Enlarging the knowledge of nano

★ Our knowledge of synthesising nanostructures at the molecular level is progressing at a remarkable pace, but our current understanding of how to interface and assemble parts of different materials is still limited. **Dr Yves Bellouard** explains how the GOLEM project is changing this situation

Technology developers are constantly striving to copy the innovations found all around us in the biological world. As our understanding of the molecular level workings of the natural world improves, so the chasm between our 'cutting-edge' innovations and those mechanisms improved by evolution.becomes apparent.

The challenge for researchers lies not simply in understanding how we can synthesise similarly complex interactions, but how they can be adapted to innovative and beneficial ends. It is with this in mind that the GOLEM research project, led by Dr Yves Bellouard, approaches its work From the production of bone, dentine and enamel in our own bodies, to Abalone shellfish, which provide a template for the crystallisation of calcite into hard shell, biomineralisation frequently occurs in nature and Bellouard believes that mimicking events like this interface of organic and non-organic materials can bring unique benefits to the fabrication of micro-systems in general. Fabrication of parts is just one element of far wider reaching possibilities for implementing a new approach at this scale of industry. "In nature" Bellouard observes, "selective assembly is commonly found. For instance, a virus will only bind to specific cells through an efficient molecular recognition mechanism. Various, highly specific, bio-molecular recognition mechanisms are found, such as antibodies/antigens, protein receptor/ligand interactions or DNA hybridisation. Each of them is potentially a 'smart-bond' for future self-assembled micro- and nano- systems."

> "The fabrication of mesoscale systems is not only an interesting scientific challenge, but can clearly enable the development of high-impact and high-value products"

The need for mesoscale assembly

In the electronics industry there is an ongoing miniaturisation of integrated devices with broad functionalities. New technologies are required to overcome the challenges imposed by the need for efficient and accurate assembly which is also cost-effective. At present there are two approaches to the miniaturisation process, each with limitations. The first method, commonly known as 'top-down', shrinks and adapts technologies developed for larger scale systems. At the sub-millimetre range, this approach currently breaks down as the difficulties created by adhesion forces and component size requirements at this scale become insurmountable. Conversely, the 'bottom-up' approach, based on the self-assembly of complex structures from atoms and molecules, cannot currently yield components bigger than a few tenths of a nanometre.

To tackle the limitations of the existing approaches, an alternative solution has emerged, known as 'meso-scale self assembly' (MESA). MESA, in the case of GOLEM, uses bio-inspired assembly to fabricate parts using 'top-down' processes, and assembles them using 'bottom up' methods. Meso-scale components are self-assembled using a variety of interaction forces and to date, experiments in MESA have yielded degrees of success.

"The fabrication of mesoscale systems is not only an interesting scientific challenge, but can enable the development of high-impact and high-value products."

The future

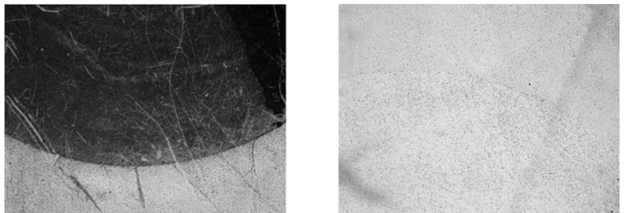
Mesoscale bio-inspired assembly is still in its infancy and many questions remain unanswered. The primary aim of the GOLEM project is to fully appreciate the potential of this technology as a future industrial assembly process by conducting a global and systematic investigation.

In addition to the bio-molecular binding mechanism, it is essential to consider issues like component handling and post-processing, in order to achieve a fully realised 'mesoscale assembly line'. Fluidic systems, which can direct the flow of parts, may be utilised to bring components to be assembled in close proximity to one another. Similarly, an appropriate platform is needed to investigate the effectiveness of self-assembly processes. The project has applied these lessons in the development of the three microrobots shown in the image on the first page. "We need to consider the process as a whole" Bellouard explains. "We are aiming to explore the frontiers of knowledge by a systematic investigation of bio-inspired events as a 'smart glue' to bond non-organic material, as well as relevant technologies to manipulate a large collection of components so that they interact properly with functionalised surfaces."

As part of the projects ambition to position Europe as a leader in the field of micro-/nano- assembly they have drawn up seven key objectives, each representing a critical step in the research process:

1. To investigate bio-molecular bonds suitable for the assembly of micro- and nano- parts
2. To develop tools and methods to selectively functionalise surfaces on which bio-molecules are attached to
3. To develop and implement a concept of mesoscale assembly line
4. To develop and implement specific tools for the assembly characterisation
5. To model and simulate the bio-inspired mesoscale assembly process
6. To characterise the mesoscale assembly process (geometry, bonding forces, repeatability, etc.) using specifically developed tools
7. To implement a demonstration of the assembly process

Ultimately, Bellouard underlines, with the results from this research, the GOLEM project aims "to support long-term innovation by providing specifically developed micro-robotic instruments and methods to investigate nano- and micro- assembly. These instruments will then be made available to the European Research Community. Indeed, a spin-off from the project's research.has recently been registered in Switzerland. (www.imina.ch/content)" ★



Microbeads assembled using DNA molecules. The beads were functionalised with single-strand DNA and only self-assembled at selective locations where the corresponding DNA strands were found. In these examples two circular patches of DNA molecules were deposited on the surface. One with the bead complementary DNA molecule and a second one with another DNA molecule. Beads were in contact with both patches but just self-assembled where they found their complementary pairs

At a glance

Full Project Title
(GOLEM)

Project Partners
Eindhoven University of Technology, Netherlands • Octax Microscience GmbH, Germany • Delong Instrument, Czech Republic • Quintenz, Germany • Ecole Polytechnique Fédérale de Lausanne, Switzerland • Commissariat l'Energie Atomique, France • Universität Stuttgart, Germany • Czech Technical University, Czech Republic • Laboratoire de Robotique de Paris, France • National Physics Laboratory, United Kingdom • University of Edinburgh, United Kingdom

Contact Details
Project Coordinator,
Yves Bellouard
Technische Universiteit Eindhoven
Dept of Mechanical Engineering/
Micro & Nano Scale Engineering,
Den Dolech 2, PO BOX 513,
Netherlands
T: +31 402 4737 15
E: y.bellouard@tue.nl
W: www.golem-project.eu

Dr Yves Bellouard

Project Coordinator

Dr Yves Bellouard is Assistant Professor in Micro-/Nano- Scale Engineering at the Mechanical Engineering Department of the Technische Universiteit Eindhoven and is recipient of the Omega Scientific Prize. Before joining the Technische Universiteit Eindhoven in 2005, he was a Research Scientist at the Centre for Automation Technologies at Rensselaer Polytechnic Institute in New York, USA where he taught Precision Engineering and Micro-Robotics. Current interests are on system integration at the micro-/ nano- scale, smart materials and femtosecond laser interaction with glass substrate.

Golem