handling flexibility, mature technology; *self-assembly* offers the potential for massively parallel handling. Nevertheless conventional robotics reaches its limits when handling very small parts due to undesired contact forces, and pure self-assembly is lacking selectivity and flexibility. Investigation of *hybrid assembly* is addressing these complex challenges on the robotics and on the self-assembly side. Furthermore, design rules for micro- and nano components have to be considered taking into account hybrid assembly scenarios already in an early stage of product development.

2 Industrial Hybrid Assembly Scenarios

Current research and development activities of hybrid assembly for industrial manufacturing are now briefly presented. The corresponding devices, components and their markets show a broad diversity. Promising assembly techniques are sketched.

2.1 Capillary based assembly for MEMS / IC components

Capillary based assembly of micro components is applied for positioning of flat micro parts (MEMS gripper, RFID chips, laser diodes) with high precision on a substrate. The common principle is that the components and the substrate provide areas with different wettability – such as metallic contact pad on a printed circuit board (PCB) - or with mechanical structures. Thus, a fluid medium (solder, adhesive, intermediate liquid) is confined to a defined area. Matching structures of the substrate and of the micro components allow precise self-assembly arranged by the surface forces between liquid and the components.

Two examples are given where components are placed in an initial coarse step close to self-assembly attractors. Finally the precise alignment is carried out unsupervised by self-assembly.

Assembly of delicate MEMS gripper on PCB

A MEMS gripper with integrated force sensing is directly being connected electrically and mechanically to a PCB. Hybrid assembly allows to replace serial wire bonding procedure with a one-step, parallel approach. The assembly procedure is carried out directly on the wafer containing the MEMS components. A proper arrangement of solder areas on substrate and MEMS allows reliable self-alignment.

Assembly of RFID chips on antenna web

RFID chips are assembled on a substrate: an antenna web. Hybrid assembly replaces a highly optimized pick-and-place process with die bonding equipment. A liquid adhesive is dispensed on the pads of the antenna. After parallel coarse positioning of the RFID chips, subsequent precise alignment on the pads is achieved by self-alignment.

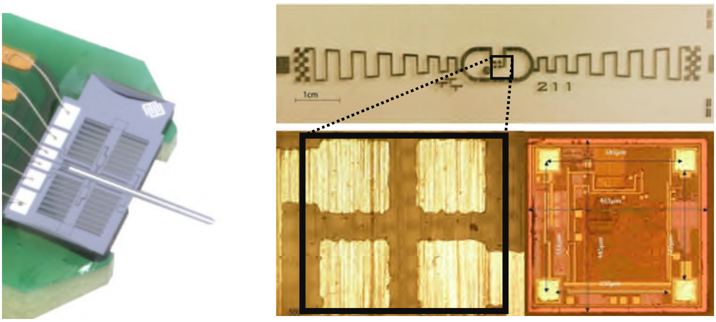

Figure 1: Left: MEMS gripper on PCB (courtesy of FEMTOTOOLS). Right: Antenna of RFID device (top) with 4 contact pads in the centre (bottom left) and matching pads on the bottom side of the RFID chip (bottom right, courtesy of DATACON).

2.2 Fluidic assembly in lab automation

Transport of small spherical objects such as biological cells can be efficiently controlled by means of fluidics. The size of the cells ranges typically between 1 mm down to 1 µm. The combination of fluidics and appropriate mechanical or chemical cell attractors allows to reversibly fix and release the objects in target positions. Batch processing of the cells is achieved.

Fully automated processing of cells

A lab-automation system has been developed that combines several aspects of cell handling. It offers automated procedures for cell selection, immobilization and microinjection. The system combines microfluidics for prior cell sorting and separation. A self-assembly unit is integrated for reversible immobilization of the cell, and microrobotics for force-controlled cell injection.

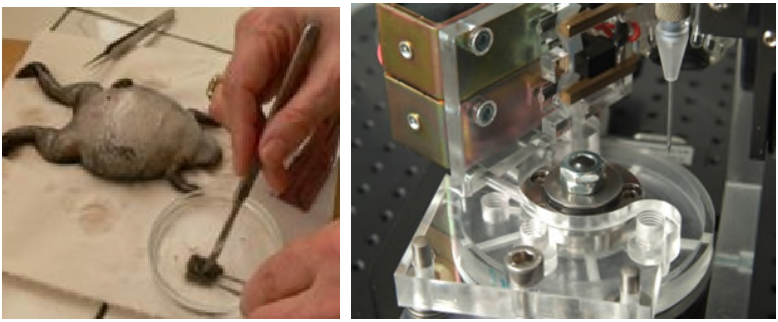

Figure 2: Left: Extraction of frog oocytes. Right: Cell sorting system with integrated injector (courtesy of CSEM).

2.3 Hierarchical assembly of micro- and nano components

Hierarchical self-assembly of components is achieved by means of external, tunable field that generates forces on the object to assemble. Here, dielectrophoretic forces allow precise and contactless manipulation of micro- and nano-objects – RFID chips and nanowires, respectively.

Dielectrophoretic handling of nanowires

Nanowires attract general interest as electrode material to increase sensitivity of electrochemical-based sensing. Hierarchical self-assembly methods have been developed in order to replace robotic pick-and-place operations of the nanoscaled components.

4 Acknowledgment

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References:

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