Nanoparticle Synthesis by Lasers

Generation of Multi-Grams of Ultrapure Nanoparticles for Industrial Applications

Ages of human history are named after the highest technological advancement achieved in that period. While prehistoric and antique ages were named after ore names (e.g. Stone Age, Bronze Age, Iron Age) in conjunction with their importance in tool-making technology we have many different technologies that could describe the age that we live in. To celebrate one of these technologies, namely the photonics technology, the United Nations announced the year 2015 as the year of light. Industry and research is called to uphold their initiatives to explore the nearly limitless future applications of light. Another potential name giver for our century is the nanotechnology, which is known to be one of the most vibrant area of research and economy of the 21st century and is likewise fascinating many researchers. Drawing its strength from these two key technologies  “synthesis of nanoparticles by lasers” (fig. 1) is an interdisciplinary field that is gaining increasing worldwide attention in terms of their extensive applications in energy science, catalysis, optics as well as biology. Today, more than 350 institutes all over the world are actively involved in the synthesis of nanoparticles by lasers.

Laser Synthesis of Colloids Compared to Conventional Synthesis Methods

Conventional wet chemical synthesis typically employs organic adsorbates or leaves a mark of residual reagents, both deactivating nanoparticles’ surface. Such chemisorbed or physisorbed ligands, e.g. weaken the catalytic activity, interfere with surface-sensitive spectroscopy and hinder surface-assisted mass spectrometry. As a physico-chemical synthesis method, laser synthesis of colloids [1] leads to ligand-free nanoparticle materials covering almost the whole periodic table of elements. When compared with ligand-coated nanoparticles, further advantages of these laser-generated nanoparticles include higher grafting density, higher conjugation efficiency, high electroaffinity towards charged biomolecules, and novel heterogeneous catalyst preparation routes.
However, industrial applications require a high amount of nanoparticles [2] which was not easy to achieve with the laser-based method that was limited to productivities of milligrams per hour. This changed with recent advances in high power pulsed laser systems and a unique upscaling concept.

**Increasing the Productivity of Nanoparticle Synthesis with Faster and More Powerful Lasers**

Today, by using the world’s fastest picosecond laser system (fig. 2) the field advanced from applications in the laboratory scale to applications on an industrial level. However, the uniqueness, which will be described in the following by an analogy, is not the speed of the laser system. Imagine that the most powerful ultrafast lasers available on the world market would be the fastest and strongest horses in the world. In this case, the horses would be wild and unrestrained in such a way that neither the speed nor the strength could be directed onto a racetrack. The cleverly devised system consisting of a laser source and additional optical elements restrains the “horse”, i.e. the laser, so that the whole speed and strength of the horse is directed onto the racetrack. As a result, speeds up to 1800 km/h at a laser power of 500 Watts were achieved. This laser beam is directed onto a target material which is placed in a liquid and used to ablate material from its surface. During the ablation process the laser pulse produces a plasma leading to a bubble in the liquid in which nanoparticles are generated and ejected into the liquid after the collapse of the bubble. By ablating a target with this one-of-a-kind laser system it is possible to synthesize multi-grams of ligand-free nanoparticles in one hour and to extend the process limits while meeting the higher demand for laser-generated nanoparticles initiated by the growing interest towards industrial application. These ultrapure nanoparticles are of special interest for applications such as heterogeneous catalysis with nanoalloys [3]. Until now, the availability of processable amounts of laser-generated nanoparticles were the limiting factor for deeper functional investigations. Plastics-processing techniques like injection
molding and extrusion requires at least kilograms of masterbatch. With the presented laser system large quantities of optically active nanoparticles can be synthesized and dispersed into polymers for optical applications (fig. 3) [4].

**Conclusion**

Laser Synthesis of Colloids has been proven to be an emerging method leading to a large variety of nanomaterials with unique properties. Research in this field has taken big leaps forward during the last years with regard to the upscaling of the laser ablation process as well as concerning the design of innovative materials. Hence, the number of application e.g. in medicine, biology and chemistry has significantly increased moving this method towards industrial applications.

**References**


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**More information on nanoparticles:** [http://www.laboratory-journal.com/](http://www.laboratory-journal.com/)
