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Editorial

Metal Oxides

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1. Introduction and Scope

Oxide materials in bulk and thin film form, and metal oxide nanostructures exhibit a great variety of functional properties which make them ideal for applications in solar cells, gas sensors, optoelectronic devices, passive optics, catalysis, corrosion protection, environmental protection, etc.

Metal oxide's functional properties are strongly dependent on oxide's crystal structure, composition, native defects, doping, etc., which govern their optical, electrical, chemical and mechanical characteristics. Processing methods and growth parameters strongly determine the morpho-structural characteristics and therefore the physico-chemical properties of metal oxides. The band gap and electronic structure of oxides can be controlled and tailored by the size and dimension, resulting in a wide range of potential applications.

This Issue is devoted to the modelling, synthesis and characterization of oxide thin films, multilayer structures (superlattices, metamaterials, devices, etc.) and nanomaterials with novel multifunctional characteristics which combine at least two excellent properties: electrical and optical, optical and mechanical, chemical and mechanical, thermal and chemical, etc.

Applications include: solar cells and optoelectronic devices; transparent conductive oxides (TCOs); plasmonics; photonic integrated circuits; chemical sensors; catalysis; corrosion protection; thermal protection; and energy conversion and storage.

2. Contributions

Ten articles have been published in the present Special Issue of *Metals*. Three of them are review papers.

The subjects are multidisciplinary, covering a wide range of applications, including (i) transparent conductive oxides (two papers); (ii) metal oxides composites and nanocomposites (two papers); (iv) welding and critical raw materials [1,2] (CRMs) saving (two papers); (v) metallurgical waste treatment (one paper); (vi) oxides for high temperature applications (thermal barrier coatings) (one paper); and (vii) nanostructured oxides and composites for gas sensing and desulfuration (one paper) and CO_2 capture (one paper).

The review paper from D'Anna et al. [3] deals with the notable synthesis of WO_3 (films and nanostructures) in ionic liquids (ILs). The synergy between ILs and metal oxides has been proposed recently to both direct oxides' production towards controllable nanostructures (nanorods, nanospheres, core-shell nanostructures, etc.) and to modify the metal oxide structure (incorporating ILs) in order to increase the gas adsorption ability, and thus the catalytic efficiency. Synergy between ILs and metal oxides can make a considerable contribution to the field of air pollutant sensing and remediation.

The review from Motoc et al. [4] deals with a novel and sustainable approach for doping zirconium oxide with mixed rare earth oxides (REOs) in the natural composition as extracted from monazite mineral. This allows to reduce the long and complex processes needed for the extraction, separation and purification of single rare earths, reducing greatly the costs and the environmental impact. Preliminary

results are reported showing the ability of the mixed REOs, as occurring in the natural composition, to be an efficient zirconia dopant for thermal barrier coatings.

The review from Yilmaz et al. [5] reports on the bibliometric analysis of publications about In-doped ZnO, to reveal the general research tendency in the study of this transparent conductive oxide. Bibliometrics is an emerging cross-disciplinary discipline based on statistic and mathematic tools to map the state of the art and the development in a given area of scientific knowledge. This study can be a guide for researchers involved in the development of In-doped ZnO films and nanostructures for optoelectronics, solar cells and gas sensors applications.

The paper from Seok et al. reports on the characteristics of ITO films sputtered on flexible invar metal foils to be used as transparent electrodes substrates for curved perovskite solar cells (PSCs). Preliminary results indicate that invar metal foils are promising flexible substrates to substitute typical flexible polymer substrates for high-performance curved PSCs [6].

Two of the papers from Balos et al. [7,8] deal with the study of the influence of metallic oxide nano- and submicron particles for the performance of the activated tungsten inert gas (A-TIG) welding of austenitic stainless steels. Oxide coatings may have an interesting role in welding technology as catalysts of the TIG welding process. The method may help in saving CRMs because the consumables used in the welding of austenitic stainless steels contain critical raw materials (CRMs), or nearly CRMs and relatively expensive materials such as chromium, nickel and silicon metal.

The topic studied in Pan et al.'s paper [9] is the direct reduction of the ironmaking process of a rotary hearth furnace (RHF) as an effective method for the treatment of metallurgical wastes. A new RHF process was proposed to avoid the generation of sediments and to maximize the use of waste from the metallurgical process, thus improving the RHF energy efficiency.

The effect of various spark plasma sintering (SPS) temperatures on the properties of TiC- and TiN-reinforced alumina–zirconia composites for the precision machining of hard-working pieces was investigated in the paper by Szutkowska et al. [10]. Results demonstrate that upon increasing the sintering temperature, improvement in wear resistance and an increase in fracture toughness are observed in the tested samples. Properties of composites sintered in the case of pressure-assisted SPS were significantly better than those obtained by pressureless sintering (PS) at higher temperatures.

Another paper by Balos et al. [11] aims to study the influence of TiO_2 nanoparticles on the wear resistance of a Co-based hard-facing electrode. The hard-faced layer was produced using the common shielded metal arc welding (SMAW) technique. Results indicate that the wear resistance and hardness values of the hard-faced layers obtained with the TiO_2 nanoparticle coated on the SMAW electrode are higher with respect to the layers obtained with untreated electrodes.

Finally, the last published paper from Luisetto et al. [12] reports on the study of CaO-$CaZrO_3$ sorbents synthesized using the self-combustion method. $CaZrO_3$ was introduced into CaO-based sorbents to increase stability during repeated CO_2 capture/release cycles. The best stability was attributed to the correct balance between CaO, the active component, and the $CaZrO_3$ nanoparticles. The experimental data corroborated the adoption of the shrinking core spherical model for the interpretation of CaO conversion to $CaCO_3$.

3. Conclusions and Outlook

Papers collected in this Special Issue compose a miscellaneous encompassing several research topics where metal oxides play a fundamental role. Some papers give also insights into novel synthesis methods and processes which can be guides to researchers for future studies.

The studies covered here offer richness and substantial depth on various topics, also taking into account the concern to reduce the negative environmental impacts and increase materials and process efficiency, thus covering a broader concern on sustainability issues.

As guest editor of *Metal Oxides*, I hope that the papers of this Issue will catch the interest of many scientists, will be useful for their future work and contribute to advance the different research fields.

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