NMP3-CT-2005-013619

NOVOPOLY

Novel Functional Polymer Material for MEMS and NEMS Applications

Instrument: STREP
Thematic Priority: **Nanotechnologies and nano-sciences, knowledge-based multifunctional materials and new production processes and devices**

Publishable final activity report

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Francesc Pérez-Murano
IMB-CNM (CSIC)

Contributors:

Name	**Partner**
Francesc Pérez-Murano	IMB-CNM (CSIC)
Cristina Martín	IMB-CNM (CSIC)
Andreu Llobera	IMB-CNM (CSIC)
Gemma Rius	IMB-CNM (CSIC)
Michael Lillemose	MIC-DTU
Gabriela Blagoi	MIC-DTU
Anja Boisen	MIC-DTU
Vahid Fakhfouri	EPFL-LMIS1
Joo Yeon Kim	EPFL-LMIS1
Juergen Brugger	EPFL-LMIS1
Harm-Anton Kolk	EPFL-LP
Ciara Ingrosso	IPCF-CNR
Lucia Curri	IPCF-CNR
Anja Voigt	*micro resist technology* GmbH
Gabi Gruetzner	*micro resist technology* GmbH
Mathieu Burri	NanoWorld AG
Manfred Detterbeck	NanoWorld AG

Contents

1.- Project objectives and major achievements

1.1 Project objectives, list of contractors and coordinator contact details

The goal of NOVOPOLY is the development of a new class of functional materials for targeted applications in the fields of micro- and nano- systems technology (MEMS and NEMS). Starting point of the proposal is the need to add functionality to existing photostructurable polymers (in particular SU-8) and the limitations of these systems with respect to their mechanical and electrical properties, as well as to high temperature stability. **The novel objective of NOVOPOLY is to increase functionality of the materials while maintaining their excellent micropatterning capabilities**.

New materials will require new and adapted methods of processing and micro-patterning. The availability of these methods is then fundamental to the final goal of NOVOPOLY. This is the reason why a parallel objective in NOVOPOLY is the **development**, **improvement and innovation of patterning and structuring methods for materials of interest in the field of MEMS and NEMS.** In consequence, standard/innovative methods will be adapted / developed to the specific requirements of the new materials:

The new set of materials and processes will enable a large variety of **applications** in the areas of MEMS and NEMS. In NOVOPOLY, we propose to demonstrate and validate our approach by two defined applications: **(i) Functional AFM probes** with improved material properties (Hardness) and with integrated sensor capabilities (conductivity, piezoresistivity) **(ii) Functional cantilever biosensors with integrated read-out**, improved sensitivity and simpler fabrication, with applications in the environmental and biomedical fields.

List of contractors

Partic Role	Partic .No	Participant name	Short name	Country	Date enter project	Date exit project
Co	1	Consejo Superior de Investigaciones Científicas-Centro Nacional de Microelectrónica	CNM-CSIC	Spain	M1	M36
Cr	2	Technical University of Denmark	MIC	Denmark	M1	M36
Cr	3	Ecole Polytechnique Federale de Lausanne	EFPL	Switzerland	M1	M36
Cr	4	Consiglio Nazionale delle Ricerche – Instituto per I Processi Chimico Fisici sezione di Bari	IPCF-CNR	Italy	M1	M36
Cr	5	Micro Resist Technology GmbH	MRT	Germany	M1	M36
Cr	6	Nanoworld AG	NW	Switzerland	M1	M36
Cr	7	Cantion A/S	CT	Denmark	M1	M11 (*)

(*) Cantion ended its operation in January 2006. In consequence, it is not more participating in the project and he has not contributed to the preparation of the progress report.

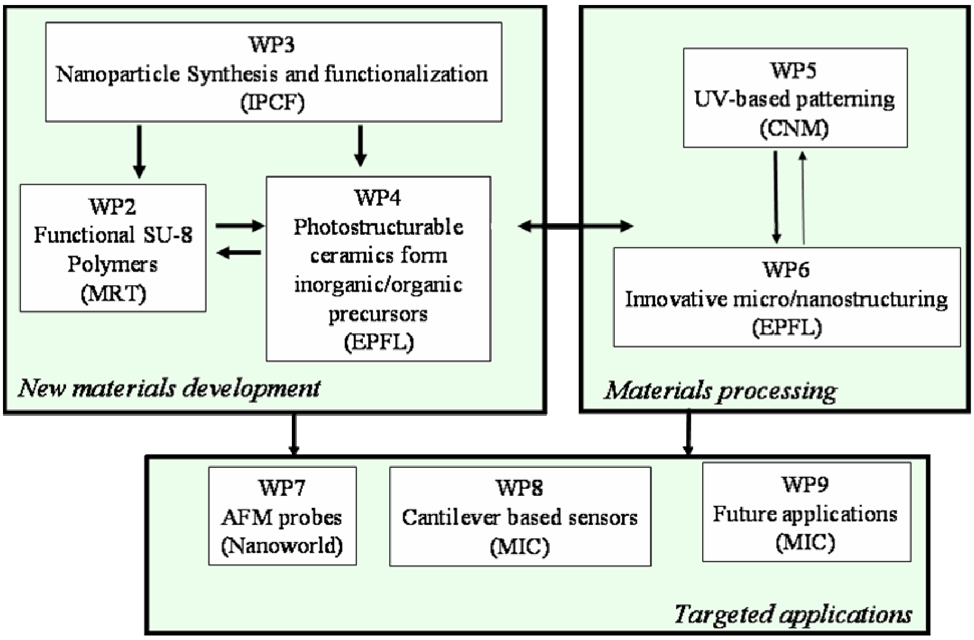
Coordinator contact details

Francesc Pérez-Murano
Instituto de Microelectrónica de Barcelona- Centro Nacional de Microelectrónica. (IMB-CNM)
Consejo Superior de Investigaciones Científicas (CSIC)
Campus de la Universitat Autònoma de Barcelona
E-08193 Bellaterra. Spain,
Phone: +34 935 947 700; Fax: +34 935 801 496; e-mail: Francesc.Perez@cnm.es

1.2 Workpackage

	Workpackage title & number	Partner Leader	Person month	Start month	End month	Deliverable no
	1 Coordination	CNM	13,6	0	39	D1.1 – D1.5
Materials	2. Functional SU 8 based polymers	MRT	65,1	0	39	D2.1 – D2.6
	3. Nanoparticle synthesised and functionalised for polymer modification process	IPCF	42,2	0	39	D3.1 – D3.5
	4.- Photostructurable ceramics from organic-inorganic hybrid precursors	EPFL	26	0	39	D4.1-D4.4
Processing	5. UV based patterning	CNM	34,1	0	39	D5.1-D5.3
	6. Innovative polymer micro/nano structuring	EPFL	35,5	0	39	D6.1-D6.3
Applications	7. AFM probes	NW	21,7	0	39	D7.1-D7.2
	8. Cantilever based biosensors	MIC	35,1	0	39	D8.1-D8.4
	9. Future applications	MIC	12	18	39	D9.1
	10 Exploitation	CNM	8,7	0	39	D10.1-D10.4
	TOTAL		**294**			

Next figure shows how the inter-relation between each work-package:



1.2 Summary of main results

(In the annex, graphical representation of main results are presented)

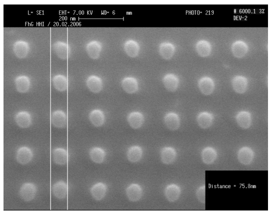
WP2. Functional SU-8 based polymers

The aim of this workpackage is the development of a toolbox of a variety of materials for different applications. Starting point is SU-8 or other epoxy resin based photosensitive materials, that have been improved by adding additional components like nanoparticles or nanocrystals to creat hybrid organic/inorganic materials with additional functionality:

- electrical conductivity
- magnetic
- mechanical hardness
- fluorescence
- specified intermolecular forces (hydrophilic, hydrophobic): surface functionalization of the patterns to manufacture cantilevers for BioMEMS

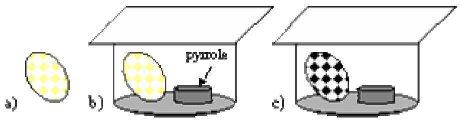
Results obtained in this WP but as a result of the collaboration between all the partners in the rest of WPs can be summarized as follows:

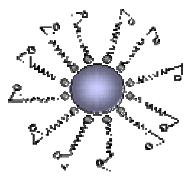
New Products have been developed, described and produced



- mr-EBL 6000
- SiO2 doped material
- Black coloured material

New knowledge has been generated about:





- Conductive NP and conductive polymers in combination with epoxy resin based materials
- Methods to generate conductive layers (vapour diffusion)
- Compatibility of NP to epoxy resins and solvents (epoxy resin coated SiO2-NP, CdSe@ZnS NC, surfactants,...)
- Long-term stability of modified resist solutions and layers
- Methods of surface functionalization
- New research direction for future products (Ormocer-typ, which is insensitive to oxygen during exposure)

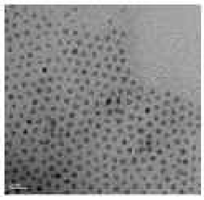
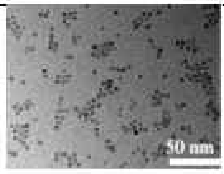
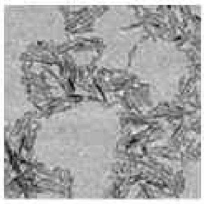
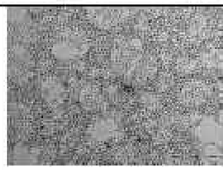
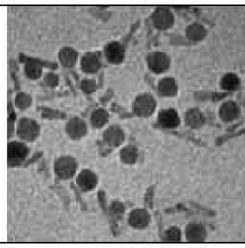
WP3. Nanoparticles synthesized and functionalized for polymer modification process.

The activity in WP3 has aimed to achieve novel nanostructured materials by means of an effective modification of selected polymers and resist with nano-objects, in order to combine organic structurable polymer and inorganic compounds in a unique material with peculiar properties, which can be relevant for many application fields such as optics, electronics, mechanics, sensing and biology.

The tasks in this WP have been developed in order to, respectively:

- Synthesize metal, oxide and semiconducting, colloidal nanocrystals (NC)
- Functionalize nano-particle to make them processable and dispersible in a variety of polymers and resists, including SU-8 based one
- Local deposit and positioning of nanoparticles
- Characterize nanoparticles all along the processing steps from a structural, optical, morphological, electrical and magnetic point of view.
- Preliminary investigate the fundamental properties of nanocomposites by using modelling and simulation methods

A large variety of organic surface functionalized NCs were prepared with different size, shape and physical and chemical properties which allow to suitably modified organic polymers in order to convey them target functionalities exploitable in the field of MEMS and NEMS devices. Next table reports a summary of the chemical and physical properties of the prepared NCs.

NC	NC surface chemistry	NC Size and shape	NC properties	TEM images
CdS	OLEA, alkyl amines	2-8 nm spherical	Optoelectronic, emission, absorption, electroluminescence	
CdSe@ZnS	TOPO,TOP HAD, amines	2-10 nm spherical	Optoelectronic, emission, absorption, electroluminescence	
TiO_2	Amines, carboxylic acid, phosphonic acid	3-5 nm spherical, 3-5×10-30 nm elongate	Semiconducting, photocatalytical, optical, mechanical and charge transport	
γ-Fe_2O_3/ Fe_3O_4	Oleic acid/ Oleic acid, Oleilamine	8 nm/10 nm	Magnetic, catalytical, biocompatibility	
TiO_2/ Fe_3O_4	Oleic acid, oleilamine	20 nm×3 nm TiO_2 rods, 12 nm Fe_3O_4	Semiconducting, photocatalytical, optical, mechanical and charge transport Magnetic, catalytical, biocompatibility	

WP4: Photostructurable ceramics from organic-inorganic hybrid precursors

The objective of WP4 has been to synthesize polystyrene-polymethylphenylsilane-polystyrene (PS-PMPS-PS) or polymethylmethacrylate-polymethylphenylsilane-polymethylmethacrylate (PMMA-PMPS-PMMA) triblock copolymers, which will be explored as precursors for the fabrication of ceramic micro/nanostructures. The strategy relies on using the self-assembly of the triblock copolymer to generate the desired nanoscale structures, followed by a pyrolysis step, which removes the PS or PMMA domains and converts the PMPS into a ceramic material. A new and simple one-pot multistep protocol for the synthesis of these triblock copolymers have been developed. The protocol typically resulted in triblock copolymers with molecular weights (M_n) ranging from 15.000 – 30.000 g/mol. Small-angle x-ray scattering experiments on this first generation of triblock copolymers indicated that these samples do not phase separate to form the desired nanoscale morphologies This was attributed to the relatively low molecular weights of the polymers. It was found that the use of ultrasound in the first step of the synthesis resulted in a large increase of the molecular weight of the PMPS block. Using ultrasound during the synthesis of the PMPS block, PMMA and PS containing triblock copolymers with overall molecular weights of ~ 120.000 g/mol could be obtained, which is a factor of 4 higher compared to the first generation of materials.

WP5: UV based patterning

The objective of WP5 have been to establish and develop processing methods for modified polymers based on standard UV based processing. Within this work-package, methods to pattern the polymeric materials generated on previous workpackages have been employed to defined micrometer-size structures. Processes are based as much as possible on already industrial accepted methods, which have been modified/adapted according to the specific characteristics of the new polymeric materials, keeping always compatibility with existing/standard processing methods,

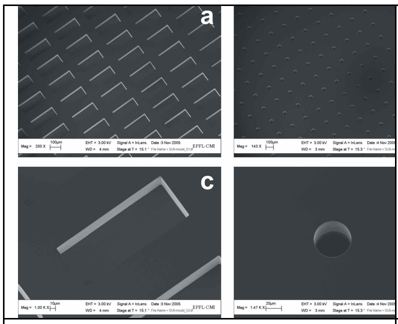
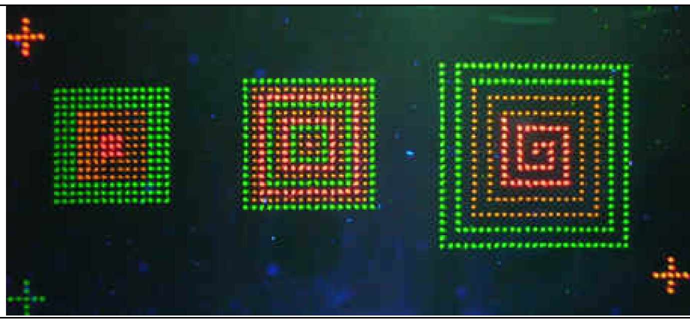
Following table summarized the different optimized processes for the materials developed

Mechanism	Material	Resolution	Applications
UV Lithography	mr-L 5005 XP	2.5 µm	Cantilever of devices
	mr-L 5025 XP	40 µm (at least)	Body of devices
	mr-L 5002 XP	50 µm (at least)	Cantilever of devices
	mr-L 5000 SiO2-50	3 µm	Waveguides cantilever
	mr-L 6005 γ-Fe2O3 -XP	5 µm	Cantilever AFM probes
	mr-L 6005 TiO2 -XP	50 µm (at least)	Cantilever AFM probes
	mr-L 6002 PANI-20-XP	8 µm	Optothermal actuators
	mr-L 5010 PANI-XP		Optothermal actuators, waveguides
	mr-L 6005 C-XP	20 µm	Optothermal actuators
Soft Lithography	mr-L 6005 C-XP	2 µm	AFM tips
	mr-EBL 6000.1 XP	60 µm (at least)	Polymeric Hydrophobic Barriers

WP6: Innovative polymer micro/nanostructuring

Photolithography methods based on spin-coated polymer layers can only be applied to substrates that are flat, and stable (mechanical and chemical). This WP has develop alternative, non-lithographic, structuring methods, and applyed them to the new materials developed in other WP's. Alternative polymer structuring includes:

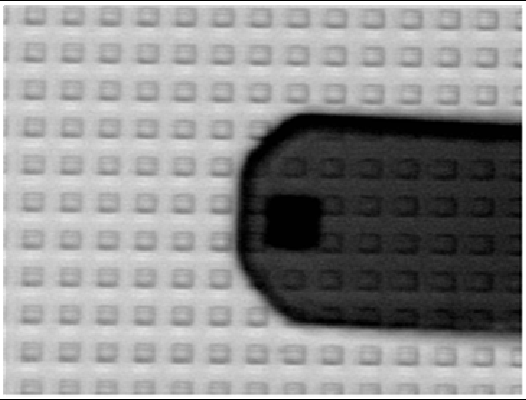
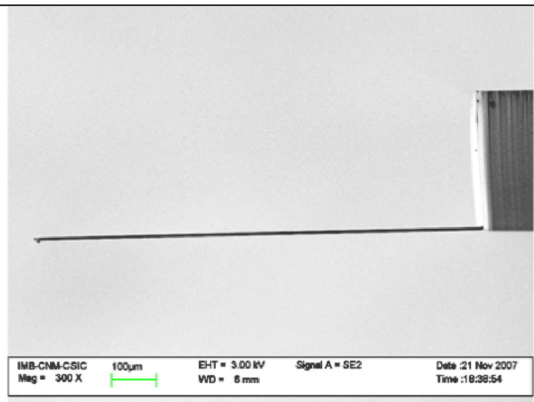
a) micro/nanomoulding for 3D replicas combined with sacrificial layer techniques
b) inkjet printing of new functionalized materials

	
SEM images of micro-moulds of different shapes from SU-8 50 with an Al + 1%Si coating.	Fluorescent photograph of inkjet-printed multi-color pixels by UV lamp at 366 nm, with 25 drops (per pixel with 1 mm pitches) of different sized CdSe@ZnS NC embedded: up) 5 wt% PS nanocomposites with a single-nozzle ink-jet printing system and 400 ~ 480 µm of the pixel's size, down) 3 wt% PS nanocomposites with multi-nozzle ink-jet printing system and 550 ~ 620 µm of the pixel's size

WP7: AFM probes

New polymers developed within Novopoly has allowed to improve the quality and performance of photoplastic AFM probes. The following results should be emphasized:

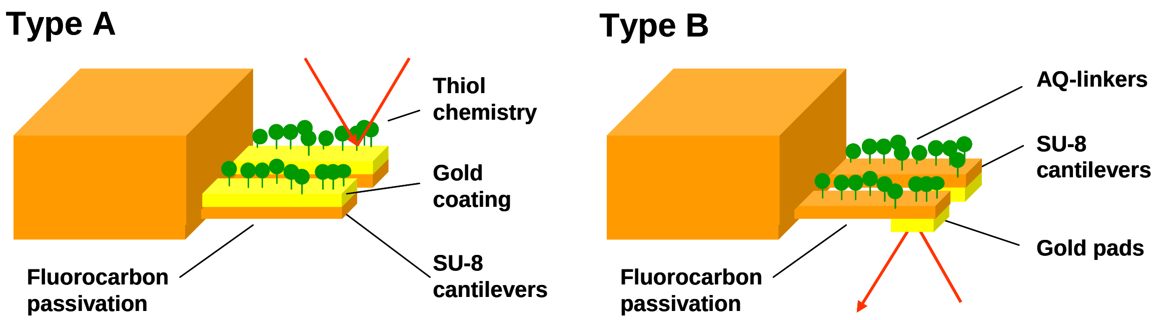
- Obtaining flat cantilevers in a reproducible way was targeted as one of the basic goals of the project, given that this would be critical for an eventual commercialization of this kind of probes. Several processing steps and release methods were investigated, finding out that the most stable process was to perform a hard bake during 120 minutes at 120°C and then release the structures etching the oxide sacrificial layer using a buffered HF solution.
- The fabricated devices were then tested in different commercial AFM equipments. They were proved to be valid for contact and non-contact mode, the latter both in air and liquid. As a general remark, it is possible to assert that the resolution of the tip can be as good as a commercial Si probe.
- A complete aging study has been performed during more than 1 year in some cases in which it has been shown the fact that the probes fabricated by the process flow presented here are stable and neither the shipping nor the storage out of controlled environment affects them.
- Iron oxide composite had also demonstrated the enhancement of the mechanical properties as a structural resist for cantilevers. They are completely flat (below the 0.5° deflection angle) and they have a low intrinsic stress gradient. Furthermore, the frequency spectra is more clear and less noisy than for the initial epoxy based resist cantilevers, being the quality factor at least doubled. Small tip radius can be obtained (in the same range as the tips fabricated out of non doped resist), making this material optimum for the polymeric probes fabrication.

	
Photoplastic AFM probe mounted on a commercial AFM sytem	Fe2O3 doped photoplastic AFM Probe

WP8: Cantilever based biosensors

The optimized processes developed in the previous chapters were used for the fabrication of cantilever chips for surface stress measurement with optical read-out. For this purpose, Au coatings had to be integrated on the cantilevers to allow for reflection of the laser beams.
This still allowed for optical read-out and the bending of the cantilevers due to fabrication was significantly reduced.
Two sensor designs illustrated in figure 14 are suggested for surface stress measurements with the optical readout-setup were evaluated. Both devices feature metal coating for optical-readout, surface functionalization and backside-passivation as an integral part of cleanroom fabrication on wafer scale.

Type A: The Au covers the complete cantilever and serves simultaneously as reflective layer and as anchor for surface functionalization. Immobilization of thiols is possible due to acceptable surface contamination of the Au. The backside of the SU-8 cantilever is passivated by fluorocarbon.
We have demonstrated detection of DNA hybridization using a SU-8 cantilever based sensors (5.5 µm thick). The SU-8 cantilevers are as sensitive as Si base ones that are much thinner (500nm) and more expensive.



Two sensor design for surface stress measurement with optical read-out including Au coating, surface functionalization and backside passivation

We anticipate that SU-8 cantilever-based biosensors in combination with DNA will be useful for sensitive and label-free detection of cancer. We also envision that SU-8 cantilever-based stress sensors will enable understanding certain aspects of protein- DNA interaction (such as intermolecular forces between DNA- protein and their effects on conformational changes). Effects that cannot be understood with mass-dependent, label-free detection techniques. We anticipate these cantilever sensors can provide information about analyte-dependent structural rearrangements; rearrangements can be engineered to provide additional sources of surface stress and about the biomolecular cause of cancer.

Type B:, There, only the apex of the cantilever is coated with Au to minimize cantilever bending. We anticipate that using AQ-photolinkers for direct photochemical functionalization of the top-side of the cantilevers with biomolecules. This step can be done before or after the release of the devices from the substrate, providing the opportunity to work at the wafer scale, minimizing the cost and improving the reproducibility and the robustness of the cantilever surface functionalization. These type of SU-8 cantilevers provide the opportunity to step away from the most used functionalization chemistry of cantilever surfaces: Au-thiol chemistry for the cantilever functionalization. On Au surfaces impurities absorb as soon as the deposition is finished giving spurious results, the thiol-gold bond is not stable and the cantilever sensors cannot be reused after cleaning.

WP9: Evaluation of future applications

Within this workpackage, some envisioned applications have been evaluated for the new materials generated within the project. While the main direction of the project has been the application of the new material for the fabrication of AFM probes and cantilever based sensors, other applications have raised after the properties of the new materials have been recognized. Two of these applications have been analyzed in deep, as it is explained in this deliverable.

The first set of applications that have been selected is the following:

1. **Optothermal Actuators.** Pani-doped epoxy based resist presented good photostructurable properties together with increase of light absorption. Fabrication of devices that would be actuated by light is straightforward with the processing capabilities developed within the project. Devices are based in two layers of materials, one doped and one non doped.
2. **Magnetic cantilevers.** Epoxy based resist doped with iron-oxide nanoparticles is a candidate to have a photostructurable polymer with magnetic response. Applications are for the detection and actuation on a cantilever implemented with a magnetic material, using a single-layer structure. Results on this point are detailed in deliverable D7.2. An extension is to use magnetic actuation to build new class of devices, as it is explained in section 3 of this deliverable.
3. **Hydrophobic barriers.** mr-ebl 5005 material has been developed by Microresist within the project and in process of being commercialized as a negative resist for electron beam lithography. An additional application of this material is in the area of microfludics, where it can be used, in combination with processing by soft-lithography methods, to fabricate hydrophobic barriers for microfludics systems. Details about this are described in deliverable D5.3
4. **Photonic structures.** Doping of epoxy based result with nanoparticles as silicon dioxide or titanium dioxide induces the change of the refraction index of the material. It can be used to fabricate integrated-optics devices like single mode polymeric waveguides of interest for communications and sensing. Preliminary results demonstrate good guiding properties.
5. **Micro-optical devices.** Ink-jet printing has been successfully used to fabricate polymeric microlenses, with interest in many areas of microsystems technologies. EPFL is successfully applying this technique.
6. **Photolumniscent devices.** Incorporation of photoluminiscent nanoparticles into epoxy based resist allows incorporating photoluminescence to the polymer. Applications in the areas of biosensing and communications are envisioned.

2.- Dissemination and use

As a result of the activity carried-out within NOVOPOLY, new knowledge have been generated with a prospective for exploitation, either commercially or as a seed for further developments. Areas of application include Microsystems, Telecommunications, environment, research, biomedics, etc. The objective of this deliverable is to summarize the specific knowledge that has been generated and which is its situation in terms of further exploitation.

A comprehensive list of exploitable results are identified The activity within Novopoly has been framed in three areas: Materials development, application and generation for processing methods, and device fabrication. The results are classified in these three areas.

The IPR situation within the Consortium is fairly reasonable and does not show major conflicts among partners.

General issues for exploitable knowledge regarding materials development

In the consortium there is a Company that sells SU8 and related materials (Microresist technology) and that it has benefit from the new materials that has been generated.

There are no industrial partners within the Consortium to manufacture the NC which prevents scaling-up of some of the materials. This is a good opportunity for academia to grant a production license to external partners.

General issues for exploitable knowledge regarding processing methods

Several methods, processes and techniques have been developed and optimized within the project. They will be exploited in the near future by several of the partners, either by their own or in collaboration with other. It is good to emphasize two results: optimize processing of SU-8 based materials for building-up AFM probes and methods related with ink-jet printing. The first may trigger the commercialization of photoplastic probes by Nanoworld.

General issues for exploitable knowledge regarding applications

Demonstration of the feasibility for short term exploitation of photoplastic AFM probes (for dynamic mode AFM, for example) is one of the strong outcomes of Novopoly. Advances for the exploitation of polymer-based cantilever sensors and the outcome of new and potentially high impact devices for new applications are also positive aspects.

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List of exploitable materials

Exploitable Knowledge (description)	**Exploitable product(s) measure(s)**	**Sector(s)** of application	Timetable for commercial use	**Owner** & Other Partner(s) involved	
1. Epoxy based resist for electron beam nanolithography	*Resist*	1. Semiconductor industry 2. R&D Labs related with nanofabrication	February-2008	MRT	CNM
2. Epoxy based material doped with SiO2 nanoparticles	*Resist*	1.- Microsystems technology. 2.- Telecommunication	Defining market and market size	MRT	CNM
3. Epoxy based material doped with PANI	*Resist*	1. Microsystems and Micro/nano electronics tech.	Defining market and market size	MRT	CNM
4. Epoxy based material dyed doped	*Resist*	1. Microsystems and Micro/nano electronics tech	Defining market and market size	MRT	CNM
5. Epoxy based material doped with Fe2O3 nanoparticles	*Resist*	1.- Microsystems technology 2 .- AFM systems	Defining ways to scale-up NC production	IPCF	MRT, CNM, DTU
6. Epoxy based material doped with TiO2 nanoparticles	*Resist*	1.- Microsystems technology. 2.- Telecommunication	Defining ways to scale-up NC production	IPCF	MRT, CNM
7. Epoxy based material doped with luminiscent nanoparticles	*Resist*	1.- BioMEMS. 2.- Microsystems technology	Defining ways to scale-up NC production	IPCF	MRT, EPFL
8. Nanoparticle / nanocrystal synthesis and processing	Process	1.- New material development	N/A	IPCF	
9. Surface modification with nanoparticles / nanocrystals	Process	1.- New material development	Defining ways to scale-up NC production	IPCF	MRT, DTU
10. PS doped with luminiscent nanocrystals	Polymer ink	1.- BioMEMS. 2.- Microsystems technology	Defining ways to scale-up NC production	IPCF	EPFL
11. Synthesis of ceramic precursors	Process	1. Microsystems technology 2. R&D Labs related with nanofabrication	Not feasible	EPFL	
12. Method for defining hydrophobic barriers based on soft lithography	Method	1.- Microsystems technology. 2.- Microfluidics.	Ready for small series	CNM	MRT
13. Method for defining hydrophobic barriers based on ink-jet	Method	1.- Microsystems technology. 2.- Microfluidics.	Ready for small series (case by case study)	EPFL	CNM MRT

Exploitable Knowledge (description)	**Exploitable product(s) measure(s)**	**Sector(s)** of application	Timetable for commercial use	**Owner** & Other Partner(s) involved	
14. Micromoulding based processes	Process	1.- Microsystems technology	Not defined	EPFL	
15. Inkjet printing of polymers	Method	1.- Microsystems technology. 2.- Biomedical devices.	Defining ways to scale-up NC production	EPFL	SU-8: MRT PS: IPCF
16. Micromoulding + inkjet printing	Method	1.- Microsystems technology	Not defined	EPFL	MRT
17. Bio-functionalization of SU-8 for sensing applic. using photolinkers	Method	1.- Sensors. 2.- Optofludics. 3.- inmuno assays	Next operative SU-8-based sensors	DTU	
18. Process to define micrometer size mechanical structures made of Fe2O3 doped SU-8	Process	1.- Microsystems technology. 2:- AFM probes	Defining ways to scale-up NC production	CNM	IPCF, MRT
19. Improve processing to define micrometer size mechanical structures made of SU-8	Process	1.- Microsystems technology. 2:- AFM probes. 3.- Biomedical microdevices	Evaluating cost of scaling-up	CNM	IPCF, MRT
20. Transparent AFM probes made of SU-8	Device	1.- AFM probes. 2.- Biomedical microdevices	Evaluating fabrication costs	CNM	MRT
21. SU-8 probes (doped and not doped) for NC operation in liquid	Device	1.- AFM probes. 2.- Mechanical sensors	Evaluating cost of scaling-up	CNM	MRT, IPCF
22. Doped Su-8 Cantilever sensors for optical read-out	Device	1.- Mechanical sensors	Needs some more years of research	DTU	MRT, IPCF, CNM
23. PiezoresistiveCantilever sensors with strain gauge	Device	1.- Mechanical sensors	Limits related with reproducibility	MIC	
24. SU-8 based Optothermal actuators	Device	1.- Microssytems technology. 2.- Human interfaces	Evaluating cost of scaling-up	CNM	MRT
25. micro-optical devices made by ink-jet printing of SU-8	Device	1.- Microssytems technology. 2.- Biomedical microdevices	Evaluating cost of scaling-up	EPFL	MRT
26. Photoluminiscent devices made of UV and ink-jet printing	Device	1.- Optolectronics Technology. 2.-. Microsystems technology	Evaluating costs in a case by case basis	EPFL	IPCF
27. Micro-optical mechanical devices made with doped SU-8	Device	1.- Microssytems technology. 2.- Biomedical 3.- Integrated optics	Evaluating cost of scaling-up	CNM	MRT

Dissemination and Knowledge

Overview table

Planned/actual Dates	Type	Type of audience	Countries addressed	Size of audience	Partner responsible /involved
12 articles in International refeered journals (up to now, more in preparation)	*Publications*	*Research*	**World Wide**	*Research Community*	*ALL*
> 30 presentations in international conferences	*Conference*	*Research*	**World Wide**	*Research Community*	*ALL*
Lessons within Microsystems and nanofabrication courses	*PhD Courses*	*Higher education*	**Spain**	*20- 40*	*CNM, EPFL, IPCF, DTU*
Lessons in Master Courses	*Other courses*	*Higher education*	**EU**	*20-30*	*CNM, EPFL, IPCF, DTU*
Several Exhibiton attended	*Exhibition*	*Industry (sector semiconductor)*	**EU**	*Research Community*	*Microresist*
Since beginning of project	*Project web-site*	*Research and industry*	**World wide**	*Research Community*	*CNM*
Novemeber 2007	*Flyers*	*Research and industry*	**World Wide**	*Research Community*	*IPCF, EPFL*
2007-2008	*4 PhD Thesis*	*Research & training*	**World Wide**	*Research Community*	*CNM, IPCF, EPL, DTU*
2006-2009	*6 Master Thesis*	*Research & training*	**World Wide**	*Research Community*	*CNM, IPCF, EPL, DTU*

ACCEPTED PUBLICATION

ARTICLES IN JOURNALS		
TITLE	**REFERENCE**	**AUTHORS**
TiO2 colloidal nanocrystals functionalization of PMMA: a tailoring of chemical absorption and optical properties	Sensors and Actuators B (2007) 126 138–143	A. Convertino, G. Leo, M. Tamborra, C. Sciancalepore, M. Striccoli, M.L. Curri and A. Agostiano
Seeded growth of asymmetric binary nanocrystals made of a semiconductor TiO2 rod-like section and a magnetic ?-Fe2O3 spherical domain	Journal of American Chemical Society (2006) 128(51); 16953-16970.	Raffaella Buonsanti, Vincenzo Grillo, Elvio Carlino, Cinzia Giannini, Maria Lucia Curri, Claudia Innocenti, Claudio Sangregorio, Klaus Achterhold, Fritz Günter Parak, Angela Agostiano, and Pantaleo Davide Cozzoli
Improved properties of hybrid epoxy nanocomposites for specific applications in the field of MEMS/NEMS	Microelectronic Engineering, 84, 1075-1079 (2007)	Voigt, A. / Heinrich, M. / Martin, C. / Llobera, A. / Gruetzner, G. / Perez-Murano, F
Electron beam lithography at 10 keV using an epoxy based high resolution negative resist	Microelectronic Engineering, 84, 1096-1099 (2007)	Martin, C. / Rius, G. / Llobera, A. / Voigt, A. / Gruetzner, G. / Perez-Murano, F.
An Epoxy Photoresist Modified by Luminescent Nanocrystals for the Fabrication of 3D High-Aspect-Ratio Microstructures	Adv. Funct. Mater. (2007) 17, 2009–2017 (cover page)	C. Ingrosso, V. Fakhfouri, M. Striccoli, A. Agostiano, A. Voigt, G. Gruetzner, M.L. Curri and J. Brugger
Inkjet Printing of Su-8 for polymer-based MEM: a case study for microlenses	IEEE Journal of Microelectromechanical Systems	V. Fakhfouri, N. Cantale, G. Mermoud, J. Y. Kim, D. Boiko, E. Charbon, A. Martinoli and J. Brugger
Novel Methods to patter polymers for microfludics	Microelectronics Engineering, 2008	C. Martin, A. Llobera, T. Leïchlé, G. Villanueva,c, A. Voigt, V. Fakhfouri, J. Y. Kim, N. Berthet, J. Bausells, G. Gruetzner, L. Nicu, J. Brugger and F. Perez-Murano
Intrinsically conductive polymer thin film piezoresistors	Microelectronics Engineering, 85:969-971,2008	M. Lillemose, M. Spieser, N.O. Christiansen, A. Christensen, A. Boisen
."Piezoresistive SU-8/carbon nanoparticle composites",	Composite Science and Technology, 68:1831-1736, 2008	M. Lillemose, L.Gammelgaarg, J. Richter, E.V Thomson, A. Boisen
Nanospheres vs. nanorods: shape and surface chemistry for tailoring swelling behaviour in polymer nanocomposites	J.Mater.Chem (submitted)	L. Curri et al.
Novel photochemical method for chemical modification and patterning of the SU-8 photoresist	Langmuir (submitted)	A. Boisen et al
Functionalization of SU-8 photoresist with proteins	Applied Surface Science (submitted)	A. Boisen et al

Title	Conference
Drop-on-demand Ink-jet printing of functional materials: Case studies of SU-8 and NCs-embedded Polymer nanocomposites	DF 2008
Inkjet printing of SU-8 for Polymer Based MEMS: A Case Study of Microlenses	MEMS 2008
Novel methods to pattern polymers for microfluidics	MNE 2007
Improved properties of hybrid epoxy nanocomposites for specific applications in the field of MEMS/NEMS	MNE 2006 32nd International Conference on Micro- and Nano- Engineering 2006 17-20 September 2006 Barcelona (Spain).
Electron beam lithography at 10 keV using an epoxy based high resolution negative resist	MNE 2006 32nd International Conference on Micro- and Nano- Engineering 2006 17-20 September 2006 Barcelona (Spain).
Chemical sensing properties of Poly(methyl metacrylate)- TiO2 nanocomposites	Symposium V: Functional Materials for Chemical and Biochemical Sensors 2007
Luminescent Nanocrystal Modified Photoresin for Fabrication of High-aspect Ratio Three-dimensional Microstructures	MRS Material Research Society Fall Meeting 2006
An EPR Study of Nanocrystals with an Anatase Rod-Like TiO2 Section and a Size-Tunable Magnetic Domain	EFEPR- 2006
Colloidal oxide nanocrystal heterostructures with an anatase rod-like TiO2 section and a size-tunable magnetic domain	35th Physical Chemistry National Congress 2006
Photocatalytically active nanoparticles	CIMTEC 2006
TiO2 colloidal nanocrystals functionalization of PMMA: a tailoring of chemical adsorption and optical properties	E-MRS 2006
Nanocomposites based on luminescent colloidal nanocrystals in polymers: new opportunities for micro and nano fabrication	Nanotech Montreux 2005
"Colloidal nanocrystal based nanocomposites as novel functional materials"	NANAX3 Nanoscience with Nanocrystals 21-23 May Lecce (Italy).
"Covalent Immobilization of Surface-Functionalized TiO2 and γ-Fe2O3 Nanocrystals onto epoxy photo-resist films "	E-MRS 2008 Spring Meeting, 26-30 May 2008 Strasbourg (France).

"Effect of the nanoscale curvature and surface chemistry of TiO2 nanocrystals on the organic vapour absorption capacity of TiO2/PMMA composite"	2nd International Conference on Advanced Nano Materials, ANM 2008 June 22nd -25th 2008, Aveiro, Portugal
"Luminescent Nanocrystal Modified Photoresist for Fabrication of High-aspect Ratio Three-dimensional Microstructures"	MRS Material Research Society Fall Meeting 27th November – 1st December 2006 Boston (USA)
"High-aspect ratio three-dimensional photoresist-based microstructures doped with luminescent nanocrystals"	MNE 2006 32nd International Conference on Micro- and Nano- Engineering 2006 17-20 September 2006 Barcelona (Spain).
Nanocomposites based on luminescent colloidal nanocrystals in polymers: new opportunities for micro and nano fabrication	Nanotech Montreux 2005
Surface micromachining of Ceramic-MEMS based on SU-8 micromoulding of Polyureasilazane	CIMTEC 2006
Novel method for photochemical modification and patterning of the SU-8 photoresis	Proceedings of the 11th International Conference on Miniaturized Systems for Chemistry and Life Sciences, Oct 9-11,(2007), Paris, France
Functionalizing Polymeric Cantilevers With Proteins	Proceedings of the International Workshop on Nanomechanical Sensors, Copenhagen, May 7-10, 2006
"Colloidal nanocrystals as tailored building blocks for nanocomposites and assemblies: original opportunities for functional materials"	37th Conference of the Italian Physical Chemical Society, Camogli (Genova) – Italy 24-29 February 2008
"Nanoparticles as functional building blocks for tailored materials towards device applications"	33rd International Conference on Micro- and Nano-Engineering 23-26 September 2007, Copenhagen Denmark 23-26 September 2007.
"Polymer nanocomposites based on colloidal nanocrystals as novel functional materials towards systems and devices"	Nanoforum Conference 27-28 September 2006 Milan (Italy).
"Photocatalytically active nanoparticles"	Cimtec International Ceramics Congress Acireale Italy 4-9 June 2006

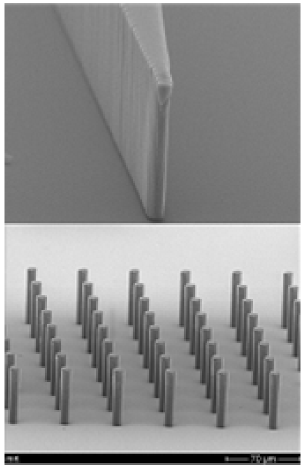
PhD Dissertation		
Completed		
Chiara Ingrosso. IPCF	Hybrid Organic/Inorganic Materials based on Colloidal Nanoscrystals Towards Sensing Applications	March 28th 2008
Cristina Martin, CNM-CSIC	Nanofabrication with polymers	March 6th, 2008
In progress		
Vahid Fakhfouri, EPFL	Combination of ink-jet printing and micromoulding for the microfabrication of hybrid devices	August, 2008
Michael Lillemose, MIC	Micro and Nanomechanical Sensors Realised in Functionalised Polymers	Fall 2008

ANNEX

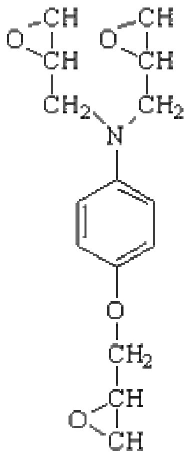
Graphical summary of main results

New functional polymeric materials

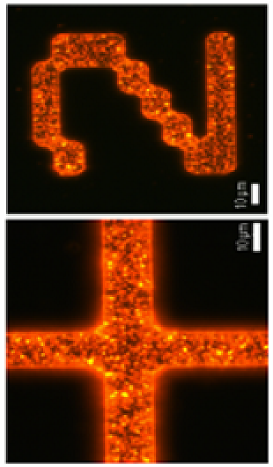
SiO_2 Doped polymer



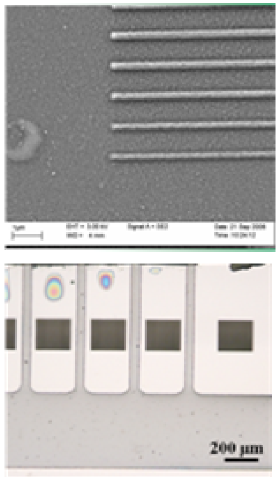
Higher cros-linking properties



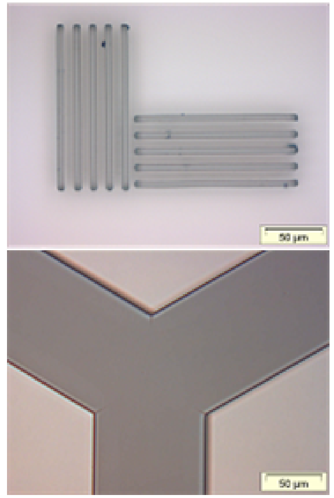
Photoluminiscent polymer



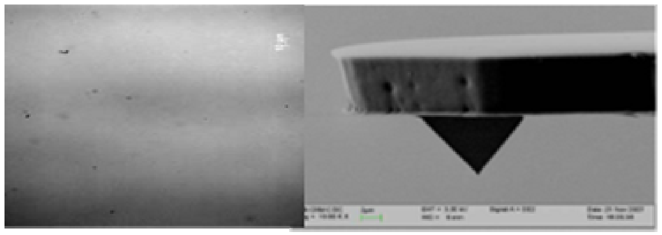
e-beam sensitive polymer



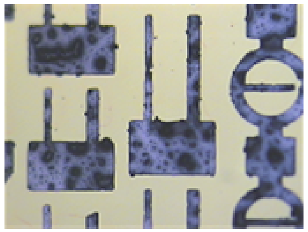
Black coloured polymer



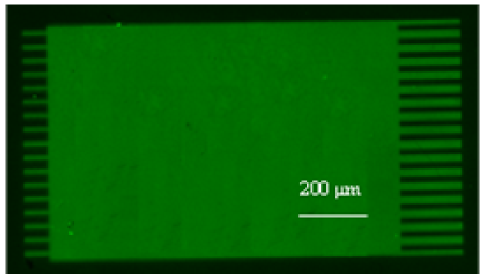
TiO_2 and Fe_2O_3 doped polymer



Carbon doped polymer



Biofunctionalized polymer



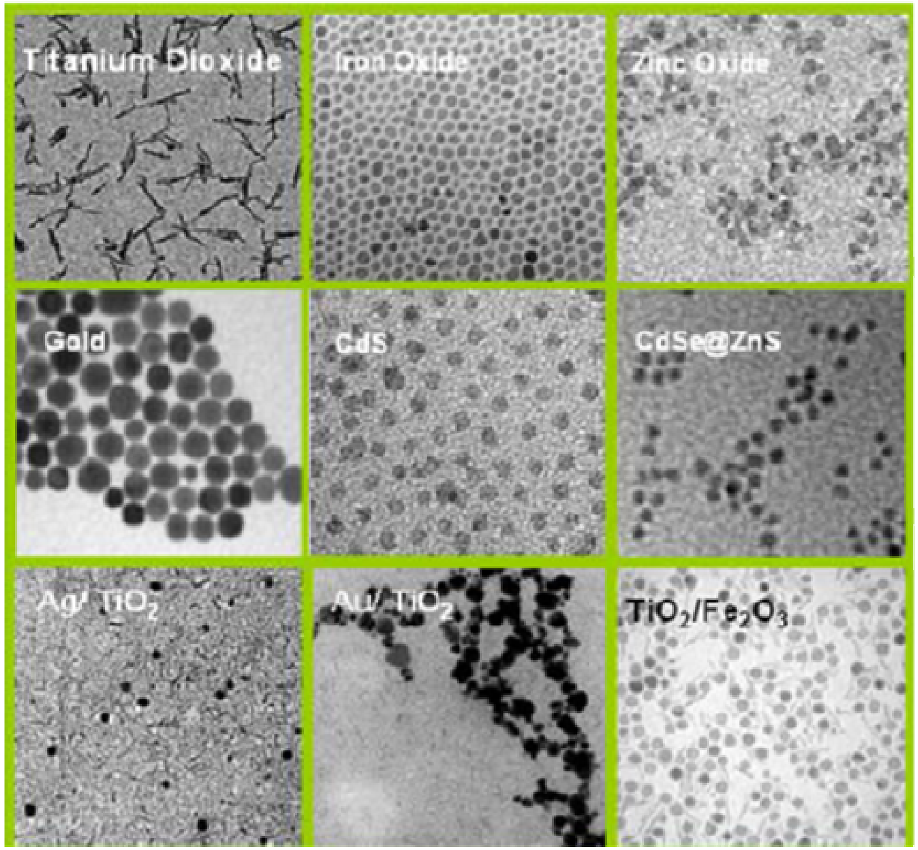
Nanolab CNR IPCF Bari

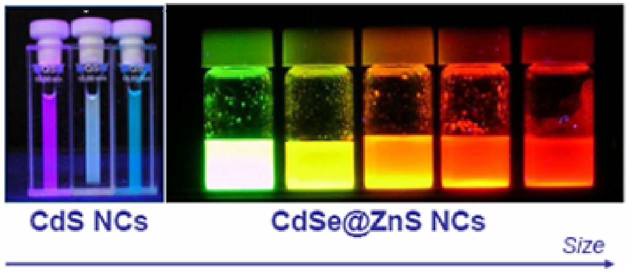
Nanopartice synthesis and functionalization

micro resist technology

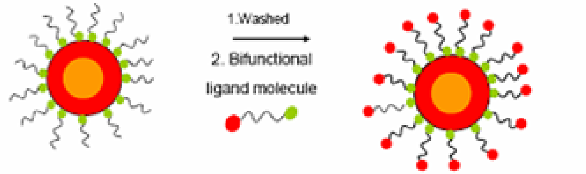
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Synthesis of metal, oxide and semiconducting colloidal NCs

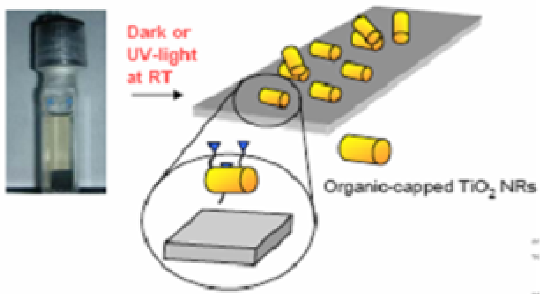




Surface modification of nanocrystals via ligand exchange reaction

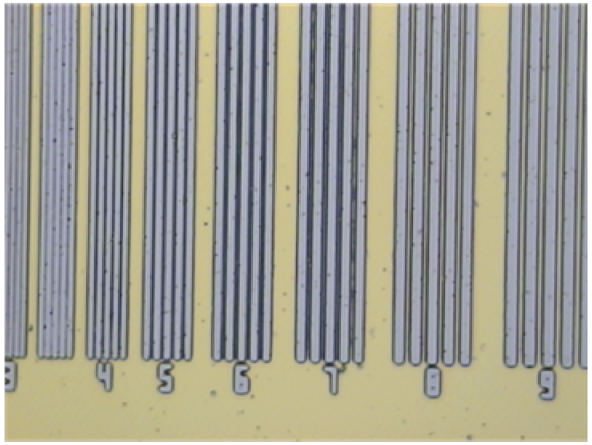


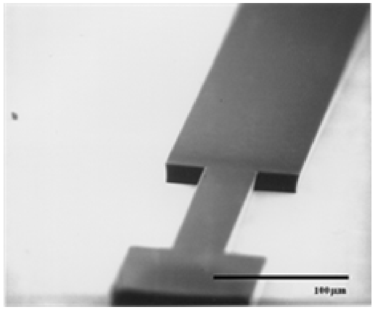
Immobilization of TiO_2 NRs and γ-Fe_2O_3 NCs onto SU8

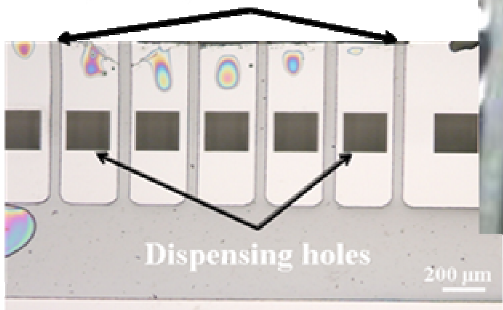


UV patterning of new functional polymeric materials

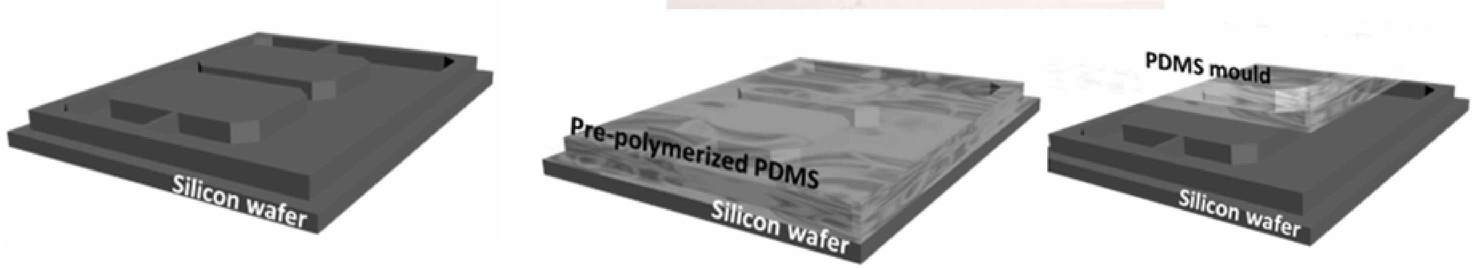
UV processing parameters established for all polymers







Soft-lithography method established

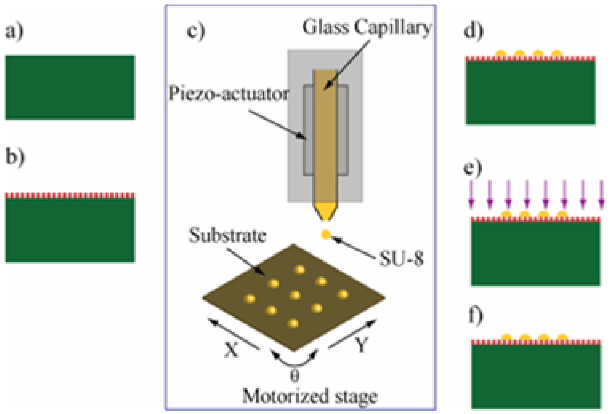


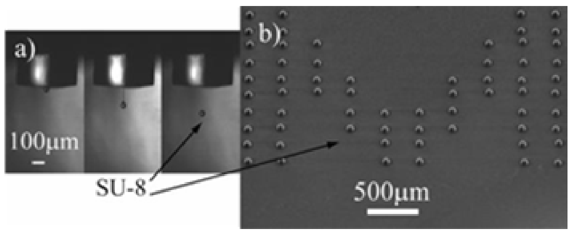
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

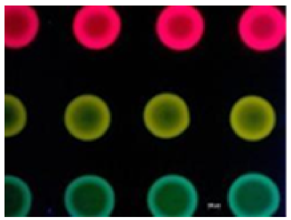
Ink jet printing of new functional polymeric materials

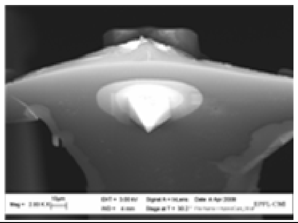
Nanolab CNR IPCF Bari
micro resist technology

Single nozzle

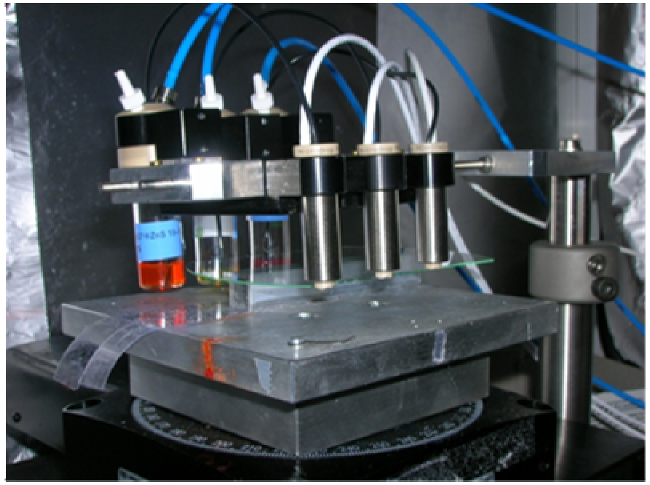


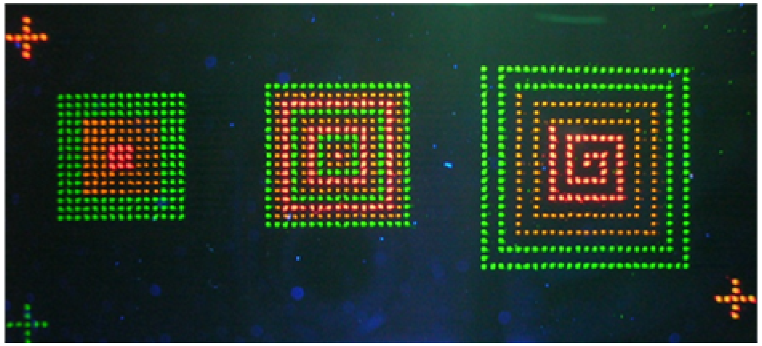






Multiple nozzle





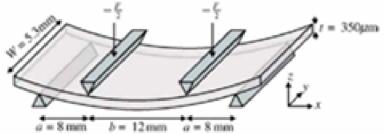
DTU

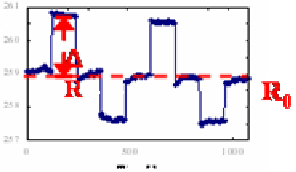
Cantilever sensors made of functional polymeric materials

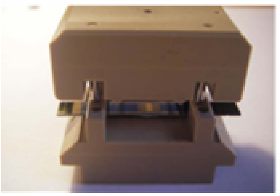
micro resist technology

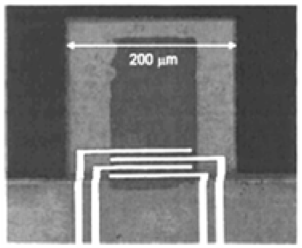
Piezoresistive cantilevers

- ❑ Platform for testing the piezoresistive properties of polymeric cantilevers
- ❑ SU-8 cantilever chips with integrated piezoresistors for detection of surface stress changes
- ❑ Functionalization of SU-8 cantilever surface/Bio-analytical application



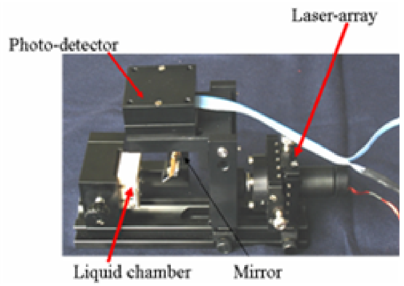


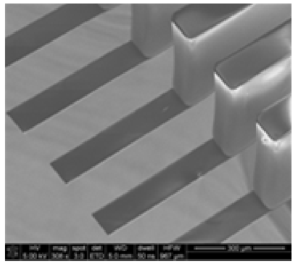


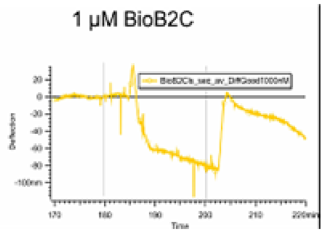


Optical read-out cantilevers

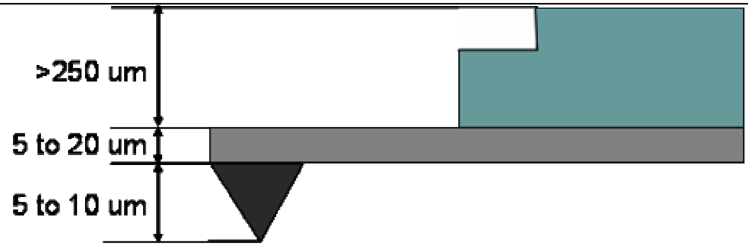
- ❑ Platform for testing the cantilevers
- ❑ Optimization of fabrication
- ❑Deflection assay for DNA hybridization and for Biotin- Streptavidin interaction
- ❑New type of cantilevers for optical read-out: Au padded



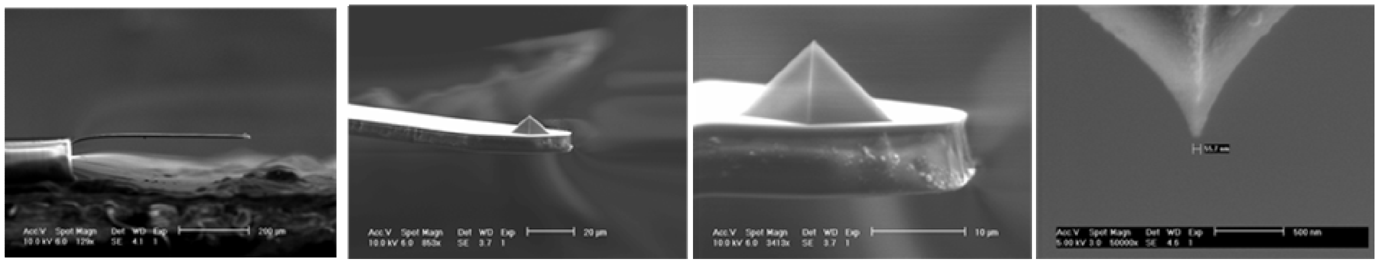


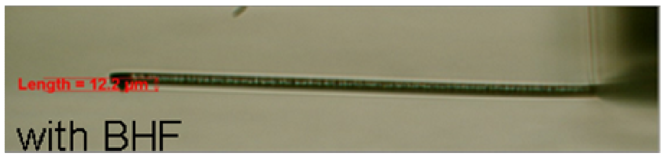


AFM probes made of functional polymeric materials

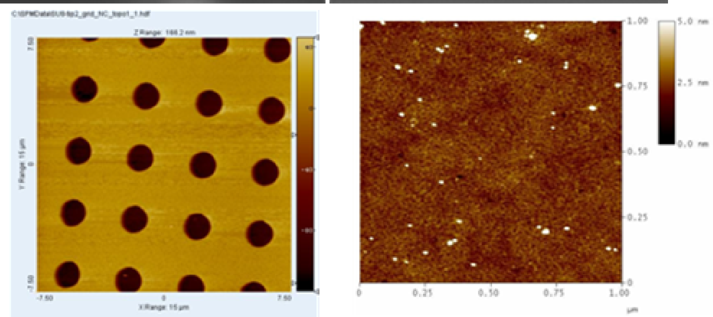


AFM probes with the new polymers succesfully realized





NC AFM images



Optothermal actuators made of functional polymeric materials