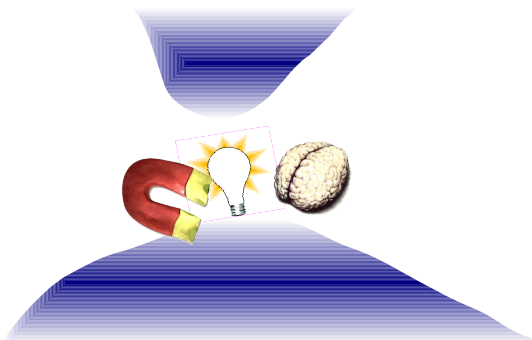


# Advanced Scanning PRobes for Innovative Nanoscience and Technology (ASPRINT)

[www.asprint.sci.kun.nl](http://www.asprint.sci.kun.nl)



on behalf of the ASPRINT team, by Sylvia Speller  
(Institute for Molecules and Materials, University of Nijmegen, 6525 ED Nijmegen, The  
Netherlands, [sspeller@sci.kun.nl](mailto:sspeller@sci.kun.nl))

## **International State of the Art**

Scanning probe methods are at the base of nanoscience and technology. Scanning a sharp probe over the nano-object under study allows for investigations of material properties with nanoscopic, in some cases atomic resolution in real space. Novel nanoprobng methods are mostly derived from scanning tunneling microscopy, atomic force microscopy, and scanning near field optical microscopy. Each physical interaction or effect allows one in principle to develop a new nanoprobng method, but only a fraction of such methods is realized and an even smaller fraction is broadly applicable. Every new interaction and capability (e.g. magnetic, photonic, specific forces, fast, manipulation, etc.) that is realized as nanoprobng method opens up a new field of research and technology.

A number of nanoprobng modes are already working fine, for instance topographies and maps of various structural and chemical properties can be acquired on nano-scale for a number of systems. Also spectroscopy modes like electron spectroscopy and force spectroscopy have become powerful tools for characterization on nanoscale.

Many important cases, like nano-optical imaging, nano-magnetic imaging, soft protein surfaces, very rough solid surfaces, or processes, are excluded or accessible in a limited way only. Also the quantification and reproducibility of current nanoprobng is unsatisfying.

The problem of developing novel nanoprobng modes for all kind of physical properties is involved. On the one hand, often the contradiction has to be overcome that the probe has to be made sensitive for a property, but at the same time it should be non-intrusive. In the sub-nm a theoretical limit is imposed by the Heisenberg uncertainty.

The other kind of problems arises from the unpredictability how a physical property evolves with reduction of size. This makes it difficult to find a system for the demonstration of

a new nanoprobing method. ASPRINT addresses nanoprobing of three important types of properties and phenomena that need to be probed on nano-scale.

### **Objectives, Goals, and Strategies**

To get beyond the state of the art the ASPRINT project is focused on new SPM directions grouped in the three areas:

#### *Nanomagnetic scanning probes*

Magnetism is a fundamental material property, which has a large importance for practical applications. Especially in nano-technology magnetism plays an important role. To name a few examples: - high density recording, both the medium and reading and writing heads; - magnetic random access memories; GMR-effect sensors; - spintronics. In all these examples one needs new tools to study magnetic phenomena and properties at a length scale which is far outside the range of conventional research instruments. In particular important goals are: - sub-nanometer/atomic resolution; - non-magnetic probes for non-intrusive observations; - using SPM-tips to form magnetic nanostructures by atom manipulation and to investigate their magnetic behavior; - decreasing response time of probes to the level relevant for study of high speed data recording devices like hard disk drive recording heads and MRAMs; - getting absolute values for magnetic quantities instead of only magnetic contrast. - demonstrating the new SPM methods by studying technological important materials and devices; - making the methods reproducible, simple, and suitable for an industrial environment.

Concrete modules are:

- Spin-polarized STM in media
- Atomic manipulation and characterization of artificial nanostructures by a spin-polarized scanning tunneling microscope
- Visualization of the high frequency response of magnetic materials, and especially, hard disk recording heads
- Development of nanotemplated oxide surfaces and their studies using magnetically sensitive tunneling probes

#### *Nano-optical scanning probe*

The combination of scanning probe microscopy with an optical contrast mechanism, affording high-resolution spectroscopy and ultra-fast time response, has long been the dream of nano-scientists. This is the domain of *near-field optical microscopy*. The feasibility of near-field optics has been explored experimentally already in the early eighties by funneling light through a sub-wavelength aperture. Yet compared to the enormous impact of AFM and STM the optical alternative has long been struggling with technological obstacles. Through decisive technological achievements, such as the development of adiabatic fiber pulling and shear force feedback, near-field scanning optical microscopy (NSOM) has entered a period with abundant growth with rapidly expanding applications in photonics and material science. Especially the achievement to detect and image molecules using the aperture type near-field method has opened a complete new field of applications in chemistry and biology. Near-field optical microscopes are commercially available yet technology remains critical and specifically probe

fabrication tedious. As a result research has moved into novel probe concepts: field confinement around metallic tips; plasmon field enhancement; transient plasmas; single particles or even single molecules as nanometric light sources, etc.

Concrete modules are:

- Advanced Probes for Near-Field Fluorescence Imaging
- Local optical density of states of photonic structures.
- Spin polarized Scanning Tunneling Induced Luminescence.

### *Smart probing/probes*

Nanoprobng can go beyond just mapping or local spectroscopy of properties. One of the most intriguing sides of nano-probing is exploiting or mapping the spatial variation of an *effect* by a smart probe concept or an integrated probe circuit. Mostly simply *interactions* like force or tunnelling are use to make a probe sensitive for a property, and very seldom physical phenomena or effects themselves are used as a channel to obtain information.

One nice example of a smart probe is extracting physical properties from the fluctuation of electro-magnetic near fields of surfaces. When this works, it will be applicable very generally to a very broad class of materials, including "free" surfaces and buried interfaces.

Special integrated circuits can also be "outsourced" in the control electronics as in the case of video rate SPM, that will serve to meet more the time scales of the processes occurring on the nanostructure and material in general and diminish the stroboscope like character of the acquisition.

Concrete modules are:

- Scanning Fluctuating Electromagnetic Field Microscopy
- Video-rate Scanning Probe Microscopy and beyond
- Smart probes

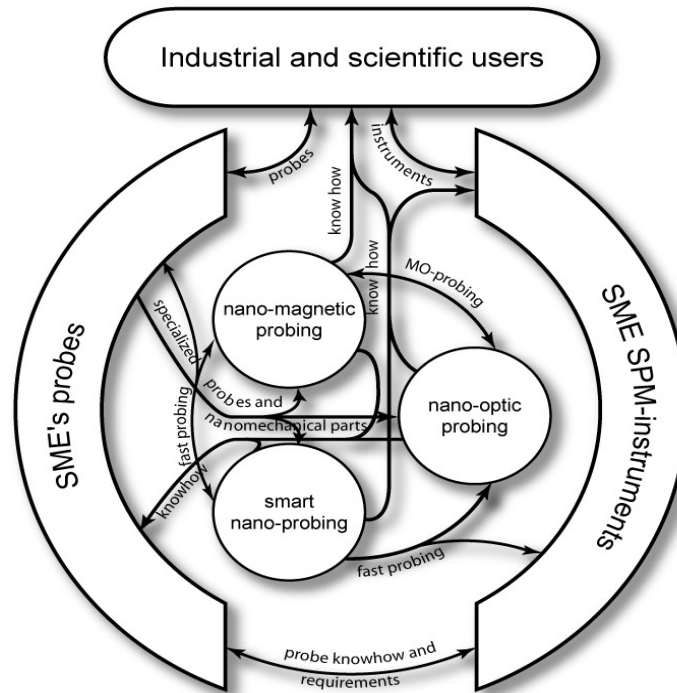
### **Consortium and Skills**

The ASPRINT consortium is composed of 9 research groups and 3 SME's with distinct complementary background in order to optimally address the objectives of the project:

- 4 research groups (P1, P2, P3, P4) focus on nanomagnetics and have a large experience in inventing and refining novel methods to study magnetism with a high spatial resolution down to atomic scale.
- 3 research groups (P6, P7, P8) focus on nano-optics. All three groups are pioneers in the nano-optical field with excellent track records.
- 2 research groups (P5, P9) and 2 SME's (P10, P11) focus on advanced probes and probing (smart probes). Both research groups are pursuing new approaches which will have a high impact and wide general applicability, but also high risk. The beyond video SPM is of importance for all types of scanning probes and will be implemented also in a number of the other developed probes in this programme. The other group aims for a determining the dielectric function at the nm scale, a completely new research tool.

- 2 SME's (P10 and 11) are high technology commercial enterprises specialized in production of, among others, advanced probes. The third SME (P12) produces top of the line SPM instrumentation and is a world leader in the field of research SPMs.

The combination of research groups and SME's is extremely powerful because the research groups can very well invent new advanced probes but the SME's can produce them efficiently and can contribute their extensive expertise. On the other hand, the research groups are well suited to test and characterize new types of probes from the SME's. For the SPM producing SME the same holds but then on the scale of complete instrumentation. This SME plays an important advising role in every workpackage.



### List of Partners

<i>No</i>	<i>Participant name</i>	<i>Participant short name</i>	<i>Responsible</i>	<i>Role</i>
1	University of Nijmegen	KUN	Prof. Dr. Sylvia Speller	Spin-polarized STM in media
2	Universität Hamburg	U Hamburg	Prof. Dr. Roland Wiesendanger	Atomic manipulation and characterization of artificial nanostructures by spin-polarized scanning tunneling microscopy.
3	Universität des Saarlandes	USAAR	Prof. Dr. Uwe Hartmann	High frequency magnetic force microscopy

<i>No</i>	<i>Participant name</i>	<i>Participant short name</i>	<i>Responsible</i>	<i>Role</i>
4	Trinity College Dublin	TCD	Prof. Igor V. Shvets	Preparation and characterisation of novel STM probes and nanotemplated oxide surfaces for nanomagnetic sensing applications.
5	Leiden University	LU	Prof. Dr. J.W.M. Frenken	Video rate SPM and beyond
6	COBRA-Inter-University Research Institute on Optical Communication	COBRA	Prof. Dr. Paul Koenraad	Spin-polarized scanning tunneling induced luminescence
7	Université de Bourgogne	UB	Prof. Dr. Alain Dereux	SNOM tips to selectively observe specific optical near-field effects Fabrication of nanostructures to tailor the optical Local Density of States (LDOS)
8	Westfälische Wilhelms-Universität Münster	WWU	Prof. Dr. Harald Fuchs	Scanning Fluctuating Electromagnetic Field Microscopy; imaging material properties on the nanometer scale
9	MESA+ Research Institute, University of Twente	MESA+ Twente	Prof. dr. Niek F. van Hulst	Development of advanced probes and single molecule imaging of biomolecules. Near-field single molecule detection Fabrication of nano-antenna's, conventional NSOM probes, etc.
10	Nanoworld Services GmbH	Nanoworld	Dr. Thomas Sulzbach	Prototyping and commercial production of advanced magnetic scanning probes
11	Nascatec GmbH	Nascatec	Dr. Tomasz Debski	Developing, prototyping, and producing optical SPM sensors, micromechanics for application in R&D, characterization of surface topography and process control.
12	Omicron NanoTechnology GmbH	Omicron	Dr. Ingrid Oebbeke	SPM consultancy

### **Acknowledgement**

This project is supported by the EU (contract NMP-CT-2003-001601).