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Editorial

Advances in the Field of Nanostructured Ceramic Composites

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In recent years, the production of ceramic composites having nanosized features is receiving increasing attention, as they demonstrated enhanced mechanical and/or functional performances as respect to conventional micronic materials [1]. Significant examples can be found in literature, starting from the early works of Niihara and co-workers. In their studies, composites made by a fine dispersion of SiC particles added into micronic-sized alumina, silicon nitride and yttria matrix [2–4] were successfully produced and demonstrated superior mechanical properties in comparison to the conventional monolithic alumina. Nowadays, further advances in the tailoring of material architectures and micro/nanostructural features have allowed nanocomposite ceramics to achieve outstanding properties, with a challenging combination of very high fracture strength and fracture toughness in a single material [5].

In addition, the development of new and more controlled manufacturing methods enabled these materials to move from a laboratory production to a pre-industrial or industrial scale, thus, enlarging the interest towards ceramic nanocomposites. As a consequence, such materials are increasingly used in different industrial applications such as in aerospace, automotive, medicine, as well as for energy and electrical uses [6].

In 1991, Niihara proposed for the first time the concept of structural ceramic nanocomposites [7], with the intent of improving the mechanical properties of advanced ceramics throughout microstructural tailoring and processing improvement. Ever since, several types of nanocomposite structures can be found in the scientific literature, where the material architectures mainly differ on (*i*) location of the nanosized particles within the matrix and (*ii*) morphology of the second phase. Concerning the first point, it is common to distinguish the composites as *intragranular* or *intergranular*, according to the preferential location of the nano-grains inside the matrix or at the grain boundaries. Intergranular second-phases are able to induce a proper pinning effect on the grain boundaries of the matrix material, thus, limiting its grain growth during sintering, and enhancing the hardness and the strength of the sintered ceramics [8]. Intragranular reinforcements, on the other hand, can provide strengthening and toughening effects by residual thermal stresses within the composites. In fact, the thermal expansion coefficient mismatch between the matrix and the second-phase grains causes strain during cooling from high-temperature sintering to room temperature [9]. With reference to the second point, the nanoscale reinforcements generally present the morphology of rounded nanoparticles, which are relatively equiaxed. However, ceramics containing fibers, whiskers or other types of elongated second-phases characterized by high aspect ratio are more and more developed, in reason of the crack deflection and bridging toughening effects exerted by these particles. For the same reason, platelets, which are flattened particles characterized by the thickness of few nanometres and larger surfaces (leading to the aspect ratio of at least 25 [10]) are used as well.

A common feature to all these different kinds of nanocomposite architectures is the need to understand the materials' properties across length scales. To engineer the design of such nanocomposites and towards more advanced materials, even with multi-functionalities, a deep knowledge of the nano/microstructure-properties relationship is required. The following step involves the development of the expected nanocomposite architectures, by tailoring the microstructural and compositional features. To achieve this goal, it is necessary to perform a careful control of each manufacturing step, from the synthesis of the composite powders to the forming of the green parts and their densification.

This Special Issue "Advances in the Field of Nanostructured Ceramic Composites" provides examples of the outstanding properties which could be achieved today by the development of suitable nanocomposite ceramics, both in the field of structural [11–13] and functional materials [14]. In spite of the differences in composition and manufacturing methods between the materials here illustrated, as a common point, the manuscripts belonging to this Special Issue clearly evidence the need of optimizing many parameters of design (e.g., material composition [12,13], second-phase content, etc.) and processing (e.g, dispersion, homogenization [11], sintering, etc. [12]) to achieve the expected performance. Most of all, the attainment of a homogeneous distribution of nanosized particles inside the matrix materials is a still a challenging issue, in particular, when a fine control of the location of the particles in the matrix material is required. Therefore, new strategies, including innovative synthesis and manufacturing methods that are able to overcome such limits are desired and represent one of the main current frontiers in the field of nanocomposite ceramics.

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