Spark plasma sintering of lanthanide doped Lu_2O_3

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Lutetium oxide (Lu_2O_3) is a host material with favourable properties for the detection of high-energy ionizing radiation (X-ray, γ-ray). It features one of the highest densities among inorganic host materials (9.4 g/cm^3) along with high effective atomic number (Z_{eff} = 67), both of which attribute to a short attenuation length of a high energy photon followed by its scintillation conversion into lower energy UV-Vis light. Due to its high thermal conductivity and low coefficient of thermal expansion, it has also attracted attention for development of high power lasers. Despite its favourable properties for optical applications, its fabrication in the form of single crystals is seriously hindered by the very high melting point of 2490 °C. Because of this, extensive research has been carried out in recent years to prepare this material in the form of a transparent ceramics.

In this work, the fabrication of dense ceramics of Ln:Lu_2O_3 (Ln = Pr, Eu, Tb, Dy) by spark plasma sintering is presented. Nanocrystalline powders of Ln:Lu_2O_3 were prepared using co-precipitation followed by a pre-annealing treatment at a high temperature of 1000 °C or 1250 °C. These powders were SPS-processed into dense ceramics using a two-step sintering program. The pre-annealing affected the microstructure and transmittance of sintered ceramics. Transparency was achieved for samples pre-annealed at the higher temperature of 1250 °C. Post-annealing of sintered ceramics increased its transmittance in the visible region and removed the dark colouring of SPS-processed ceramics. However, if the post-annealing temperature is too high, the transmittance can decrease instead, to a point where the transparency is lost. The dense ceramics exhibited luminescence corresponding to the element doped into the Lu_2O_3 host. Both radioluminescence and photoluminescence emission of the Ln:Lu_2O_3 dense ceramics is fully determined by radiative transitions of the Ln^{3+} luminescent centres. The luminescence integral light yield increased with post-annealing of the sintered ceramics.

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