Publishable Summary

Reporting Period 2

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Project Acronym:	**NanoBits**
Project Title:	Exchangeable and Customizable Scanning Probe Tips
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Project Partner: OFFIS, DTU Nanotech, EMPA, Fraunhofer IOF, NanoWorld Services, JPK Instruments

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Project full title:	Exchangeable and Customizable Scanning Probe Tips
Project acronym:	NanoBits
Type of funding scheme:	Collaborative Project (CP) – Small or medium-scale focused research project (STREP)
Work programme topics addressed:	Objective ICT-2009.3.9: Microsystems and Smart Miniaturised Systems a) Heterogeneous Integration
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List of participants:

Participant no.	Participant organisation name	Participant short name	Country
1 (CO)	OFFIS e.V. -- Institute for Information Technology	OFFIS	Germany
2	Nanointegration Group, DTU Nanotech, Copenhagen, Denmark	DTU	Denmark
3	Swiss Federal Laboratories for Materials Testing and Research, Thun, Switzerland	EMPA	Switzerland
4	Fraunhofer-Gesellschaft zur Förderung der Angewandten Forschung e.V.	Fraunhofer	Germany
5	Nanoworld, Erlangen, Germany	Nanoworld	Germany
6	JPK Instruments, Berlin, Germany	JPK	Germany

Objectives

The atomic force microscope (AFM) has become a standard and wide spread instrument for characterizing nanoscale devices and can be found in most of today's research and development areas. The NanoBits project provides exchangeable and customizable scanning probe tips that can be attached to standard AFM cantilevers offering an unprecedented freedom in adapting the shape and size of the tips to the surface topology of the specific application. NanoBits themselves are 2-4 µm long and 120-150 nm thin flakes of heterogeneous materials fabricated in different approaches. These novel tips will allow for characterizing three dimensional high-aspect ratio and sidewall structures of critical dimensions such as nanooptical photonic components and semiconductor architectures which is a bottle-neck in reaching more efficient manufacturing techniques. It is thus an enabling approach for almost all future nanoscale applications.

A miniaturized robotic microsystem combining innovative nanosensors and actuators will be used to explore new strategies of micro-nano-integration in order to realize a quick exchange of NanoBits. For the fabrication of the NanoBits, two different techniques are proposed. On the one hand, a standard silicon processing technique enables batch fabrication of various NanoBits designs defined by electron beam lithography. On the other hand, focused ion beam milling can be used to structure a blank of heterogeneous materials, the so-called membranes. Novel scanning modes in atomic force microscopy will be developed to take full advantage of the different NanoBits geometries and to realize AFM imaging of critical dimension structures. The innovative nanoimaging capabilities will be applied to characterize and develop novel nanooptical photonic structures in the wavelength or even sub-wavelength range and TERS applications in the nanomaterial and biomedical sector. Especially the involved SMEs will exploit and disseminate the results to potential users to realize a more efficient micro-and nanomanufacturing.

Main results in 2nd reporting period

WP 1

- Comparison of different assembly scenarios. Test of influence of NanoBits and slit parameter variations on assembly performance. Pick-up of out-of-plane bended NanoBit structures.
- Technology development of NanoBits pobes manufacturing process. Manufacturing of first NanoBits 3DAFM probes. Supply of NanoBits 3D AFM probes to the partners.

WP 2

- Reservoir chips with large number of NanoBits were produced by lithography methods and are available now for further experiments and testing.
- Out-of-plane NanoBits were realized with bilayer stress (angled) and focused ion beam milling-induced bending (angled and vertical).
- A new connector AFM probe for auto-pick-up of angled out-of-plane NanoBits has been designed, to complement the existing vertical pick-up connector AFM probe.
- FIB milling strategies were improved allowing a tip radius of 5 nm and aspect ratio 30 to be achieved, corresponding to or better than e-beam lithography.
- TERS NanoBit structures were created and tested.
- A small batch of FIB-milled NanoBit tips was attached to cantilevers using probe manipulator and FIB deposition, and obtained probes were tested.

WP 3

- The final proposed desing for the NanoBit's cartridge design was elaborated
- Mounting NanoBits onto plateau cantilevers has been demonstrated
- The automation of the cartridge assembly is developed and realized based on the manual proceeding

WP 4

- Two different scenarios have been identified and implemented onto the AFM-Controller for scanning structures with sidewalls.
    - Sidewall only scanning
    - Two plane scanning

WP 5

- Fracture strength and elastic modulus of Si/SiO2 bilayer membranes were determined by bending of FIB machined freestanding cantilevers.
- Yield stress of the joint material modelled as Pd grown by Focused Electron Beam Induced Deposition (FEBID) was determined by compression of nano-pillars.

WP 6

- The NanoBits can be easily used in a commercial AFM. The long term measurements have verified the robustness and stability of the FIB milled NanoBits.
- A procedure for the AFM in-process control for the etching parameters have been developed and experimented. An accuracy of 1% of the final depth is has been achieved.

WP 7

- Achieved TERS with silver nanowires mounted on Akiyama probes as NanoBits analogs
- Achieved TERS with sputter coated Akiyama probes to optimize metal coating protocols
- Achieved TERS spectrum with NanoBit mounted on AFM cantilever

WP 8

- Definition of project identity (logo, templates), launch of public NanoBits website, realization and distribution of NanoBits flyer, scientific publications.
- Identification of exploitable NanoBits results.
- Comprehensive patent search and analysis.

WP 9

- The NanoBits 1st review meeting incl. reporting was organized
- A Technical Meeting was organized
- The NanoBits website was reconfigured

Expected impact

The planned developments in the NanoBits project are anchored in the field of nanotechnology, which has become an interdisciplinary key and enabling technology. Nowadays, in the technology driving fields of semiconductor technology, nanoelectronics, photonics and life sciences as well as in other smaller disciplines almost everything is “nanoscale” since the sizes of circuitry in computers CPUs, nanoelectronics, optical structures and molecular structures are such. Progress in these fields of technology research is strongly driven by high-tech nanotechnological developments such as the development of the atomic force microscopy (AFM). Especially in the field of AFM-based characterization of such nanostructured devices, there is up to now a lack of tools that allow for a full characterization of 3D nanodevices having critical dimensions such as high-aspect ratio, sidewall, and even overhanging structure but that are needed to advance the aforementioned fields of science. The proposed NanoBits project will provide a very promising technique to characterize such nanostructures and thus to enhance the quality and efficiency of today's micro- and nanomanufacturing processes. The NanoBits project intends to impact on a large number of industries utilizing nanotechnology by revolutionizing the nanodevices characterization, synthesis, and their related manufacturing processes in the field of semiconductor technology, nanoelectronics, photonics and life sciences as well as in other smaller disciplines. The major impact of the NanoBits project will be that the consortium, two SMEs, assisted by the knowledge and expertise of the participating RTD institutes, will be able to realize and commercialize a unique, 3D AFM-based characterization tool for nanotechnology.

In summary, the proposed NanoBits project will offer novel customizable and exchangeable AFM tips and new AFM modes for 3D characterization of critical dimension structures to all potential AFM users. Since the AFM is one of the standard machines in micro- and nanofabrication labs and companies, the project results will allow for a more efficient manufacturing in semiconductor industry and photonics ensuring that the European industry will be at the forefront of the mentioned technologies.