A STUDY OF ELECTRICAL PROPERTIES OF ZIRCON CERAMICS DOPED WITH DIFFERENT DOPANTS

U. DAHANAYAKE AND B.S.B. KARUNARATNE

Department of Physics, Faculty of Science, University of Peradeniya

Zircon ($ZrSiO_4$) is tetragonal: $I4_1$ / amd, Z=4 and the ideal structure consists of chains of alternating, edge-sharing SiO_4 tetrahedra and ZrO_8 triangular dodecahedra extending parallel to crystallographic axis c. Zircon is an abundant and inexpensive natural mineral and is mined in very large quantities throughout the world. This material is recognized as a potential ceramic material for the applications at high temperature due to its good combination of many attractive properties such as low thermal expansion, low heat conductivity, good chemical stability, excellent thermal shock resistance and good high temperature properties. Although, many studies on structural properties of zircon ceramics have been reported in literature, electrical properties of zircon has received less attention. It was one of the two reasons why this material was selected for this investigation and the other was the superfluity of zircon in the coastal areas of Sri Lanka. This paper presents the results of a preliminary study on electrical properties of zircon ceramics doped with different dopants. It is expected that the presence of defects in the zircon host structure introduced by doping, could lead to higher electrical conduction. The dopants used in this study were Y_2O_3, Fe_2O_3, MgO, Yb_2O_3 and Eu_2O_3.

The study revealed that the electrical conductivity and the dielectric constant (ε_r) of doped zircon increased with increasing temperature, irrespective of the dopant. A good conductivity enhancement was observed in 10 mol% Y_2O_3 doped zircon and 10 mol% Fe_2O_3 doped zircon with the conductivity values 7.74×10^{-5} S cm^{-1} (ε_r – 409;10^5 Hz) and 2.56×10^{-5} S cm^{-1} (ε_r – 707; 10^5 Hz) respectively at 700°C. These conductivity values are about one order of magnitude higher than that of zircon without any dopant (3.83×10^{-6} S cm^{-1}). Since the Y_2O_3 doped zircon system showed the highest electrical conductivity, a broad range of Y_2O_3 dopant levels were investigated. This revealed that the conductivity increased with the dopant level up to 10 mol%. Further addition of Y_2O_3 was not effective to conductivity enhancement probably due to increasing the excess content of Y_2O_3 as a second phase. It was observed that the dielectric constant of 10 mol% Fe_2O_3 doped and 10 mol% Y_2O_3 doped zircon systems, having higher conductivity values, increased rapidly with increasing temperature. In contrast, the other systems having lower conductivity values showed only a slight increment in the dielectric constant with increasing temperature. The microstructures of the sintered ceramics were studied using Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray analysis (EDX). It was evident from subsequent microstructural studies that the additive oxides Yb_2O_3, MgO and Eu_2O_3 were not substituted into the host structure of zircon and appeared as a second phase. As a result there was no conductivity enhancement due to doping of these oxides. In the case of Y_2O_3 (Y^{3+}) and Fe_2O_3 (Fe^{3+}) doped samples, the most likely reason for the conductivity enhancement is that Y^{3+} and Fe^{3+} ions get substituted into the host structure of zircon creating O^{2-} vacancies to maintain the charge neutrality of the material.