XXXII Panhellenic Conference on Solid State Physics and Materials Science
Conference Center "Carolos Papoulias", 18-21 September 2016, Ioannina, Greece

The influence of wetting phenomena, thermodynamics and kinetics in the production of ceramic/metal composites

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The issue of thermodynamics (measured in equilibrium regime with surface and interfacial energies and wetting angles) and kinetics at ceramic-oxide/metal interfaces is important in joining techniques to obtain a mechanically strong interface. This presentation will focus in joining of alumina and zirconia either together or with metal devices, usually made of Ti or Ti6Al4V alloy. Whether direct bonding or brazing are considered, the system is seemingly simple, since it involves an oxide-ceramic (Al_2O_3 or ZrO_2), an active element (Ti), and noble metals (that ensure lack of oxidation, e.g. Pt, Au, Ag, or Cu), while high vacuum (10^{-6} mbar) is always applied during the experiments, due to high affinity of Ti for oxygen. Nevertheless, the microstructures of the interfaces developed at different temperatures, significantly differ one from the other, depending on each particular system. The general common features of the interfaces are the followings: (a) The reactive element (Ti) rapidly migrates towards the interface and reduces the ceramic oxide, yielding a Ti-oxide (not the same in every system) that is adjacent to the oxide, and (b) the sequence of reaction zones, whose thickness is determined by diffusion phenomena, is governed by the binary phase diagrams. However, (a) active elements, such as Al and V, can affect the microstructure of the interfacial reaction zone, (b) the features of other (more inert) elements crucially determine the microstructure and the strength of the interface, and (c) there is very different behaviour of Al_2O_3 (that is totally reduced) than ZrO_2 (that is blackened in the most of cases). Thermodynamic analysis of the experimental results suggests that the formation of the different oxides apparently depends on the kinetics of the reactions. The presentation will also briefly outline (a) phenomena which can be potentially observed at interfaces and influence interfacial strength, such as cracking (due to mismatch of thermal and mechanical properties of the contacting work-pieces), dissolution of ceramic, and penetration of reaction products along grain boundaries, including cases related to the production of glass-foams, and (b) the *in-situ* growth of superconductive nano-wires (with diameter of 15-35 nm) of Sn-mono-crystals, which exhibit a critical magnetic field (H_c) 30 times higher than bulk Sn, attributed to the nano-sized dimensions of Sn, encapsulated in C-nano-tubes, produced by catalytic chemical vapor deposition (CCVD) (Jankovic, et al. Nano Lett.2006;6:1131).