Abstract

Lanthanum magnesium hexaaluminate (LMHA, $LaMgAl_{11}O_{19}$) was synthesized by aqueous sol gel processing. The microstructure of the parent LMHA was tailored by neodymium doping. The changes of thermo-physical and mechanical properties of the neodymium doped lanthanum magnesium hexaaluminate ($La_{(1-x)}Nd_xMgAl11O19$; x=0, 0.3, 0.4 and 0.5; LNMHA) were investigated as a function of doping concentration as well as temperature. It is found that the LMHA has platelet morphology and randomly grown platelets form a porous interlocking structure at 1450°C for 2h and retain the same even at 1600°C. On the other hand self-reinforced, card house kind of structure is observed in doped specimens. EDS results reveal that the rare earth rich magnesium hexaaluminates were preferentially grown more than the stoichiometric rare earth hexaaluminates caused this kind of microstructural modification. The thermo-physical as well as mechanical properties were improved phenomenally by the doping. Thermal conductivity was decreased from 2.56 W/mK to 1.95 W/mK whereas coefficient of thermal expansion was increased from 9.6 $\times 10^{-6}$/°C to 10.54 $\times 10^{-6}$/°C. The micro-hardness and fracture toughness were also improved significantly from 11.92±0.05 to 14.1±0.07 GPa and 4.86±0.07 to 6.74±0.06 MPa.$m^{1/2}$ respectively.

Further improvement of LNMHA ceramics were made by forming composites with Yttrium aluminium garnet (YAG, $Y_3Al_5O_{12}$) and the composites were also synthesized by aqueous sol gel processing. YAG is well known for its excellent mechanical properties and extremely low oxygen ion diffusion. Thus the composites were expected to have superior properties. Microstructure of LNMHA was again altered by the presence of spherical garnet phase. Card house structure was altered to a cell-nucleus type of structure. Platelets of LNMHA form the cell and near spherical YAG is the nucleus. Thermo-physical and mechanical properties were improved one step more. The thermal conductivity of the composites decreases further to 1.75 W/mK with a little sacrifice of the thermal expansion coefficient (9.90 $\times$ 10^{-6}/°C) and fracture toughness (4.89±0.12 MPa.$m^{1/2}$). Increased hardness (14.44±0.06 GPa) is observed for the composites.

TBCs of LMHA, LNMHA, LNMHA−YAG and 7 wt% yttria stabilized zirconia (YSZ) specimens were formed on bond coated (NiCrAlY) nickel based super alloy (Inconel 718) using atmospheric plasma spraying. The LMHA and YSZ are considered as standard of hexaaluminate series and industrial standard respectively. They were characterized thoroughly and the performance of the coatings was evaluated by isothermal aging and thermal cycling life at 1400°C. Hot corrosion behaviour of them was also studied under molten sulfate-vanadate salt at 1050°C for 100 h. The higher sintering resistance was observed for hexaaluminate series whereas YSZ coating undergoes severe sintering. The LNMHA was found to be the best sintering resistance. The thermal cycling life (TCL) of LNMHA (7851 cycle) as well as LNMHA−YAG coatings (4262 cycle) were much better that the parent LMHA (2904 cycle) as well as YSZ (1874 cycles). TCL of LNMHA was around 2.7 and 4.2 times higher than the LMHA and YSZ coating. Improved thermo-physical and mechanical properties were primarily contributed towards longer TCL. The main failure mechanism of the TBCs was found to be the delamination of the top coat at the interface of topcoat and bond coat. Hot corrosion properties of both the specimens were much better than the parent LMHA as well as YSZ. Based on the above results, it can be concluded that the LNMHA and LNMHA−YAG composites are the most promising candidates for advanced TBC operating even at 1400°C.

Keywords: Thermal barrier coatings; atmospheric plasma spraying; sol gel processing; hexaaluminates; composites; isothermal aging; thermal cycling life; hot corrosion.