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Nanoparticulate Systems: A New Competence Platform at the University of Applied Sciences Northwestern Switzerland (FHNW)

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Abstract: Nanotechnology in general and nanoparticles in particular are receiving increasing attention because of their almost unlimited possibilities and applications. In the group of Nanotechnology of the Institute of Chemistry and Bioanalytics of the University of Applied Sciences Northwestern Switzerland (Fachhochschule Nordwestschweiz), a new nanoparticle technology platform has been developed. The main research axes concern silica and self-assembled nanoparticles, and their applications in life sciences. The laboratory is equipped with state-of-the-art spectroscopy and microscopy tools.

Keywords: Atomic force microscopy · Calix-arene · Nanoparticle · Scanning electron microscopy · Silica

Introduction

Nanotechnology in general and nanoparticles in particular are receiving increasing attention because of their almost unlimited possibilities. Applications ranging from optical coatings to biomedicine through a variety of areas such as electronic devices production, energy storage, personal care, *etc.* have already reached the market and one could expected that numbers of new applications will be found.

The definition of the word 'nanoparticle' is still a matter of debate and the commonly accepted version defines them as particles having a size in the nanometer range. Therefore, one could assume that particles having a size between 1 nm to 1 µm could be considered as nanoparticles.

Nanoparticles are mesoscopic systems, bridging the gap between atomic or molecular materials and bulk structures.[1] As a matter of fact, the properties of these nanostructures are often different from the bulk material and, for example, some physical phenomena such as quantum confinement,[2] surface plasmon resonance[3] or superparamagnetic[4] properties have been observed for nanoparticles whereas the bulk material does not exhibit these properties.

The group of Nanotechnology of the Institute of Chemistry and Bioanalytics of the school for Life Science of the University of Applied Sciences Northwestern Switzerland is headed by Prof. Uwe Pieles. Initially, the research focus of the group was oriented towards surface chemistry and analysis but since a couple of years new competences in nanoparticle synthesis and characterization has been developed. The focus is done mainly on two classes of nanoparticles: silica and solid lipid nanoparticles.

Research Orientations

Inorganic Nanoparticles: A Versatile Building-block for Nanotechnology

Silica nanoparticles represent maybe the most versatile class of inorganic nanoparticles (Fig. 1). They can be produced with a fine control of structure, size, porosity, surface chemistry and labeling. In the laboratory, silica core-shell nanoparticles have been produced with a ruthenium-based label and have been shown to be suitable candidates for following intracellular uptake in living cells and are expected to be used as a basis to design new target-specific drug delivery systems.[5] More recently, the group has started a partnership with the group of Prof. P. Corvini from the Institute of Ecopreneurship of the FHNW to use silica nanoparticles as models to investigate the fate and the eco-toxicity of nanotechnology-based systems in the environment.

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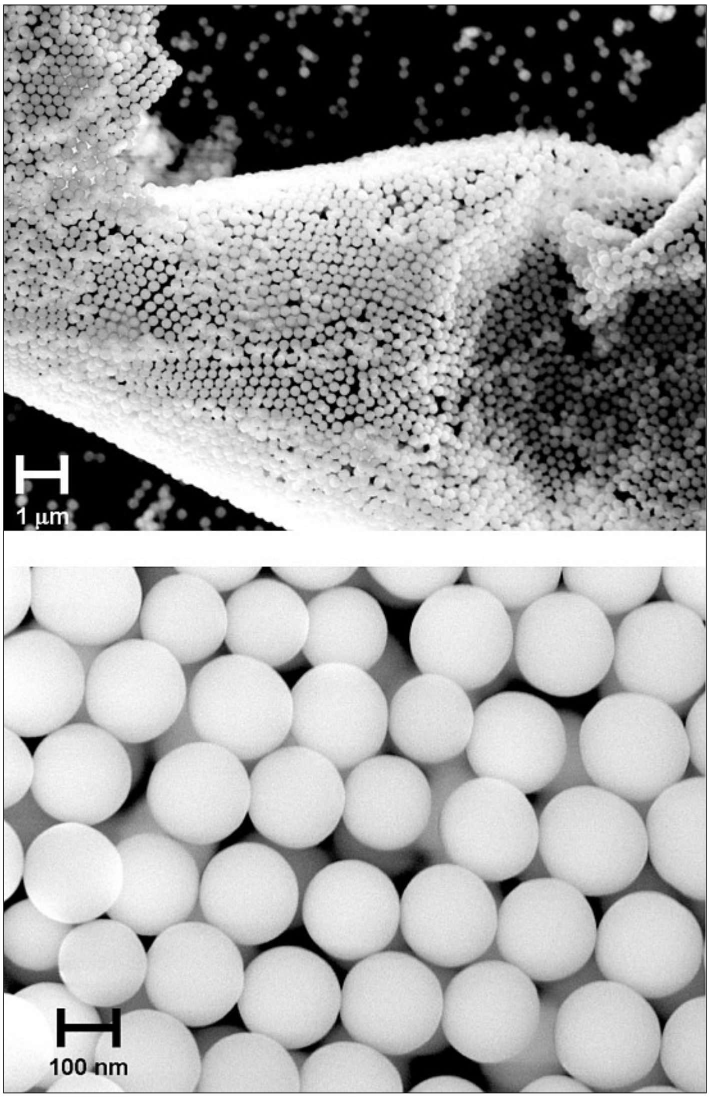

Fig. 1. Scanning electron microscopy images of silica-based nanoparticles

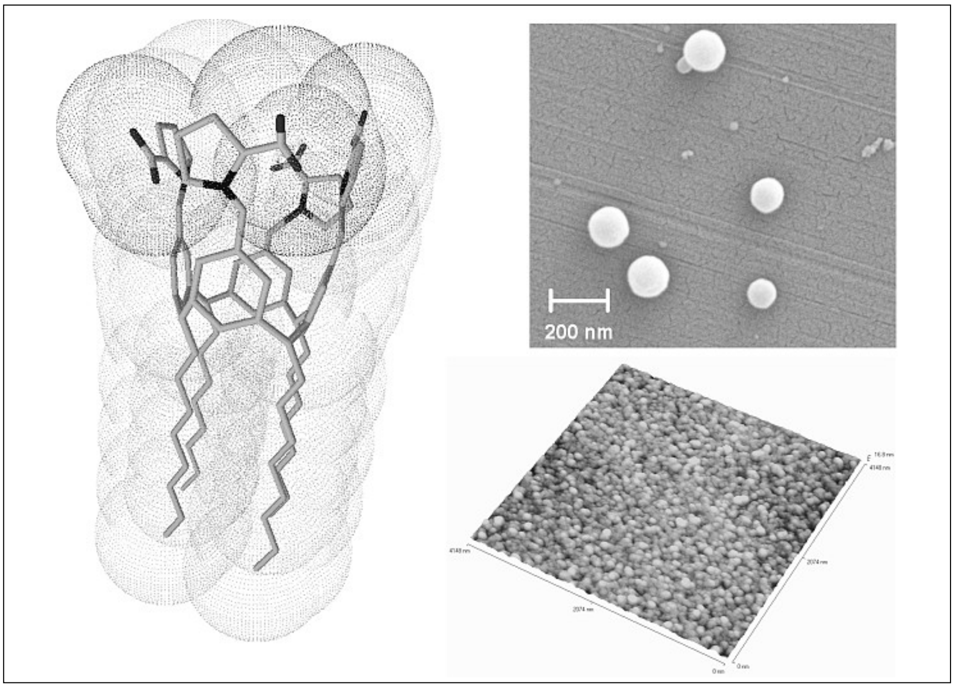

Fig. 2. Chemical structure of a (N-methyl-propyl)-tetra-undecylcalix[4]resorcinarene (left) and the derived produced SLNs images by scanning electron microscopy (top right) and atomic force microscopy (bottom right)

Solid Lipid Nanoparticles: Potential Drug-transporting Systems

Solid lipid nanoparticles are self-assembled systems formed by the self-organization of amphiphilic molecules in water. They aim at transporting pharmaceutically active molecules to their therapeutic target in order to improve the efficiency of the treatment and to decrease the associated side-effects. In addition to a large variety of natural lipids available for forming these carriers, new classes of synthetic lipids have been developed in order to improve the efficiency of these systems. Among them, a new class is based on calix-arenes. Calix-arenes are synthetic macrocyclic molecules, produced by the base-catalyzed reaction of formaldehyde and *para*-substituted phenols. Their conical shape, their relative ease of chemical modification and their high propensity to crystallize have been shown to be key parameters for the development of calix-arene based amphiphiles,[6] and their applications in supramolecular chemistry.

In the recent years, we have developed new amphiphilic resorcinarenes and have demonstrated that they possess remarkable molecular recognition properties[7] and can be self-assembled as solid lipid nanoparticles which can be further modified at their surface in order to introduce (bio) chemical functions for drug targeting (Fig. 2).[8] Indeed, a calix-resoricanerene based amphiphiles, bearing proline functions, have been self-assembled as stable solid lipid nanoparticles, which have been further modified at their surface with a protein, which stays in its native form and can be further recognized by its specific antibody. More recently, we have developed SLNs based on an amine modified calix-arene and have demonstrated that this molecule and the corresponding self-assembled systems are capable to interact with DNA.

Equipment

In addition to state-of-the-art synthetic and analytical facilities, the laboratory of nanotechnology is equipped with cutting-edge microscopy and spectroscopy techniques.

Spectroscopy

The laboratory is equipped with spectrometric methods for particle size measurements:

Laser Diffraction: This technique is based on the possibility to describe using mathematical models the diffraction of a laser light by (nano)particles in suspension in a solvent or in air. The system used (HELOS®, Sympatec GmbH) can measure particles in suspension in a solvent or dried, from sizes ranging from 0.1 to 8750 µm in diameter.

Photon correlation spectroscopy (PCS) or Dynamic light scattering (DLS): This technique is based on the possibility to correlate the hydrodynamic properties of particles in suspension to their size. It is a powerful tool to investigate the size of nanoparticles in solution and is complemented on the used set-up (Zetasizer Nano ZS, Malvern Instruments) by the possibility to measure the net surface charge of the particles (ζ-potential) taking advantage of their electrophoretic mobility.

Microscopy

"Seeing is believing…" Even if spectrometric methods for measuring particle size are very powerful, working with particles having a very broad size distribution or a non-circular shape may result in erroneous measurements. Therefore, microscopy methods that enable the direct visualization of nanoparticles are of great interest. The equipment available in the laboratory includes a scanning electron microscope (SEM), an atomic force microscope (AFM) and confocal microscopes. Scanning electron microscopy allows a very precise imaging of nanoparticles in the dried state. The system used (Supra 40V system, Carl Zeiss, Switzerland) is based on a field emission SEM column allowing ultra-high resolution and variable pressure mode imaging; it is complemented by an energy dispersive X-ray analysis system (EDX) for the chemical characterization of the samples. In addition, as some systems such as self-assembled nanoparticles are vacuum-sensitive, AFM is better adapted to their study. The laboratory is equipped with a NTegra Prima system (NT-MDT, Moscow, Russia) allowing high resolution scanning probe imaging. Additional equipments include a confocal laser scanning microscope for surface studies (LEXT, Olympus, Switzerland), a confocal laser scanning microscopy for biological samples (LSM 510 Meta, Carl Zeiss, Feldbach, Switzerland) and a mini TOF-SIMS system (Millbrook instruments, Millbrook, UK).

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