EDITORIAL
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Editorial: Radiation Assisted Modifications and Processing of Colloidal and Nanomaterials for Biomedical Applications

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Editorial on the Research Topic

Radiation Assisted Modifications and Processing of Colloidal and Nanomaterials for Biomedical Applications

Nanotechnology has melted the borders among material science, chemistry, biology and medicine. The development of structured platforms chemically and/or biologically modified in ordered patterns has an increasing impact in modern medical care, i.e. for tissue engineering, organ-on-chips, or to produce biosensors for high-throughput screening. Micro and nanofluidic systems for handling and sensing chemical and biological samples will improve their performance through the employment of materials with selected functionalities in specific regions of the device. Metal Organic Frameworks, mesoporous thin films, hierarchical structures, nanoparticles, just to cite some, present high surface to volume ratio and tunable properties, rendering them promising materials for drug delivery or sensing, just to mention a few.

In this context, the integration of micro/nano fabrication techniques for top-down processing with novel materials prepared with bottom-up approaches is an important objective. Despite the combination of these procedures has been pioneered over the last few years, the potential remains largely unexplored and unexploited.

Bottom-up methods rely on chemical reactions and molecular self-assembly, where matter is organized through molecular interactions and chemical equilibria during wet-deposition processes. Among top-down techniques we decided to focus on controlled irradiation of materials. Many micro/nano fabrication processes are based on irradiation, like i.e. UV, X-ray, electron beam and laser lithography, focused ion beam, or microwaves.

Exposure to a radiation source can lead to modifications of the materials properties, enabling the positioning of functional materials in selected areas of devices. Irradiation can also be employed to promote the in-loco synthesis of novel materials with tailored properties and deterministic spatial distribution.

In the present research topic, we collect articles about tuning structure and properties of mesoporous films through irradiation, and about the fabrication of bio/micro and nanodevices based on colloidal nanostructures or materials. The collection is composed of two reviews and two research papers.

Martínez et al. review the use of polymer-based nanocomposites as resist materials for lithographic methods. Differently from commercial resists, polymer-based nanocomposites enable extending the compositional threshold of materials used in lithography. This is important from the technological point of view, since this approach allows the direct patterning of functional materials by minimizing the number of fabrication steps. The authors make a critical analysis of the literature by selecting examples of resists containing different types of fillers (metallic, magnetic, ceramic, luminescent and carbon-based) and by discussing their role in modifying the properties of the polymer matrix. These materials have been used as resist for several lithographic techniques to obtain 2D patterns and 3D shapes with high spatial resolution. Their utilization opens important perspectives for devices fabrication: the review concludes by showcasing examples of novel devices applied in photonics, electronics, magnetism and biology.

Alberti et al. discuss the fabrication methods of planar and single-mode waveguides based on sol-gel films, for their use as optical chemical sensors. Optical methods for the detection of analytes are popular due to their sensitivity, specificity, fast response and versatility. Almost always based on the interaction of an evanescent field transmitted at the interface between cladding and core of a wave-guide and the analyte contained in the core (as it is usually the case, even though not the only configuration possible), there are still challenges to be solved. Sensors which detect the refractive index variation caused by the measured chemicals might suffer from poor specificity and the need for an internal calibration. Conversely, spectroscopic (IR and Raman) and fluorescent sensors can be affected by absorption of chemicals within their constituent materials and by scattering originating at the interfaces when defects of roughness are present. Sol-gel synthesis of thin layers with tunable chemical and structural properties (e.g. porosity) are shown to be a tremendous opportunity to solve most of these issues, with the added bonus of allowing for direct patterning through irradiation induced chemical modification.

Self-assembled mesoporous thin films are an example of bottom-up synthesized materials for which integration in devices requires top-down processing. Specific patterning of mesoporous films is a task that cannot be fulfilled by merely dip-coating or spin-coating the precursor solution onto a substrate without further processing. In order to obtain micro/nano devices with tailored properties by using mesoporous materials, morphology has to be carefully tuned.

Fuertes et al. present a systematic study about the structural and mechanical properties of mesoporous silica thin films (with various pore sizes), submitted to different doses of high energy X-rays. Moreover, they present the incorporation of silver nanoparticles within these oxide frameworks and the obtention of patterned microstructures. The results demonstrate that the hardness, rigidity, contraction and accessible porosity of the silica films depend on the irradiation dose, while the porous order is not affected by the X-ray exposure. In addition, the authors demonstrate that a thermal treatment performed after irradiation can help to increment the accessibility and structural integrity of the oxides. The results presented in this work are of key importance to design synthetic strategies to successfully integrate mesoporous silica on microdevices.

Amenitsch et al. examine the possibility to employ mesoporous silica films as interactive sample holders, able to deliver water to lipid membranes deposited on them through the mesopores due to a change of humidity of the environment. Mesoporous films are prepared using different surfactants and consolidation treatments: X-ray irradiation, thermal treatment and both. The effect of functionalization is also investigated. The phase transition of the deposited lipid membrane is measured with Grazing Incidence Small Angle X-ray Scattering while changing the environmental humidity in a controlled ramp. Results show that lipids deposited on mesoporous materials undergo hydration-driven phase transition at lower humidity with respect to silicon, confirming the possibility to feed water through the pores. The water delivery can be partly tuned with the consolidation treatment and with the functionalization. This is the first step for the employment of mesoporous films as supports for biological studies.

The articles in this research topic are only an appetizer of what can be done with the combination of irradiation techniques and nanomaterials prepared by chemical methods. We are eagerly waiting for the main course in the next future.

AUTHOR CONTRIBUTIONS

All authors conceived the ideas expressed in the article, wrote the article and approved it for publication.

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