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SPECIAL ISSUE PREFACE

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# Trends and Current Topics in the Field of Laser Ablation and Nanoparticle Generation in Liquids

In his 1857 speech, Faraday described the experimental relations of gold to light, holding a gold colloid in his hands and observing its behavior during illumination. This fascination arising from the interaction of matter with light has motivated numerous research teams all over the world to focus their work on the laser irradiation of colloids and laser ablation of solids in liquids.

Today, nanoparticles are widely implemented as functional elements on surfaces, into volumes and as nanohybrids, with application prospects as bioactive nanoparticle−polymer composites and nanobiomarkers. In this way, integration of nanoparticle-determined functions into materials may give access to novel nanomaterials with added value, creating innovations and progress in particular in the efficient use and storage of energy, and in medical diagnosis and therapy. Nanotechnology as a multidisciplinary research discipline can be applied in almost any field of research. Hence, there is a enormous demand for new classes of nanoparticulate material. However, nowadays only a limited variety of materials that may be integrated into advanced functional materials are available: Nanoparticles synthesized by conventional gas phase processes are often agglomerated to micropowders that are hardly redispersible into functional matrices, and chemical methods often lead to impurities of the nanoparticle colloids caused by additives and precursor reaction products.

When Fojtik and Henglein fabricated and analyzed laser-generated nanoparticle colloids of various materials for the first time in the early 1990s, they already recognized the unique features of this technique: the simplicity of the procedure, the versatility with respect to metals and solvents, and the absence of chemical reagents or ions in the final preparation.

In the past decade, laser ablation and nanoparticle generation in liquids has fulfilled this prospect and has been applied to generate, excite, fragment, and conjugate elemental, nanoalloy, semiconductor, or ceramic nanoparticles. In general, advantages of laser-generated can be summarized as follows: (i) laser-generated (metal) nanoparticles are charged and thus have an extremely high colloidal stability, (ii) contrary to dry nanopowders, nanoparticle colloids are not inhalable and thus lead to an improved occupational safety during product handling, (iii) chemical precursors are not required and thus the colloids are 100% pure, and (iv) this method can be applied universally with an almost unlimited variety of materials and solvents.

It has recently been shown that these advantages are of value in comparison to conventional synthesis, in particular (i) up to 5 times more biomolecules may be conjugated to a laser-generated, ligand-free gold nanoparticle surface, (ii) higher yields of laser-generated gold nanoparticle biomolecule conjugates, which is beneficial especially if costly functional biomolecules are conjugated, (iii) lower noise during surface-enhanced Raman scattering of laser-generated pure nanoparticles, and (iv) ablation in polymer solution allows embeddding into polymer matrices for rapid nanomaterial prototyping.

These topics are currently discussed with exciting insights into physics and chemistry, such as cavitation bubble dynamics and laser ablation in nonequilibrum liquids. A huge variety of materials synthesized by pulsed laser ablation in liquids has been presented, from metals to photoluminescent, carbon, or ceramic materials. An emerging field is the laser excitation of particles, e.g., addressing size tuning, fragmentation or plasmon-enhanced laser nanobiosurgery. As a horizontal trend among the community, the latest ablation chamber designs adapted to the respective investigations or drastically improved productivity have stimulated the research topic toward application. The increasing application of laser-generated nanoparticles is reflected by diversification of the disciplines addressed. Laser-generation of nanoparticles was started by physicists and physico-chemists; now more and more engineers, biologists, or even medical scientists take part in this vivid community.

As revealed during the successful first meeting of the community in the summer of 2010, aspects of the fundamentals of laser ablation in liquids as well as novel applications mainly address areas such as cavitation bubble and plasma dynamics, fragmentation and post irradiation, nonequilibrium fluids, metal and alloy nanoparticles, semiconductors and ceramics, carbon nanoparticles, biophotonics and nanosurgery, flow chamber design, bioapplications, and scale-up. In the future, the latest findings on appropriate laser ablation conditions, cross-effects with particle−laser interaction, flow conditions, kinetics, and so forth will have to be discussed for metal, semiconductor, and ceramic nanoparticles generated, excited, fragmented, or chemically converted by laser radiation.

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