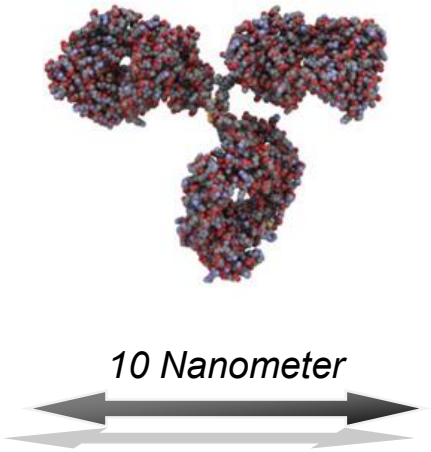
nano3DSense™

Sensor-Platform

The Eye of Nanotechnology



Pioneering 3D Printing for Force Sensors with Nanometer Precision

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Content

Introduction

Dear business partners,


Dr. Alexander Kaya, General Manager & Founder

The so-called “top-down” approach has dominated the microsystem and semiconductor technology as it is used today in the manufacturing of electronic circuits for more than five decades. The demand for higher throughputs for cost-effective quantities has been continuously increasing and has decisively changed our life.

With an extensive drawback for the coming years: More than 250 sophisticated process steps in cleanroom technology are required – from idea to finished circuit – to provide high level micro components, such as sensors, in ensured quality and quantity.

So far, compromises and trade offs as well had to be made with respect to customized solutions and efficiency in the case of highly specialized tasks. Nevertheless our customers demand flexible systems which quickly adapt to R&D as well as to production cycles. In contrast current methods function profitably only, if they are driven by rigid high throughput silicon techniques. For this reason, they can only slowly respond to quickly changing boundary conditions and customer requirements. Every, even tiny, modification in design or layout usually means additional time consuming production cycles, often of several weeks. With extra costs or devastating results for the entire planning. Therefore to overcome the increasing pressure for shorter development times and quickly changing product generations, as e.g. established in entertainment electronics nowadays, highly flexible and efficient rapid prototyping methods will give the best solutions.

NanoScale Systems (Nanoss) GmbH uses a radically new approach to meet these challenges with unmatched performance. With 3D nanoprinting we venture the next step into miniaturization: once again we shift the traditional limits and boundaries for microstructures. We also say good-bye to classic silicon, which is commonly considered to be today’s inert base material for microsystem technology. With our patented **nano3DSense™** technology, for the very first time we successfully found a way to close the long-lasting gap between price-sensitive high throughout (top-down) and individually tailored solutions with added value.

In contrast to these classic methods, **nano3DSense™** is a revolutionary single-step process, which allows to completely bypass time consuming multiple cleanroom procedures, such as mask and silicon techniques. With **nano3DSense™** technology, a dedicated single processing step, the innovating 3D printing method, is used for micro structuring instead: with unsurpassed nanometer

precision, fast, and cost-efficient.

The new 3D printing with **nano3DSense™** can be used e.g. for highly customized sensors and sets a new benchmark for today's measuring technology in many areas: For the first time, powerful force and strain sensors can be directly printed on a great variety of materials with a previously unknown degree of flexibility. There, they can immediately be used for manifold measurements in highest quality. 3D printing with **nano3DSense™** offers an unbeatable advantage in efficiency and adaptability when it comes to enter unknown territories and discover groundbreaking solutions in R&D and production.

An example is the development of new biocompatible medical sensors for blood pressure and force measurements in the human body. Another example is the application of new methods in chemical and biological analytics, such as the label free detection of antibodies in real time or fast and compact atomic force microscopy (AFM), e.g. for cell analytics and force spectroscopy:

When implementing your ideas in the micro word, we all jointly enter into new territory.

Please feel free to contact me for our help and support.

Your Alexander Kaya

General Manager and Founder, NanoScale Systems GmbH

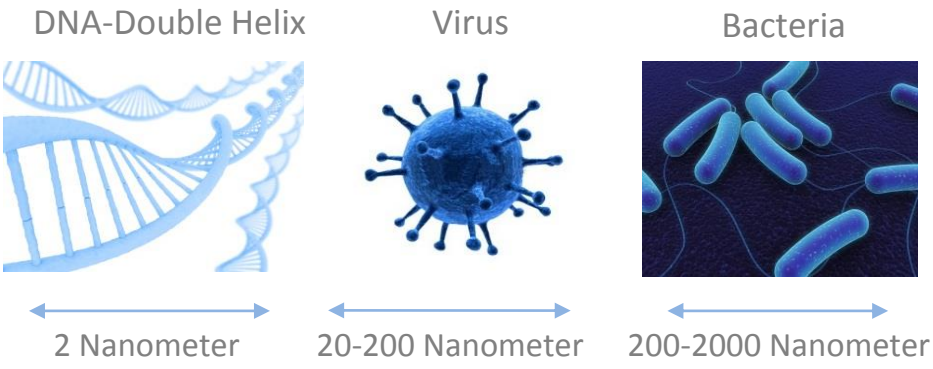
Alexander.Kaya@nanoss.de

Force Sensors

The challenges in Current Force Measuring Technology

Numerous measuring and detection methods in life sciences, medical technology, analytics, diagnostics, and microbiology use simple force measurements. In the case of atomic force microscopy (AFM), biological or chemical analytics, and the detection of antibodies, cell analytics, force spectroscopy, or biocompatible long-term implants: When entering new territory in the micro world, the focus is on **miniaturization and adaptivity**.

The challenges on the measuring technology increase significantly with progressing miniaturization. If such devices are miniaturized to the nanometer level of several hundred nanometers (nm) only, they are referred to as extremely compact **MEMS/NEMS (Micro/NanoElectroMechanical Systems)**.



nano3DSense™ Sensor-Platform

The Limits of Conventional Methods in Industry and Research

Conventional devices for force measurements, such as **laser, piezo resistors, or capacity sensors**, quickly reach their limits in the case of highly miniaturized MEMS/NEMS applications, often already at dimensions below 20 microns (µm) (1 µm = 1000 nanometers).

In **atomic force microscopy (AFM)** e.g., the diffraction limit of the laser, which cannot become smaller than 1.4 µm (HWFM, "Half Width at the Full Maximum"), already represents a natural barrier for further miniaturization of optical probes.

The situation is similar for other force sensors, such as piezo resistors. As they require sophisticated cleanroom and doping processes, the miniaturization potential is often already exhausted at dimensions of 20–50 µm.

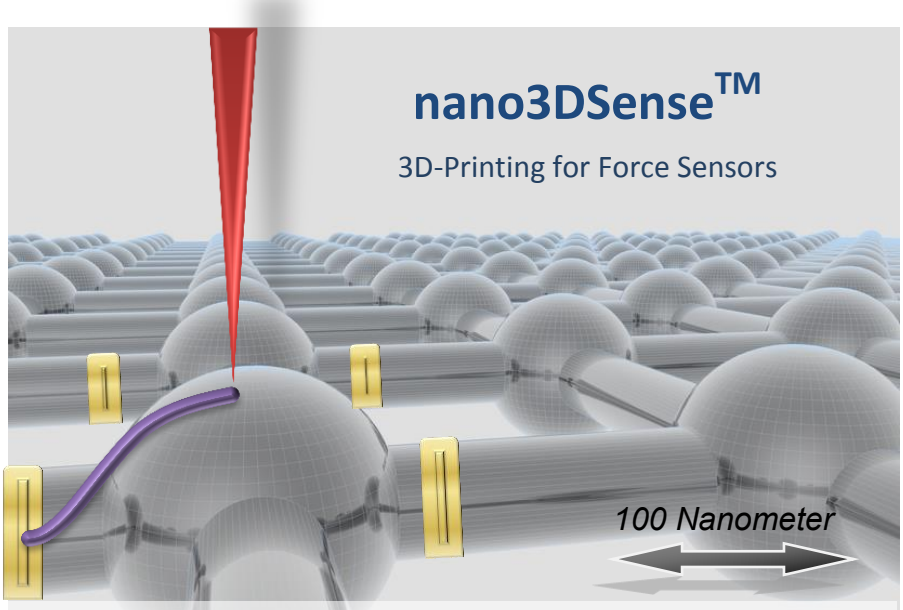
nano3DSense™

Smallest Force Sensors Worldwide

The next generation of force and strain sensors

nano3DSense™ was especially developed with the goal to eliminate the limits in the micro world, which have existed for decades, and to provide more flexible as well as more sensitive measuring methods for force sensors.

And this in the most effective way possible: Using **nano3DSense™**, sensors are for the first time directly printed **using 3D printing** – with nanometer precision and on almost all material substrates!



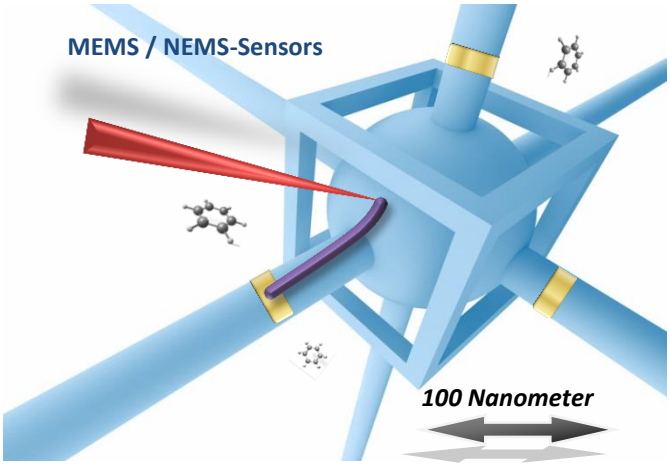
Printable Sensors with Nanometer Precision

nano3DSense^{TM} Sensor-Platform

New Standards

Our company sets new standards with unrivaled miniaturization capabilities and flexibility advantage. And this even under difficult material and measuring environment conditions. Contrary to traditional sensors, our sensors adopt to the measuring requirements. And not the other way around!

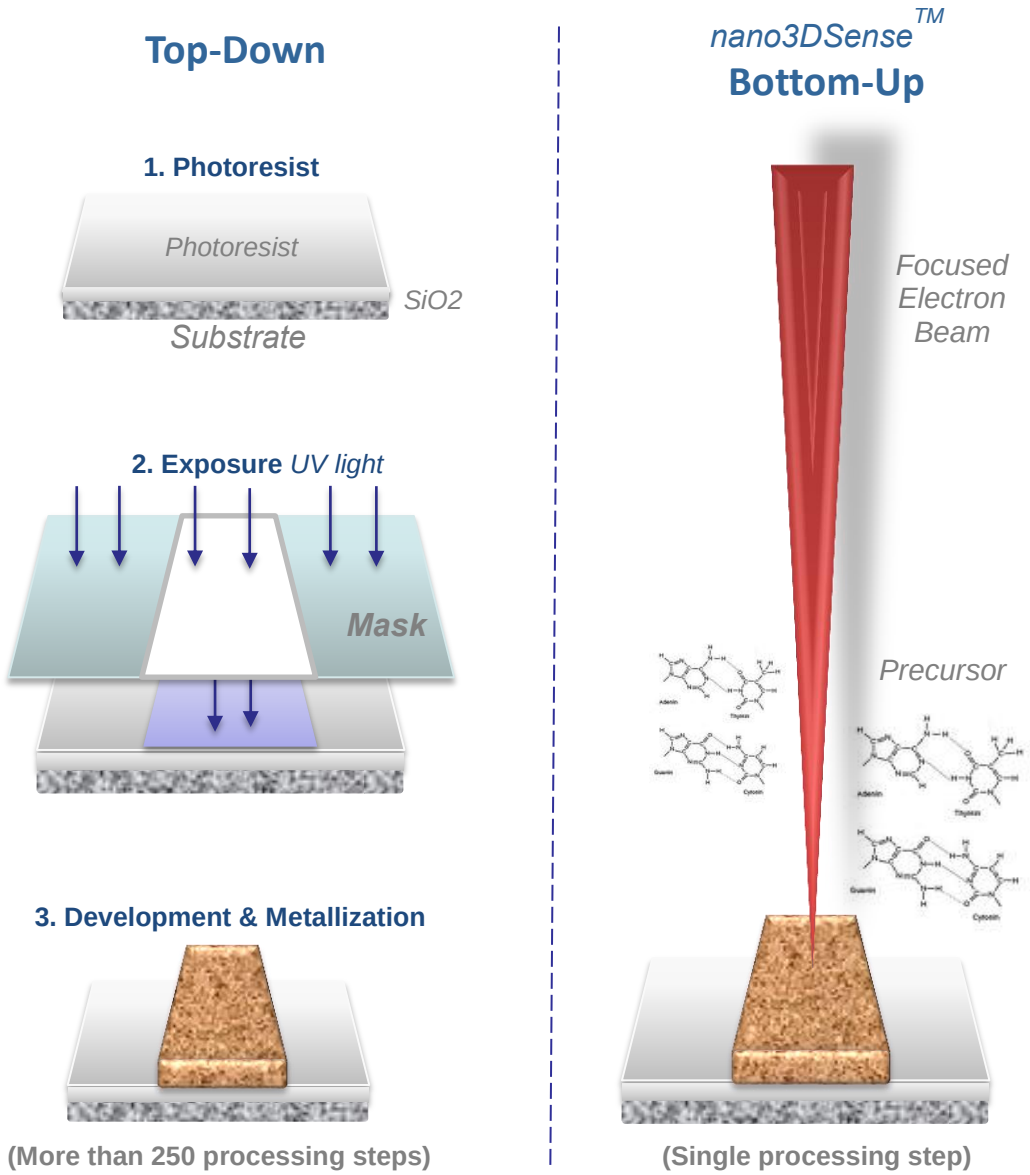
This technology can be used for **force, pressure, acceleration, or torque measurements**, e.g. in medical technology, robotics, and in the aerospace and automotive industry. A single technology platform offers multi-functional solutions for industry as well as demanding R&D tasks if uncompromising requirements are placed on precision and adaptivity.



3D-Nano Printing

How does 3D Nanoprinting for Sensors Work?

nano3DSense™ is a new generative (bottom-up) production technology, which enables seamless printing of microelectronic components, such as force and strain sensors, onto customer-specific material substrates with nanometer precision. In contrast to the classical semiconductor procedures (top-down), with **nano3DSense™** no error-prone lithography technologies or costly cleanroom processes are needed.



Comparison of the two dominant approaches in microsystem technology. Left side: "Top-down" in traditional semiconductor industry. Right side: New 3D printing using "bottom-up" (**nano3DSense™**) eliminating more than 250 process steps.

nano3DSense™ Sensor-Platform

Rapid Prototyping

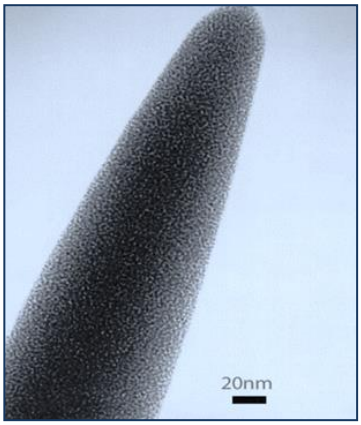
More than 250 Process Steps can be Eliminated

Bypassing many complicated cleanroom processes, our electronic components are for the first time directly printed onto the desired material substrate, such as steel, plastic, oxides, etc., using a novel process, and are there immediately available for further use.

More than 250 complex process steps in cleanroom technology are eliminated and the overall production cycle drastically simplified. This new flexibility enables e.g. the fast and cost-effective implementation of customer-specific small series or of highly customized **rapid prototyping** requests.

Radically New Measuring Principle

For the first time worldwide, a **radically revised sensor principle** with improved properties is used for the **nano3DSense™**. Nano crystalline composite materials, so-called nanocomposites, are used for force and strain measurements of electronic components. In addition to improved performance characteristics, e.g. measuring resolution, linearity, and long-term stability, we have also fundamentally redefined the application spectrum of today's force sensors.



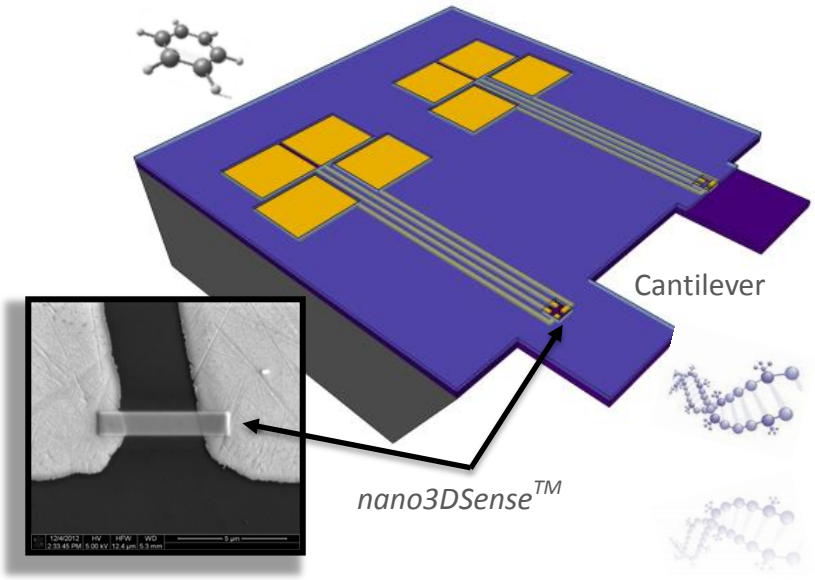
Nano crystalline sensor composite material (nanocomposite) produced using **nano3DSense™** nanoprinting

3D-Nanoprinting in an advanced electron microscope (SEM)

Force Measurements

How Does the Force Measurement Using nano3DSense™ Work?

The figure illustrates the simple functional principle for force measurements using **nano3DSense™** on the example of **micro-fabricated mechanical cantilevers**: The force sensor is shown in the enlarged section, at the bending edge of one of the two cantilevers with maximum force application. In the case that the substrate bends, e.g. caused by mechanical pressure or tiny molecular forces, an electrical signal is generated in the sensor, which is proportional to the force application and can be read out using standard electronics.



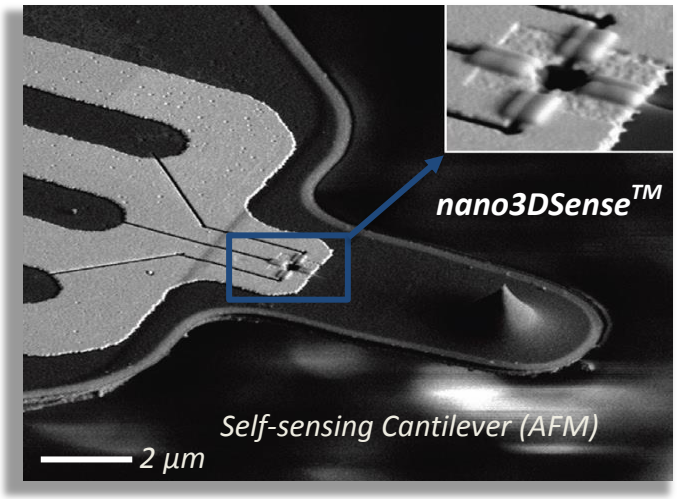
Functional principle of the force measurement on a microchip with cantilevers using a sensor printed onto the substrate using **nano3DSense™**.

nano3DSense™ Sensor-Platform

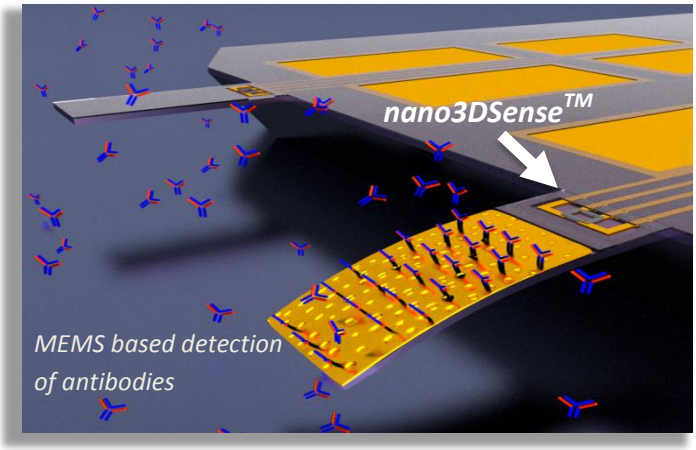
Printable Sensors

Using the patented **nano3DSense™** technology, sensors are for the first time easily printed with nanometer precision on almost all material substrates and surfaces, such as MEMS/NEMS components and are there immediately available for powerful force measurements. All substrates made of e.g. silicon, oxide, plastics, polymer, steel, ceramics, and more are suitable.

nano3DSense™ adapts seamlessly and in the best possible way to every MEMS/NEMS environment and offers a positioning accuracy on the substrate of less than 5 nanometers for sensor dimensions down to 10 nanometers (if needed). This is a world record! The sensor is accurately applied at the point, where forces and other measuring variables are actually generated or must be measured. Unlike in the case of e.g. piezo resistors or strain gauges, no interfering intermediate layers or complex bonding or joining technologies are required anymore.



Self-sensing AFM cantilever with integrated **nano3DSense™** force sensor as full bridge. (FP7-Projekt ALBICAN/FALCON)



Cantilever for the label free and fast detection of antibodies, gases and much more

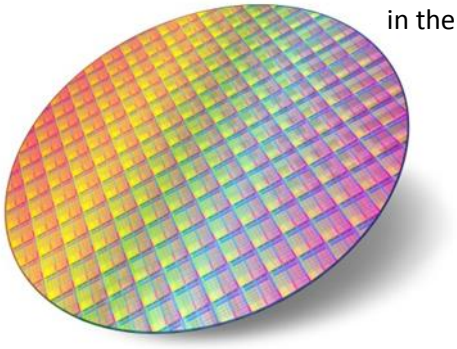
nano3DSense™ Sensor-Platform

Features

Discover the Unparalleled Maximum of Precision and Flexibility

nano3DSense™ is an highly customizable platform for force and strain sensors suitable for a broad range of applications. For the first time challenging measuring tasks in industry and R&D can be mastered in an unmatched simple manner. Discover the unique advantages of **nano3DSense™** for your own applications using this groundbreaking new approach:

- First available and exclusive 3D printing with nanometer precision for the production of force and strain sensors
- Unrestricted freedom in all three spatial dimensions (3D) of the sensor
- Applicable to almost all force substrates, such as ultra-compact pressure membranes, cantilevers, and other MEMS/NEMS components
- Free material selection for the force substrate, e.g. silicon, silicon nitride, SU8, plastics, polymers, glass, ceramics, steel, metals, etc.
- Extremely compact dimensions of the force substrate, such as cantilever or membrane, if needed even < 1 µm, for material thicknesses down to < 100 nm
- Sensor size can be continuously varied from 10 nm to 100 µm
- Sensor positioning accuracy on the force substrate down to < 5 nm
- Simple electrical sensing/output signal
- Excellent linearity behavior with high long-term stability and service life
- Low power consumption and small electrical resistance
- Direct measurement of forces, pressures, strain, torques, etc., with nanometer precision at the point of the force cause, without complex intermediate layers or joining and bonding technologies
- Effortless use in difficult measuring environments, e.g. in biocompatible media (cell and blood tissue), aggressive solutions, vacuum, at high or low temperatures, and at points and edges with geometrically difficult access
- Maskless production method without expensive cleanroom technology, advantageously usable for tailored rapid prototyping in R&D or dedicated series production, e.g., for highly profitable small series with constantly changing parameters and boundary conditions in the production sequences



nano3DSense™ Sensor-Platform

Innovation and Multi-Functionality

Focus on Your Ideas

nano3DSense™ provides an innovative and unique approach to cost-efficiently and quickly create innovations: Many tasks, which previously could not be completed using conventional methods or only with great efforts, can be advantageously solved using **nano3DSense™**, e.g. in the following areas:

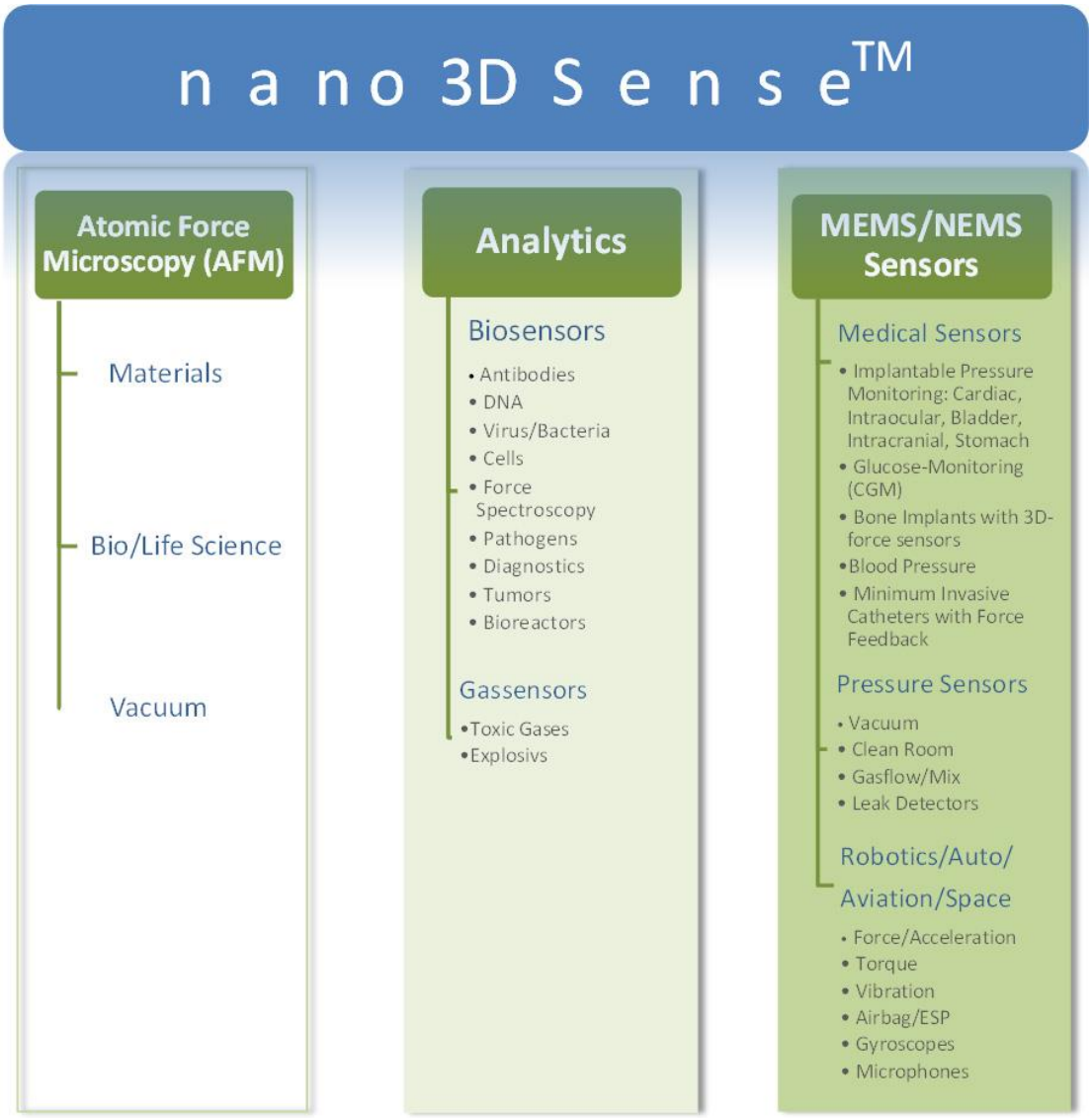
- **Calibration- and laser-free atomic force microscopy** (AFM) using self-sensing cantilevers. E.g. for fast imaging or simple AFM integration into microscopic instruments, such as scanning electronic microscopes (SEM) or optical microscopes
- Analytics and/or diagnostics, e.g. for **label-free detection of antibodies in real time**, as powerful alternative to the ELISA test, for viruses, bacteria, fungi, tumor diagnosis (leukemia, prostate cancer), cell analytics, food analytics, or bioreactor monitoring
- **Minimum-invasive and biocompatible medical sensors**, for implants, catheters, and pressure sensors, miniaturized defibrillators (ICD), glucose measurements (CGM), etc.
- Chemical sensors for the detection of hazardous gases, explosives, etc. for monitoring in personal protection and homeland security
- **MEMS/NEMS** sensors for various force, pressure, acceleration, torque, or vibration measurements, e.g. for robotics, UHV vacuum measuring technology, lab-on-a-chip, aerospace and automotive industry

nano3DSense™ Sensor-Platform

The new nano3DSense™ – Sensor Platform

Any Questions? Would You Like to Learn More About Our Technology?

A single technology platform offers multi-functional solutions for highest requirements on micro and nano sensors. Find out about the various options of the **nano3DSense™** technology – also for your applications. We are looking forward to advice and support you in the migration of existing sensor systems, and to help you in the realization of your own ideas, from initial planning to the finished product.



Further Information

- www.nanoss.de
- "A Tunable Strain Sensor Using Nanogranular Metals", Sensors 2010, 10(11), 9847-9856 (C. Schwalb et al)
- www.falcon.freesponsible.info
- www.development.freesponsible.biz

nano3DSense™ Sensor-Platform

Tailored Solutions

What We Can Do for You

The importance of force sensors in life science, biotechnology, medicine, pharmaceutical and chemical industry, and material analysis is rapidly increasing. Whether in research and development (R&D) or in industrial engineering, we offer tailored solutions e.g. within the **scope of collaborations** or on your behalf, which cannot be provided anymore using traditional microsystem technology methods or only with great efforts.

Ultra-Compact Production Process in Revolutionary 3D Printing

Consequently avoiding traditional semiconductor and silicon technology methods (such as photo masks, resists, and cleanrooms), **nano3DSense™** allows us to bypass complex and expensive production steps for microelectronic components and to revolutionize the entire production cycle. 3D printing was mainly developed to overcome the inert barriers of traditional microsystem technology and to provide fast and cost-effective production processes.

Research and Academics

We provide our knowhow as input into short-term or long-term research and academic projects. In this context, we offer strictly confidential individual services for your research work, as well as collaboration possibilities, e.g. in R&D projects.

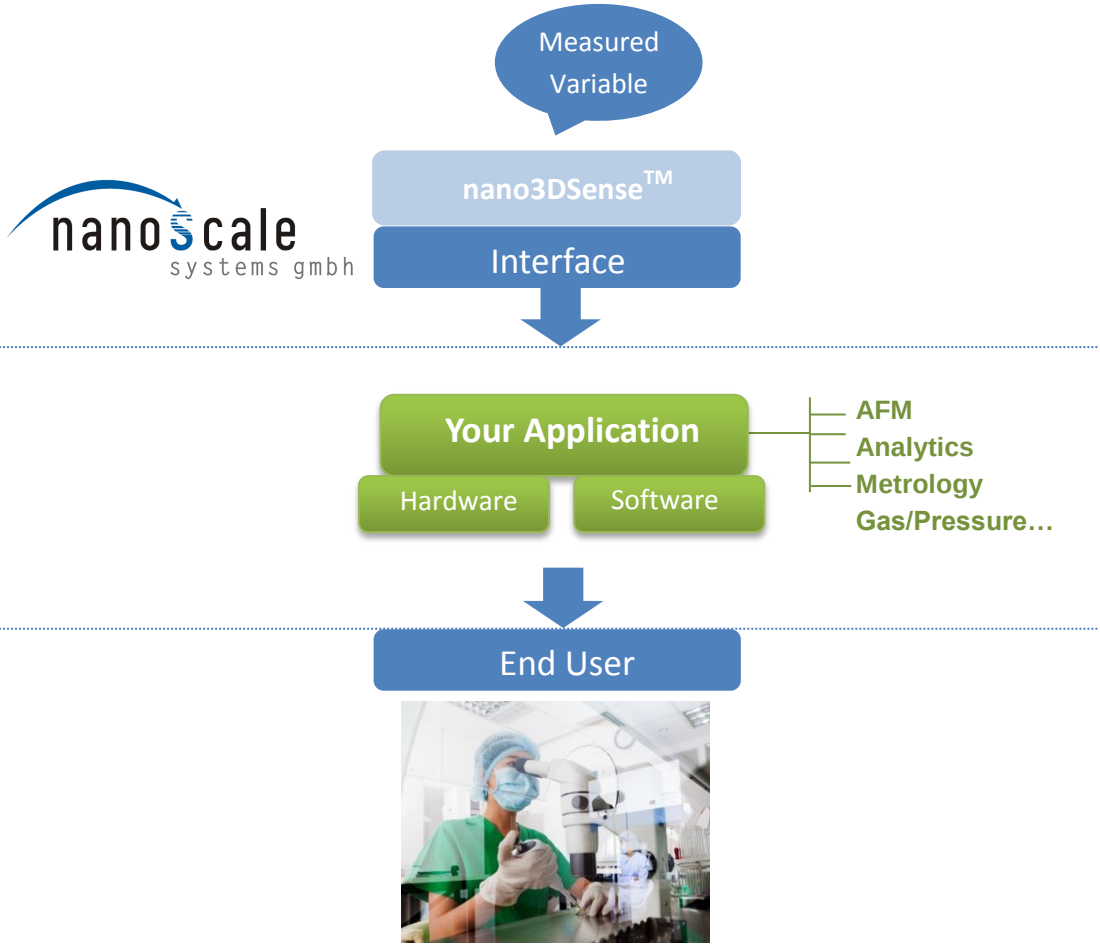
nano3DSense™ Sensor-Platform

Your Decision

Migration to the Patented nano3DSense™ Platform

We provide manufacturers and developers of equipment and measuring devices in the mentioned sectors individual migration and upgrade services to the new independent **nano3DSense™** platform for their existing systems (e.g. laser-optical, piezo-resistive, capacitive, or piezo-electrical methods). In particular in the case of systems, which are still based on optical sensing methods (e.g. AFM or ELISA) and require complex precision mechanics with high calibration effort, a real innovative and performance boost can be generated via a dedicated migration to the new compact **nano3DSense™** platform.

Please contact us: We support you in the analysis of your migration options or ideas and provide information on how you can achieve the greatest possible benefits for your applications. The patented **nano3DSense™** technology offers the flexibility of individually and cost-consciously addressing even “exotic” customer requirements.



Migration to the nano3DSense™-Platform

nano3DSense™ Sensor-Platform

NanoScale Systems (Nanoss) GmbH

Leading in Force-Based Nano Sensors

NanoScale Systems (Nanoss) GmbH was founded in March 2005 as a spin-off of the Johann Wolfgang Goethe-University Frankfurt am Main/Germany. The company has more than 20 years of experience in software-control production of nanostructures as well as the market introduction of new product generations in the area of nanotechnology, microsystem technology, semiconductor technology, and surface technologies. NanoScale Systems GmbH is the leading and only manufacturer of force-based nano sensors using innovating 3D printing via electron beam.

With our patented 3D printing platform **nano3DSense™**, we offer equipment manufacturers and R&D groups a radically new concept for dedicated force and strain sensors with a wide application spectrum. With the consequent merging of conventional semiconductor methods (“top-down lithography’) and flexible “bottom-up” technologies, we provide new tools for rapid prototyping as well as object visualization and measurement down to the molecular scale to our customers. As protagonists and pioneers of silicon-free microelectronics, we serve central technology sectors in life science, medical technology, microbiology, and many other MEMS/NEMS sensor areas, which cannot be served anymore using traditional methods or only with great effort.

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