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Editorial

Ceramic Conductors

Maria Gazda * and Aleksandra Mielewczyk-Gryń

Faculty of Applied Physics and Mathematics, Gdansk University of Technology, 80-233 Gdansk, Poland; alegryn@pg.gda.pl

* Correspondence: maria.gazda@pg.edu.pl

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For more than 4000 years, mankind has used and developed ceramics. Starting from basic sun-dried pots in Neolithic times, ceramics have evolved through Medieval clay sculptures to high-temperature superconductors in modern times. Nowadays, it is simply impossible to overestimate the importance of ceramic materials. Ceramics have been traditionally considered to be electrically insulating. Within this issue, only $NiCr_xFe_{2-x}O_4$ studied by Lin et al. [1] may be considered as an insulator, or rather n-type semiconductor; however, this material exhibiting interesting magnetic properties is far from being a traditional ceramic. Nevertheless, several groups of modern advanced ceramics are electrically conducting. Among them, electronic-, ionic-, as well as mixed electronic-ionic-conducting ceramics are very important groups of materials. Proton conductivity may be observed in acceptor-doped perovskite oxides such as $Ba_{0.9}La_{0.1}Zr_{0.25}Sn_{0.25}In_{0.5}O_{3-a}$, as studied by Skubida et al. [2], and terbium-substituted lanthanum orthoniobate [3]. Oxygen ions are mobile charge carriers in materials such as substituted bismuth vanadate [4] and doped cerium oxide [5,6], as studied by Ring and Fuierer, and to a minor extent and at high temperature, they are also mobile charge carriers in ceramic proton conductors. Fluorine ions, the first mobile ions studied in solid-state ionic conductors, are present in SrF_2–YF_3 solid solutions, as reported by Breuer et al. [7]. Finally, electronic-type charge carriers dominate in such ceramics as donor-doped and reduced strontium titanate, as reported by Presto and collaborators [8].

The electric and electrochemical properties of conducting ceramics, apart from their chemical composition, strongly depend on the material morphology, micro- or nanostructure, and porosity. This means that the properties may be modified and optimised by the proper choice of fabrication method. The most often used method of ceramic materials preparation, which is usually used as a first-trial method, is the solid-state reaction method. This method was used for the preparation of doped barium indate $Ba_{0.9}La_{0.1}Zr_{0.25}Sn_{0.25}In_{0.5}O_{3-a}$ [2], terbium-doped lanthanum orthoniobate [3], and doped strontium titanate [8]. On the other hand, the solid-state reaction route often does not allow the achievement of single-phase ceramics with expected properties. One of the interesting synthesis methods which may be used for manufacturing either fine ceramic powders [4] or even single crystals is molten-salt synthesis. Also, sol–gel self-combustion synthesis [5] and spray-pyrolysis [8] lead to the formation of nanosized ceramic powders. On the other hand, the application of mechanosynthesis not only produces nanoceramic powder but also facilitates the formation of phases which do not form with the use of other methods. By employing mechanosynthesis, a single-phase solid solution of YF_3 and SrF_2 was obtained before the $Sr_{0.7}Y_{0.3}F_{2.3}$ composition [7].

Moreover, the variety of phenomena related to ion and electronic transport in ceramics render them very interesting for applications. Indeed, these materials have been applied in gas sensors, solid oxide fuel cells, electrolysers, batteries, memory cells, and other devices. Most of the materials reported in this Special Issue are developed with the long-term aim of usage in high-temperature electrochemical devices. For example, samarium-doped ceria thin films deposited using e-beam evaporation [6] or other method are used for various purposes in solid oxide fuel cells (SOFCs). La-doped strontium titanate was studied as a ceramic component of a composite current collector in a metal-supported SOFC [8]. Similarly, the development of proton-conducting ceramics [2,3] is aimed at future applications in SOFCs with proton-conducting electrolytes. SOFCs both with oxygen ion- and proton-conducting electrolytes operate at high temperatures, i.e., between 600 °C and 800 °C. Even the YF_3–SrF_2 solid solutions are considered as electrolytes for high-temperature all-solid-state fluorine batteries [7]. Electro-ceramic devices like solid oxide fuel cells, electrolysers, and batteries are multi-layered systems consisting of different materials. This feature brings about several important technological issues. One of them is the optimization of the layer deposition method. An example of this is presented by Sriubas et al., who studied the influence of the powder characteristics on the properties of Sm-doped ceria thin films [6]. Another important issue is the requirement of structural and chemical compatibility of materials in a wide temperature range. Moreover, the relevant data are usually difficult to obtain. The thermomechanical properties of a wide group of proton-conducting ceramics were reviewed by Løken et al., giving substantial data on numerous systems within this group of materials [9].

The variety of properties and applications of conducting ceramics makes them very important for the future of societies worldwide. Thus, the papers included in this Special Issue should not only be viewed as presenting scientific data but also as giving information in a much broader context. We believe that understanding the importance of both basic and applied research in the field of conducting ceramics is key for the future development of many industrial areas. The broad spectrum of materials presented in this issue reflects the variety of applications and possible modifications of modern ceramics.

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