602b Advanced Ceramic Materials for High Temperature Coal Combustion

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The development of advanced coal-fired power generation systems is receiving considerable worldwide attention. Further improvement in the thermal efficiency of steam cycle power plants is currently achieved by increasing the steam temperature and pressure. For example, the thermal efficiency is increased from ~40% to nearly 50% when the steam temperature and pressure are raised from 1,000oF/3,500 psi to 1,500oF/5,500 psi during advanced pulverized coal combustion. Increased combustion temperatures also result in more efficient coal use, reduced greenhouse gas emissions (~20% less CO2), more complete SOx and NOx removal (~99%), as well as afford cleaner and, therefore, more marketable coal combustion byproducts, such as fly ash. However, the main challenge limiting the application of higher combustion temperatures over a range of coal qualities is that even optimized austenitic steels used in combustion systems undergo severe fireside corrosion by molten alkali-iron-trisulfates and coal slag (e.g. CaO-SiO2-'FeO'-K2O-SO3-Al2O3) as well as steam oxidation in the presence of SOx, CO2, etc. The influence of materials on these systems can be considerable as it is necessary that components have adequate lifetimes in their required operational environments. Therefore, there is a critical need in new protective coatings with improved corrosion resistance, thermal conductivity and mechanical strength for more efficient power generation during high temperature coal combustion. Ceramics based on mixed metal niobates and tantalates and possessing the pyrochlore, fluorite and other crystal structures (Ln3MO7, where Ln = rare earth, Y or La; M = Nb or Ta) are particularly promising as protective coatings in aggressive environments at high temperature in view of their superior mechanical strength, extremely high melting points (>3900oF) and expected high corrosion resistance. In this study, Y- and La-containing Ln3MO7 (M = Nb or Ta) materials were synthesized by the conventional ceramic method in which Ln2O3, M2O5 used as starting materials were sintered at high temperatures (1550 0C) to obtain desired phases. The obtained materials were characterized with respect to their crystalline phase and elemental composition, crystal morphology, structural porosity and microstructure by XRD, electron microscopy (SEM) with EDS, nitrogen adsorption-desorption isotherms and bulk elemental (ICP) analysis. Thermal expansion coefficients of these materials were measured using high temperature dilatometer and elastic modulii were obtained using spherical indentation method. Thermal expansion behavior of these materials was similar to typical austenitic steels used in boiler materials. Thermal expansion behavior match of the coating with the substrate is very critical factor in obtaining stable coatings at high usage temperatures. The mixed metal oxide phases were spray-coated onto on stainless steel substrates using organic binders, plasticizers and dispersants to enhance the adhesion of these coatings. These mixed metal oxide coatings were investigated under simulated and real corrosive boiler conditions for extended time periods (>500 h). Metal oxides were characterized before and after corrosion testing by XRD, SEM and elemental analysis to study the effect of extremely aggressive conditions on their structure and extent of corrosion.