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Editorial

Raman Spectroscopy of Crystalline Materials and Nanostructures

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One of the biggest challenges in the field of material science lies in understanding the structure and behavior of crystalline materials and nanostructures. In this regard, Raman spectroscopy has emerged as a powerful technique enabling the probing of molecular vibrations and offering invaluable structural information on molecular materials. The Special Issue on "Raman Spectroscopy of Crystalline Materials and Nanostructures" aims to shed light on novel and groundbreaking developments in this field, highlighting the central role that Raman spectroscopy has played in unraveling the mysteries of crystalline materials and nanostructures across diverse domains.

1. Advancements in Raman Spectroscopy

The Raman effect was initially discovered by Chandrasekhara Venkata Raman and Kariamanikkam Srinivasa Krishnan in 1928 [1]. C. V. Raman was awarded the Nobel Prize in Physics in 1930 "for his work on the scattering of light and for the discovery of the effect named after him". However, it has only been in recent decades, especially since the 1970s, that significant advancements in Raman spectroscopy instrumentation and techniques have broadened its usefulness in characterizing crystalline materials and nanostructures. In particular, the development of lasers and high-resolution Raman spectrometers with advanced data analysis algorithms has enabled the precise identification and characterization of subtle structural variations at the nanoscale [2]. Furthermore, the incorporation of new techniques, such as surface-enhanced Raman spectroscopy (SERS), Tip-Enhanced Raman Spectroscopy (TERS) and Spatially Offset Raman Spectroscopy (SORS), has facilitated the examination of materials with enhanced sensitivity and spatial resolution [3]. Additionally, Raman spectroscopy enables the study of materials under a wide range of conditions, from vacuum to high pressures, cryogenic and high temperatures, and under the influence magnetic and electric fields. New experimental set-ups which exploit near-field microscopy allow the Raman mapping of material surfaces, also in conjunction with other local probes such as AFM/STM. These advancements have put Raman spectroscopy at the forefront of material characterization techniques, enabling researchers to obtain unprecedented insights into the structural characteristics of various materials.

2. Characterization of Crystalline Materials

Raman spectroscopy is a versatile tool for the characterization of crystalline materials, providing information on their lattice vibrations, phonon modes, and crystal symmetry. Hence, by analyzing the Raman spectra of crystalline materials, it is possible to identify crystal phases, evaluate crystallinity, and detect defects or impurities [4]. Moreover, the ability of Raman spectroscopy to probe local structural variations makes it particularly well suited to studying heterostructures and interfaces within crystalline materials [5]. The non-destructive nature of Raman spectroscopy further enhances its effectiveness in the characterization of delicate crystalline samples, making it an indispensable tool in material science research. Raman measurements in polarized light provide invaluable information

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on a crystal's structure and symmetry when single crystals are available and state-of-the-art modeling of the Raman response is performed [6].

3. Exploring Nanostructures

Advancements in nanotechnology have paved the way for a new era of material design and engineering, where the properties of materials can be tailored at the nanoscale for enhanced performance and functionality. In this field, Raman spectroscopy not only offers the possibility to elucidate the structural and vibrational properties of nanostructures, but it also provides insights into their size, shape, composition, and surface properties [7]. From carbon-based nanostructures such as graphene and carbon nanotubes to semiconductor nanostructures like quantum dots and nanowires, Raman spectroscopy provides a wealth of information crucial for understanding their behavior and optimizing their properties for various applications [8]. Additionally, Raman imaging techniques can spatially map nanostructures with high resolution, facilitating the study of their distribution and interactions within complex systems [9]. Hence, the ability to characterize nanostructures with precision and sensitivity positions Raman spectroscopy as an indispensable tool in the expanding field of nanotechnology.

4. Applications

The applications of Raman spectroscopy in the realm of crystalline materials and nanostructures are diverse and far-reaching, as evidenced in the present Special Issue. Indeed, the twelve works published here span various areas of application, from quantum and nonlinear optics to magnetic and electric field devices, optoelectronics, conservation-heritage, and pharmaceutical fields. As fundamental research, the manuscripts in this Special Issue clearly demonstrate the utility of Raman spectroscopy in studying crystal morphology, crystal growth, and crystallization kinetics, investigating phase transition and cocrystals, and examining the surfaces and reactivity of nanoparticles. Furthermore, the articles in this Special Issue feature a range of Raman techniques, including polarized Raman, resonance Raman, THz Raman, and SERS, showcasing the high level of technological development in Raman spectroscopy. Complementary investigations with various other physical–chemical techniques and quantum chemical calculations are also included within the articles in this Special Issue.

In conclusion, Raman spectroscopy stands as a cornerstone technique in the characterization of crystalline materials and nanostructures. Through continuous advancements and innovative applications, as demonstrated in the articles published here, Raman spectroscopy continues to drive progress across diverse scientific disciplines, paving the way for transformative discoveries and technological breakthroughs.

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