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NaNaX 2: A Conference Devoted to "Nanoscience with Nanocrystals"

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From January 7–10 this year, the conference "NaNaX 2 – Nanoscience with Nanocrystals" took place in Grenoble-Autrans in France (see Figure 1 and also the conference homepage: http://www-drfmc.cea.fr/spram/nanax2/). The objective of this conference was to bring together scientists who are active in the emerging field of nanoscience with a particular focus on colloidal semiconductor and metal nanoparticles and their applications in chemistry, physics, biology, and information technologies. The main topics of this conference comprised 1) chemical synthesis, shape control, and surface functionalization of nanoparticles, 2) assembly and self-assembly of nanoparticles, 3) optical and magnetic properties of nanoparticles, and 4) applications of nanoparticles in biology, optoelectronics, and magnetic-data-storage media. NaNaX 2 was the second conference of a series that started in 2003 at the Ludwig-Maximilians-Universität (LMU) in Munich, Germany. This year the conference was organized by **Peter Reiss** (CEA, Grenoble) and **Andrey Rogach** (LMU, Munich). After a welcome address by the organizers, 65 participants from 14 different countries presented their work in 34 oral and 31 poster contributions.

Figure 1. The conference center at Autrans (France) where NaNaX 2 took place.

The synthesis of colloidal nanoparticles in an organic surfactant solution is well established nowadays and high-quality particles with excellent size distribution can be grown for a huge number of materials. In this conference several trends for the *future directions of nanoparticle growth* were discussed. Improved synthesis methods offer the possibility to also control the shape of the particles and their composition out of more than one unit. **Bruno Chaudret** (CNRS, Toulouse) demonstrated how important the choice of the organometallic precursors is for advanced synthesis protocols. Due to their uniform size and shape distribution, the metal and metal oxide particles synthesized in his group self-assemble to give two- and three-dimensional clusters.[1] **Michael Delande** (CEA, Grenoble) also talked about magnetic nanoparticles; in particular he showed how concepts of measuring structural and magnetic properties that have been established with thin magnetic films can be transferred to magnetic nanoparticles.[2] The remaining presentations in this section mainly focused on fluorescent semiconductor nanoparticles. **Liberato Manna** (National Nanotechnology Lab, Lecce) explained how the shape of nanoparticles can be tailored by using different chemical surfactant molecules during their synthesis, based on different binding affinities of the surfactant molecules to the different facets of a nanoparticle. This principle of selective attachment can also be exploited to grow sophisticated nanostructures that are composed of sections from different materials, such as spheres grown on the tips of a rod.[3] **Stephen Hickey** (Univ. of Hamburg) and **Efrat Lifshitz** (Technion, Haifa) demonstrated in their presentations that besides particles that are fluorescent in the visible spectrum, it is now also possible to prepare high-quality particles that emit in the infrared. Improvements in the optical properties have been mainly achieved by growing shells of another material around the cores.[4,5]

Advanced synthesis methods allow for highly defined particles. This is especially important for *optical characterization of nanoparticles*. **Andries Meijerink** (Debye Institute, Utrecht) explained that under certain conditions the quantum yield of fluorescent semiconductor particles can increase with temperature, in contrast to intuition.[6] **Jochen Feldmann** (LMU, Munich) presented his vision of how superstructures of inorganic nanoparticles could be tailored to be efficient light collectors, similar to light-harvesting molecules known from biology.[7] Whereas the above authors were reporting measurements on nanoparticle ensembles, their optical properties can also be investigated on a single-particle level. This phenomenon was discussed in the presentations of **Christian von Borczyskowski** (TU Chemnitz) for fluorescent semiconductors and by **Markus Lippitz** (Univ. of Leiden) for gold nanoparticles.[8,9] Not only can one measure the optical properties of single particles; they can also be used to construct new optical tools. **Yannick Sonnefraud** (CNRS/UJF, Grenoble) presented his ideas on how fluorescent nanoparticles can be attached to the tip of near-field optical microscopes in order to obtain improved spatial resolution.[10]

This conference demonstrated that, in addition to optical characterization techniques, the *electrochemical characterization of nanoparticles* is an inter-

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esting complementary method. **Thomas Nann** (Univ. of Freiburg) and **Adam Pron** (CEA/CNRS, Grenoble) showed how cyclic voltammetry of colloidal semiconductor nanoparticle solutions can be used to investigate the energy levels and surface chemistry of the nanoparticles.[11,12] **Said Sadki** (CEA/CNRS/UJF, Grenoble) described how electrochemical methods can be used to investigate polymerization processes in sol–gel polymerization-derived nanoparticles.[13]

For biological applications, nanoparticles have to be water soluble. Although methods exist to synthesize particles directly in water, for a variety of materials synthesis in organic surfactant mixtures is preferred, as described above. In order to render these particles water soluble, appropriate *surface modification of the nanoparticles* has to be employed. **Igor Nabiev** (Univ. of Reims) provided an overview of the different strategies for such modification, which included ligand exchange, surface silanization, and polymer or micelle coating.[14] **Masih Darbandi** (Univ. of Freiburg) focused his presentation on surface silanization techniques, which can basically be described as embedding nanoparticles within a silica shell.[15] A very flexible method is to embed particles within a polymer shell, which was discussed by **Ralph Sperling** (LMU, Munich).[16] When polyethylene glycol (PEG) molecules are linked to such a shell the solubility properties are dramatically improved. Similar work was presented by **Nicholas Kotov** (Univ. of Michigan), who showed that PEG molecules attached to particles have a temperature-dependent conformation and thus can act as temperature sensors.[17]

As has already been mentioned, high-quality particles can be synthesized to such precision that the sizes and shapes of individual particles are very similar and therefore the particles arrange on substrates in regular patterns. Such *self-assembly of nanoparticles* was discussed by **Christophe Petit** (Univ. Paris IV) and **Nikolai Gaponik** (Univ. of Dresden).[18,19] Alternatively, nanoparticles can be also organized along templates or via their interaction with the substrate (see Figure 2), as shown by **Lifeng Chi** (Univ. of Münster),[20] and **Romain Bernard** (Univ. Paris-Sud).[21] The control of self-assembly is particularly important for the construction of nanoparticle-containing devices. **Marija Drndic** (Univ. of Pennsylvania) gave some examples of such devices and their electrical characterization.[22]

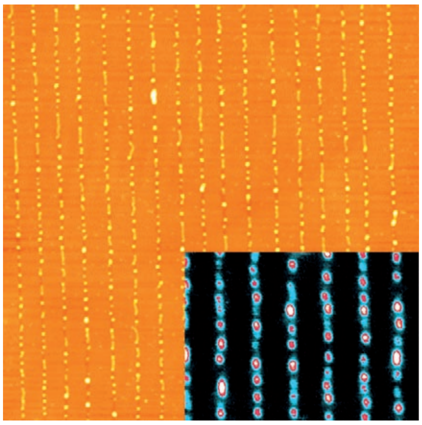

Figure 2. Topographic surface force microscopy (SFM) image of CdSe nanoparticles that have been deposited on a periodic organic template (20 μm × 20 μm image size). The inset shows a scanning near-field optical microscopy (SNOM) fluorescence image of the same sample. Details can be found in Ref. [20] (courtesy of L. Chi).

The next section discussed applications of nanoparticles, whereby the first part focused on *applications of nanoparticles within living cells*. **Maxime Dahan** (École Normale Supérieure, Paris) presented his vision of an intracellular global positioning system (GPS), in which individual molecules are labeled with fluorescent nanoparticles of different color, so that their position can be monitored in real time. This vision is based on previous work where diffusion of membrane receptors was traced by labeling them with fluorescent CdSe/ZnS nanoparticles.[23] The author of this report pointed out that despite the great prospects of nanoparticles, possible cytotoxic effects also have to be considered.[24] **Yuri Volkov** (Trinity College Dublin) explained that as well as using new labels, such as fluorescent nanoparticles, improved imaging techniques are also required; he presented his concept of high-content screening (HCS).[25] **Andre Skirtach** (MPI for Colloids and Interfaces, Potsdam) demonstrated in his presentation that gold nanoparticles, as well as fluorescent nanoparticles, also are very useful for biological applications. Irradiating polymer capsules with metal nanoparticles in their walls leads to heating of the nanoparticles and breaking of the capsule wall. In this way drugs can be released from the interior of the polymer capsules, which might be useful for the development of new drug-delivery systems.[26]

The second applications section was dedicated to *optoelectronic applications using nanoparticles*. **Sergei Romanov** (Univ. College Cork) showed how gold-particle-coated spheres can be used as photonic-bandgap structures.[27] When such particle-coated spheres are aligned, waveguides can be obtained, as was shown by **Ulrike Woggon** (Univ. of Dortmund).[28] In addition, **Nicolas Le Thomas** (Univ. of Dortmund) explained what happens if rod-shaped nanoparticles are used instead of spherical particles.[29] A major field for potential optoelectronic applications is in telecommunications. Infrared-emitting nanoparticles[30] can, for example, be used for optical waveguides, since they offer emission at a suitable wavelength range, as was discussed by **Stephen Kershaw** (Trackdale Ltd. Framlingham, UK). **Victor Klimov** (Los Alamos National Lab.) advanced the potential of carrier multiplication, that is, the excitation of multiple excitons with one photon, for photovoltaic devices, namely, converters of light quanta into charge carriers (see Figure 3).[31] In addition, **Neil Greenham** (Univ. of Cambridge) and **Elif Arici** (Siemens AG, Erlangen) introduced new models for hybrid solar cells and electroluminescent devices.[32,33]

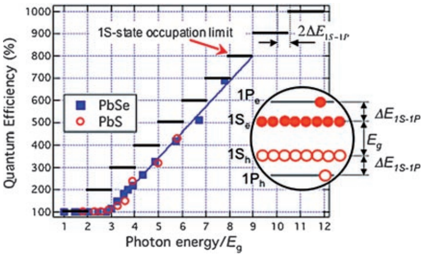

Figure 3. Seven excitons for the price of one: Redefining the limits for the conversion efficiency of photons into charge carriers. Details can be found in Ref. [31] (courtesy of V. Klimov).

The conference series will be continued with NaNaX 3, which will be organized by Liberato Manna and Wolfgang Parak in May 2008 in Lecce (Italy), and we hope to welcome you there. Please consult the NaNaX 2 homepage (see above) for further details.

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