Bismuth based materials: Environmental remediation, alternative energies, and smart ceramics

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Abstract. Bismuth is an element scarcely present in Earth´s crust and it is known that the most important ores (bismuthinite and bismite) are concentrated China, Australia and México. One of the main research lines of the Mexican Laboratory for Thermal Spray (CENAPROT) is the development of novel materials and processes to use the Bismuth available in the country. In this presentation, a summary of the most important applications of bismuth-based ceramic compounds that include environmental remediation, smart ceramics and piezo-alternative energies are presented and discussed. Apart from the general properties of bismuth-based ceramics including polymorphism, the general strategies followed in each current project that practically cover the whole value chain, from the processing of metallic Bismuth to the preparation of functional devices. The polymorphism of bismuth oxide and solid solutions compounds with other metallic oxides are currently being used to enhance the intrinsic photocatalytic properties for applications in environmental remediation. Optimization efforts are currently being done to obtain the β-Bi_2O_3 tetragonal phase, which is a p-type semiconductor that exhibits a remarkable photoconductivity, photoluminescence, high oxygen ion conductivity, a narrow band gap and a positive flat band potential. These properties enhance its use to be applied for pollutant degradation and hydrogen production under visible-UV solar light. The synthesis of Bi_2O_3-Y_2O_3, Bi_2O_3-Dy_2O_3-Ta_2O_5 solid solutions in delta cubic phase has open good opportunities for applications as oxygen ionic conductors in electrolyte membranes for medium temperature solid oxide fuel cells (SOFC). This related, the cathode in SOFC, which also involves ionic conduction phenomena consists of $Bi_{0.6}Sr_{0.4}FeO_3$ compounds, synthesized by low temperature solid state reaction. In the case of smart ceramics, the family of bismuth sodium titanate ($Bi_{0.5}Na_{0.5}$)TiO_3 (BNT) is an excellent candidate for the substitution of lead-based piezoelectrics (PZT) due to the combination of multifunctional, piezoelectric and ferroelectric properties. The underlying concerns are stablished by their field-induced extended strain behavior, surpassing to the PZT for “soft” applications, as well as their peculiar temperature-dependent properties. The occurrence of this behavior has been attributed to the particular “lone-pair” electronic configuration of Bi^{3+} which plays the same role of Pb^{2+} in the PZT ceramics. In CENAPROT, the BNT-BKT-BT quasi-ternary system is intensively studied, where BKT stands for bismuth potassium titanate and BT for barium titanate in compositions close to the morphotropic phase boundary, where the tetragonal and rhombohedral phases coexist, and the ferro/piezoelectric properties are maximized. The direct piezoelectric effect in these materials has potential applications piezoelectric energy harvesting especially dealing with thermal sprayed coatings, whereas the inverse effect is the basis of transducers, e.g. in the development of biosensors. An example of a biosensor for the early detection of pesticide carbaryl is presented and discussed.