Synthesis of novel La-B-C single source precursor and ceramization for ultra-high temperature functional applications

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Abstract:

La-B-C ceramic composite systems are an interesting class of materials that find its use in many applications such as resistors, thermistors, gas sensors, electrodes, heating elements, fuel cells and batteries. Most of these rare earth metal borides and carbides are well known for their high-temperature stability and good electrical properties because of a spare electron after donation of two electrons to the boron sublattice gives rise to the formation of small range polarons. These materials are in general obtained through solid-state reactions, melt electrolysis, vapour deposition, metal gas reactions and combustion synthesis. These conventional strategies usually result in chemical heterogeneities, the requirement of high synthesis temperatures and offer little flexibility. A novel alternative involves the usage of single source preceramic polymers that circumvents the aforementioned issues offering enhanced control and diverse product forms such as fibers, thin films, etc. Hence, in this work, lanthanum carbide (LaC_2) and lanthanum hexaboride (LaB_6) nanocomposites were prepared via solid-state carbothermal treatment of single source polymer precursors. The polymers for the polymer-derived ceramics route were prepared by the modification of phenolic resin with lanthanum and boron precursors (denoted as B-Lamp). The B-Lamp resins were crosslinked and pyrolyzed upon which they were converted into amorphous ceramics. Chemical modification of phenolic formaldehyde (PF) resin with lanthanum acetylacetonate hydrate and boric acid was confirmed through spectroscopic techniques (FTIR) and the composition with maximum amount of reacted lanthanum and boron was determined. Thermogravimetric analysis was done for crosslinked single source precursors to determine thermal decomposition, pyrolysis temperature and ceramic yield. High temperature heat-treatment of these amorphous ceramics led to the crystallization of nanocomposites yielding phases such as $LaB_6/B_{13}C/LaC_2$ which were confirmed through X-ray diffraction (XRD) and

high-resolution transmission electron microscopy (HR-TEM). Interestingly, crystallization of boron carbide was observed at specific heat treatment and composition. The structural decomposition of icosahedral boron carbide upon heat-treatment at higher temperatures and crystallization of $LaB_6/B_{13}C/LaC_2$ were revealed through Raman spectra and HR-TEM. The optimized ceramic composition was sintered using spark plasma sintering and characterized. The electrical conductivity and coefficient of linear thermal expansion were measured to exemplify the potential of these materials as high temperature electrical conducting materials possessing low CTE.