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Editorial

Formation of Advanced Nanomaterials by Gas-Phase Aggregation

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Gas aggregation is a well-known phenomenon, often seen in nature under temperature lowering, as, for example, cloud, fog or haze formation. Atoms and molecules of atmospheric gases form very small aggregates known as clusters or nanoparticles. Several decades ago, the principle of gas–phase aggregation became a basis for a new technology to synthesise atomic and molecular clusters in laboratory conditions for specific research applications [1,2]. Since then, this technology has been gradually developing into a widely used approach getting a significant impetus in the 1990s and thereafter due to a high relevance for the rapidly progressing nanoscience and nanotechnology field [3–6]. Different types of gas aggregation sources, which are currently commercially available, provide a number of advantages compared to other physical and chemical means of nanoscale synthesis, allow tailoring nanoparticle parameters and assembling them into functional systems, which are of very high demand in various research and industrial branches [7,8]. In recent years, a lot of activities have been carried out on improving the performance and capabilities of the gas aggregation sources as well as related systems for the manipulation of cluster beams [9,10]. Many studies look into the physics of cluster aggregation and the key parameters affecting their formation, thus, paving a way for control of their composition, shape, size and structure [11,12]. A huge amount of research is devoted to applications of gas-phase synthesised nanoparticles as building blocks of functional nanomaterials and devices for optics, catalysis, sensing and imaging, biotechnologies and other fields [13].

Our intension with this special issue was to address recent advances in gas-phase aggregation techniques, trends in synthesis and functionalization of nanoparticles, as well as applications of cluster beams in preparation of functional nanomaterials or modification of surfaces on the nanoscale. Overall, the book provides the reader with a variety of topics within the field: from the technology on the formation of core@shell nanoparticles to the applications of nanoparticle-assembled matrixes and surface modification on the nanoscale. This diversity shows a many-sided interest in the field of nanoparticle gas aggregation and cluster beams.

The collection is started with a review by Popok and Kylián [14], which analyses the state of the art regarding the synthesis of nanomaterials using gas-phase aggregation methods and outlines the main application fields such as catalysis, formation of magnetic media, utilization of nanoparticles for sensing and detection, as well as production of functional coatings and nanocomposites. The paper gives a good overview of different cluster-matter interaction regimes and advantages of the cluster beam method from the application point of view. It also addresses a paradoxical situation between the enormous development of the cluster technology branch and the sparse use of cluster sources at the industrial level.

The second paper by Skotadis et al. [15] is also a review on nanoparticle synthesis in the gas phase but with the specific focus on applications in sensing technologies. The article overviews the operation principle of sensor matrixes based on the change of conductivity

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and then systematically analyses numerous examples of nanoparticle-assembled films utilised for strain-, gas- and bio-sensing.

Magnetron sputtering-based gas aggregation sources are known as unique tools for controlling the composition, structure and shape of nanoparticles. In the article by Soler-Morala et al. [16], the studies of clusters with Co core and Cr shell spontaneously formed under sputtering of CoCr target are reported. In such structures, the interaction between ferromagnetic and antiferromagnetic materials causes an enhancement of the magnetic anisotropy and improves the thermal stability of the small particles, in particular. It is shown that one can reduce the critical size for room temperature superparamagnetism to below 7 nm.

The paper by Milana et al. [17] reports on a new fabrication process of ionogel composites containing gold nanoparticles embedded using supersonic cluster beams. Such nanocomposites show large electrochemical capacitance, considerable conductance and good electromechanical response. The proposed combination of geometry, materials and technology is promising for the fabrication of a new generation of self-sensing micro-actuators for bio-inspired applications.

The work by Prysiazhnyi et al. [18] gives one more example of application-oriented studies utilizing gas aggregated silver nanoparticles for matrix-assisted laser desorption/ionization (MALDI) mass spectrometry, which is one of the most powerful tools for composition analysis in chemistry and biology. This investigation clearly shows a strong dependence of the signal enhancement on the nanoparticle size. The obtained results, thus, allow to elaborate on the key factors affecting the detection efficiency and develop practical recommendations on the inorganic nano-matrix parameters.

Energetic cluster beams are less studied compared to nanoparticle soft-landing for practical applications. From this point of view, the work by Nikolaev and Korobeishchikov [19] on surface nanostructuring of optical materials by cluster bombardment is of special interest. The obtained results give a considerable contribution to the development of fundamental aspects of cluster-matter interaction depending on the particle energy and angle of incidence.

Finally, we would like to thank the authors for their contributions to this book despite the hard times due to a partial lockdown of research activities caused by COVID-19. We look forward to future exciting developments in this field.

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