ROLE OF COUPLED TRANSPORT IN THE FABRICATION OF SODIUM β”-ALUMINA CONTAINING CERAMICS BY A VAPOR PHASE PROCESS

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ABSTRACT

This work presents a novel approach to the fabrication of Na-β”-alumina containing ceramics, and demonstrates the role of coupled diffusion in multi-phase materials. Dense, sintered, polycrystalline bodies of single phase α-alumina and two-phase mixtures of α-alumina + yttria-stabilized zirconia (YSZ), wherein both phases are contiguous, were packed in Na-β”-alumina powder, and heat-treated in air over a range of temperatures between 1300 and 1450^{o}C for up to several hours. This led to the conversion of α-alumina in the near surface region into Na-β”-alumina. The depth to which this conversion occurred was dramatically different in the two materials. For example, at 1400^{o}C, in the starting single phase α-alumina samples, the depth to which Na-β”-alumina formed was less than 100 microns in 16 hours. By contrast, in the starting α-alumina + YSZ composites, the thickness converted into a mixture of Na-β”-alumina + YSZ under identical conditions was over 1000 microns. Also, the kinetics of conversion in the single-phase α-alumina starting material was diffusion-controlled. By contrast, in the α-alumina + YSZ two-phase material, the kinetics were linear in time over the range of conversion thicknesses examined. These observations are rationalized on the premise that conversion of α-alumina into Na-β”-alumina requires the transport of Na_2O, or a coupled transport of $2Na^{+}$ and O^{-2}, through the converted layer. Na-β”-alumina is an excellent conductor of Na^{+} ions. However, transport of O^{-2} ions through it is very sluggish. Conversion kinetics in the case of single-phase α-alumina are thus controlled by O^{-2} diffusion. By contrast, in the α-alumina + YSZ composites, a coupled transport of $2Na^{+}$ and O^{-2} can occur in such a way that while sodium ions transport through the formed Na-β”-alumina, oxygen ions predominantly transport through YSZ, which is an excellent oxygen ion conductor. Experimental results are consistent with theoretical predictions. Similar results were observed using samples in which YSZ was replaced with rare earth oxide doped CeO_2, or when the packing powder contained a K_2O source, thereby leading to the formation of K-β”-alumina + YSZ or K-β-alumina + YSZ composites.