Development of Materials for Industrial Applications

Vojka Žunič, Ines Bračko, Mojca Otoničar, Tina Šetinc, Marija Vukomanović

[1] Advanced Materials Department, Jožef Stefan Institute, Ljubljana, Slovenia

[2] Jožef Stefan International Postgraduate School (Nanosciences and Nanotechnology)

vojka.zunic@ijs.si, ines.bracko@ijs.si, mojca.otonicar@ijs.si, tina.setinc@ijs.si, marija.vukomanovic@ijs.si

Development of materials for industrial applications is associated with permanent increase in demands for: performance, effectiveness, toxicological and economical outcome of the final products. Therefore, our main goal is to improve the properties of industrially applicable materials with respect to: (i) better understanding of the basic processes and phenomena which occur in the matter, (ii) synthesis and processing of new materials and (iii) improvement of the materials' properties. Within that scope, three main groups of materials are being investigated: electroceramics, photocatalytic and biomedically applicable materials.

Photocatalytic properties of titanium dioxide (TiO_2) could be taken as advantage in manufacturing of antibacterial coatings of the white goods. Among the TiO_2 polymorphs, anatase exhibits the highest photocatalytic activity, mainly under ultraviolet irradiation. Photocatalytic efficiency of anatase depends on crystallinity, specific surface area and particle size. Therefore, our attempt was to improve these properties and to design a visible light responsive TiO_2. Nanocrystalline anatase with high specific surface area (up to 335 m^2/g) and small particle size (down to 5 nm) were prepared by the combination of sol-gel and solvothermal synthesis. Future research is aimed to achieve visible light activity of anatase by doping its' structure with small quantities of elements P, N, S and F.

Titanate-based nanotubes synthesized by the alkaline hydrothermal treatment of TiO_2 are characterized as a layered, lamellar structure with mesoporous morphology. In our research, the ability of ion-exchange of hydrothermally synthesized titanate nanotubes has been utilized for the formation of Ag-titanate nanotube composite via incorporation of silver nanoparticles onto the surface of nanotubes. Intercalation of silver nanoparticles enables modification of titanate nanotubes resulting in an enhanced photocatalytic activity at visible wavelengths and makes such composites applicable in photocatalysis and photodecomposition of water.

Research on piezoelectric materials was focused on $(Na_{1-x}K_x)_{0.5}Bi_{0.5}TiO_3$ (NBT-KBT) solid solutions and on the influence of their structure on the electrical properties. Upon cooling of sintered ceramics, the structure transforms from cubic to rhombohedral (NBT-rich) and tetragonal (KBT-rich) structure. At a Na/K = 4:1 in the NBT-KBT, a morphotropic phase boundary is formed, where the tetragonal and the rhombohedral phases coexist. In this region the values of the dielectric constant, the remanent polarization and the piezoelectric coefficient are enhanced in comparison with the NBT and KBT end members.

Relaxor ferroelectric behavior of sodium bismuth titanate (NBT) opens a possibility for application as a voltage-tunable capacitor. Hydrothermal technique was employed for the preparation of NBT powder. Nanosized crystalline particles were prepared from inexpensive precursors under moderate temperature conditions. Subsequent employment of NBT particles in the form of thin film will enable preparation of composite thin films with desirable properties.

Sonochemical synthesis method is applied for the synthesis of silver and hydroxyapatite/silver composite particles. Using this approach resulted in the formation of nanometer-sized particles of silver which were attached onto the surface of rod-like, submicrometer-sized hydroxyapatite particles. Due to the development of the pathogens in implant's surroundings high percent of immune system rejections of biomaterials for bone replacement appears. Formation of HAp/Ag coatings on the surface of bone implants or its local usage as bone filler is a possible industrial application of this material.