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Topics of dissertations

in study field **5.2.26 Materials**, study programme **Progressive materials and material design**, study beginning in academy year **2019/2020**

Topic 1: **Analysis of nitridation process of Al powders in gaseous nitrogen**

Supervisor: **Ing. Martin Balog, PhD.** (martin.balog@savba.sk)

The aim of the dissertation thesis is the fundamental description of the nitridation process of Al powders in gaseous nitrogen. The PhD student will study the effects of Al powder surface area, the effect of Mg and Sn content, the effect of temperature and time on the formation of AlN layer on the surface of atomised Al powder particles during nitridation process. Using various analyzes, the physicochemical processes will be described in detail in the distinct stages of the nitridation of Al porous powder samples. Phd student will determine the kinetics of AlN formation and the activation energy of these processes. The second part of the thesis will focus on the preparation of Al-AlN composites by quasi-isostatic forging from nitrided powder precompacts. The prepared composite consists of Al powder particles - grains which are strengthened and stabilized by the continuous network of AlN nanocrystals. The resulting forged Al-AlN composites will be characterized in terms of microstructure and mechanical properties, depending on the Al powder size and the AlN content. To study the nitridation process, PhD candidate will use the thermal analysis (DTA, DSC, TGA, dilatometry), microscopic observations (SEM, TEM), spectrometric methods (EBSD, EDS, EELS and WDS), X-ray diffraction (XRD) and mechanical testing (tensile test, notched toughness, DMA). The PhD student is expected to master experimental work such as sample preparation using laboratory powder-metallurgical techniques, to utilise the various analysis with interpretation of obtained results as well as a general explanation of the chemical-physical nature of the nitridation process of Al powders.

Topic 2: **On the effect of native TiO2 films on the mechanical properties of powder metallurgy Ti**

Supervisor: **Ing. Martin Balog, PhD.** (martin.balog@savba.sk)

The general purpose of the thesis is to study the influence of surface oxide (TiO2) films present on as-received Ti powders on the mechanical properties of Ti materials prepared from these powders. The work presupposes the detailed study of the surface of Ti powders prepared by different techniques, the description of surface oxides and their stability as a function of temperature. PhD thesis further includes the characterization of Ti compacted by various powder metallurgy methods and the detailed characterization of the microstructure with an emphasis on the presence of dispersoids formed in situ by fragmentation of surface TiO2 films. The stability of TiO2 dispersions will be determined as a function of annealing performed at different temperatures and the technological parameters used during the consolidation. In the powder-metallurgical community, the presence of O in the structure of Ti is generally undesirable, as it fundamentally degrades the toughness of the material. At the same time, the O content is very difficult to reduce as it is given by the surface of the powder itself, i.e. by the presence of TiO_2 films, which dissolve in the structure during preparation. Conversely, as is the case with various oxides dispersion strengthened and stabilized metals (ODS), if by selection of proper technological parameters nanometric TiO_2 dispersoids are retained in the structure, they can have a positive stabilizing and reinforcing effect without having a negative effect on ductility. The work aims to distinguish the effect of O present in the form of a solid solution and in the form of TiO_2 dispersoids on mechanical properties. For the characterization of powders and compacted materials, the doctoral candidate will use methods of thermal analysis (DTA, DSC, TGA), electron microscopy (SEM, HRTEM), spectrometric methods (EBSD, EDS, EELS and WDS), X-ray diffraction and tensile tests. The doctoral work will run in parallel with the research project and the student will collaborate closely with a foreign university.

Topic 3: **Development of high-strength precipitation hardenable complex concentrated alloys**

Supervisor: **Ing. Juraj Lapin, DrSc.** (juraj.lapin@savba.sk)

The research in the field of structural materials for applications at extreme conditions such as high temperatures, aggressive environment and combined loading conditions is focused on a very perspective group of complex concentrated alloys (CCAs). The CCAs should replace currently used superalloys, which will require beside the design of the basic chemical composition also an extensive research of their high temperature strengthening. PhD thesis will be focused on the design, metallurgical preparation and casting of novel high-strength precipitation hardenable Co-Cr-Fe-Ni-Al-X type of CCA, where X is minor alloying element. The improvement of high-temperature strength will be achieved by an appropriate alloying and precipitation strengthening of disordered solid solution by intermetallic phases. The PhD student will participate on preparation of CCAs using induction melting and casting. The student will propose alloying of the basic system by minor additions and will study the effect of the selected alloying additions on substitution/precipitation strengthening processes. Microstructure, chemical composition and phase composition of the alloys will be characterised by optical microscopy, scanning electron microscopy, transmission electron microscopy, energy dispersive spectroscopy, wavelength dispersive spectroscopy and X-ray diffraction analysis. Mechanical properties of the alloys will be studied by tensile testing, compression testing, creep and hardness measurements. The candidate needs to demonstrate laboratory experimental skills, knowledge of materials, phase diagrams, basic knowledge of experimental methods for microstructure characterisation, mechanical testing of materials as well as English language knowledge.

Topic 4: **Multicomponent diboride films for high temperature applications**

Supervisor: **doc. Ing. Marián Mikula, PhD.** (marian.mikula@savba.sk)

The proposed thesis deals with an experimental development of principally new hard coatings based on borides with stable structure and excellent mechanical properties up to temperatures approaching 1500°C and deposited by the novel deposition methods of highly ionized magnetron sputtering. The main idea is the development of hard high temperature multicomponent nanocomposite coatings originating from the systems TiB_2, CrB_2, TaB_2, etc. by alloying with additional transition metals with high melting temperatures (Zr, Hf, Ta, Nb, V, Mo, W, Y, etc.). The main objective of work is the increase of the temperatures of the coating structure stability and degradation of mechanical properties well above 1000 °C by means of the understanding of the mechanisms of nanostructure formation and decomposition of solid solutions deposited by novel deposition technologies. In addition to measuring the mechanical properties using nanoindentation and tribological techniques, further important properties of the coatings which are related to the mechanical behavior of thin films will be investigated: thermal stability of formed nanostructures, their decomposition processes, oxidation resistance, oxidation kinetics, etc. using several analytical methods for example scanning electron microscopy (SEM), wave dispersive X-ray spectroscopy (WDS), X-ray photoelectron spectroscopy (XPS), X-ray diffraction analysis (XRD), transmission electron microscopy (TEM) etc.