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Sustainable, Clean, and Safe Production of Nanoparticle Suspensions for Research and Development

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PURPOSE OF THE ABSTRACT

The production of finely suspended metal nanoparticles for demanding applications, e.g. in biomedicine or heterogeneous catalysis, primarily follows wet-chemical reduction routes. Many of these methods require toxic reducing agents, such as sodium bromide. Even when less critical reducing agents are used, still metal-containing acids or their salts are employed. Their preparation involves dissolving the corresponding metal in a strong acid, a safety-critical step in the entire process chain, which is rarely addressed.
Green synthesis approaches to metal nanoparticles replace toxic reducing agents by plant extracts [1] or even use microorganisms and biofilms as bioreactors for the nanoparticle synthesis [2]. Such approaches still require acids of the desired metal or their salts and thus only partially solve the problems of wet-chemical synthesis. In the case of microbial synthesis, even additional process steps such as the cultivation of the microbes and the extraction of the nanoparticles are required. The effort thus increases and especially the cultivation step limits the broad applicability of the microbial synthesis by researches and developers of different disciplines.
In addition to the (bio)chemical bottom-up methods, there are various top-down methods, in which the pure metal acts directly as the educt of the nanoparticle production. The step of dissolution in strong acids is thus omitted. However, top-down methods have received little attention so far because they either could not provide small and finely suspended nanoparticles or were associated with high instrumental effort.
Intensive scientific research and progressive technological development make top-down methods increasingly attractive. This is particularly true for the synthesis of nanoparticle suspensions by laser ablation of solids in liquid media [3]. Briefly, a high-intensity laser beam vaporizes a solid directly surrounded by the dispersion medium. Atom clusters and reactive species emerge, which form nanoparticles primarily via condensation and coalescence. Rapid cooling and chemical reactions upon contact with the dispersion medium limit further growth, resulting in very small particle diameters. The type and concentration of stabilizing molecules in the dispersion medium, as well as various laser parameters, provide opportunities for size manipulation [4]. In addition, compact and comparatively inexpensive microchip lasers were recently qualified for the method, even achieving unexpectedly high energy efficiency in the laser-based nanoparticle synthesis [5].
The compact and robust design allows the integration of the efficient lasers into a fully automated laboratory system, which makes nanoparticle suspensions available quickly, easily, and reliably (Figure 1). In the future, such machines can be used as decentralized, standardized and universal production units for nanoparticle suspensions. The direct processing of solids with a theoretical 100% yield and the absence of toxic reducing agents makes the machine significantly more sustainable than wet-chemical synthesis. In addition, the user can combine various solids (pure metals, alloys, ceramics, and organics) and dispersion media enabling the synthesis of innovative nanoparticle suspensions with a minimal process development effort.
This talk will highlight the possibilities of laser-based synthesis of nanoparticle suspensions. In addition, the background of the high energy efficiency of the microchip lasers will be addressed, as well as details of the technical realization of the fully automated system.

FIGURES

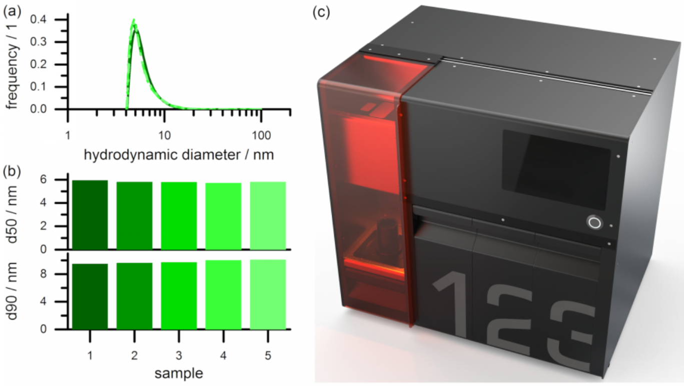

FIGURE 1

Reproducible synthesis of colloidal platinum nanoparticles using a compact, fully automated laboratory machine

Size distributions measured with an analytical disc centrifuge (a) and extracted key figures of these distributions (b) of five samples of platinum nanoparticle suspensions, which were successively produced with a fully automated synthesis machine.

FIGURE 2

KEYWORDS

colloid | automaton | PLAL | LASiS

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