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•Editorial•
Special Topic: Advances in Pulsed Laser Synthesis of Nanoparticles in Liquids

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Advances in pulsed laser synthesis of nanoparticles in liquids

Certainly, when Richard Feynman outlined his vision of the prospects of nanotechnology in 1959 with his legendary speech "There is Plenty of Room at the Bottom", no one would have thought of where we are today, only 60 years later. In the 21st century, nanoparticles (NPs) are found almost everywhere and are pervasive in science, technology, and our everyday lives. In particular, in the last two years, some of us have come in contact with one of the nanoparticle-based technologies-the lateral flow assay test systems for rapid coronavirus diagnostics. Here gold nanoparticles (Au NPs) are decorated with antibodies that can capture/detect the existence of targeted molecules. In this example, the Au NPs can be considered as vehicles transporting the antibodies to the targeted region in the assay, requiring a size in the nano-range for good flow behavior. Avoiding cross effect is crucial for flow and the antibody conjugation processes, so NPs with naked surfaces are recommended.

An innovative route to produce such naked NPs is offered by a laser-based method described for the first time by Fojtik and Henglein [1] in 1993 for a quasi-physical generation of nanoparticles free of chemical contamination-the laser ablation in liquids (LAL). Here, a ruby laser was focused on nickel and carbon films in water, initiating the production of NPs due to the strong absorption of the laser light. The essential basic concept of NPs fabrication is based on the local irradiation of a limitless number of target materials in any liquid by a pulsed, intense laser beam, which heats the material in the ablation zone to the point of vaporization or plasma formation. The productivity and properties of NPs can be controlled and optimized by many parameters of LAL (e.g., laser characteristics, properties of the target material and liquid environment) [2]. Despite initial low productivity, the technique continued to evolve. With the increasing power of available pulsed laser components, the mass yield of NPs has also increased significantly, up to more than 8.3 g/h [3]. As a result, the laser-based synthesis method has become competitive with other production methods like wet-chemical synthesis. Moreover, it enables the production of surfactant-free NPs, eliminating cross-effects from different surface adsorbed organic molecules and expanding the range of NP-based applications.

Nowadays, the scope of laser synthesis and processing of colloids (LSPC) goes far beyond LAL and has become a collective term for four different approaches: laser ablation in liquids (LAL), laser fragmentation in liquids (LFL), laser melting in liquids (LML), and reactive laser ablation in liquids (RLAL). In each of these approaches, the interactions between target material, light, and liquid play a crucial role, requiring the alteration of various synthesis/processing parameters to achieve desired characteristics of the NPs. However, the optimization of the experimental parameters is hindered by the simultaneous occurrence of different processes affecting the generation and modification of the NPs. For example, the NPs produced via LAL in a stationary batch system can be modified via LFL induced by the same laser beam used in the ablation process [4]. Furthermore, LFL and LAL can be overshadowed by reactive processes initiated by solvents present in the liquid environment [5]. The complexity of processes involved in the NP synthesis calls for concerted efforts combining advanced experimental probing [4] and computer modeling [6] of processes occurring at different stages of laser-induced ablation and fragmentation of NPs. Although a complete picture is not yet available, the field of LSPC is already having a significant impact on nanotechnology [7-9].

This Special Topic highlights some of the recent advances in the fundamental understanding of the mechanisms of laser synthesis of NPs in liquids, the emergence of new synthesis techniques, and practical applications enabled by the availability of chemically pure colloidal NPs. The ability of LAL of pure metals to produce a broad range of NPs and nanocomposites structures is illustrated by many examples in the review paper by Zhang et al. [10], where a particular attention is paid to the analysis of the connections between the synthesis conditions and the sizes, phase states, and morphologies of nanomaterials prepared by LAL. Another review paper, by Batista et al. [11], provides the first comprehensive overview of the current state-

of-the-art in the reactive (and, in particular, reductive) laser-based synthesis of nanomaterials, where the highly non-equilibrium processes of LAL are intertwined with solvated electron formation and chemical reactions controlled by molecular precursors added to the liquid medium.

Two research articles, by Guo et al. [12] and Reich et al. [13], provide new insights into different facets of the LAL process. While Guo et al. [12] show an application perspective of LAL-produced GaAs NPs embedded in perovskite wires, Reich et al. [13] report the results of time-resolved X-ray probing of the generation of Zn NPs in nanosecond LAL. The results of a computational study of picosecond LFL, reported by Huang et al. [14], reveal the existence of three distinct fragmentation mechanisms, including a new mechanism involving the inverse Leidenfrost effect and producing a trimodal size distribution of the fragmentation products at moderate laser fluences. This Special Topic also includes two News & Views articles written by Bulgakov and Bulgakova [15] and Reichenberger [16]. While the former gives impetus to the NP formation mechanisms during laser processing, the latter highlights the emerging new area of LSPC, the pulsed laser defect engineering in liquids, PUDEL. Overall, the papers in this Special Topic provide a representative cross-section of the rapidly evolving field of laser-based nonequilibrium synthesis and processing of nanomaterials in liquids.

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