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Fabrication of Dual Phase Magnesia-Zirconia Ceramics Doped With Plutonia and Erbia

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P.G. Medvedev
J.F. Jue
S.M. Frank

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P. G. Medvedev, J. F. Jue, S. M. Frank, pavel.medvedev@inl.gov
Idaho National Laboratory, P.O. Box 1625 Idaho Falls, ID 83415-6160

I. INTRODUCTION

Dual phase magnesia-zirconia ceramics doped with plutonia and erbia are being evaluated as an inert matrix fuel (IMF) for light water reactors (LWR). The motivation for this work is to develop an IMF with a thermal conductivity superior to that of the fuels based on single-phase yttria stabilized zirconia. The innovative fuel developed at INL is comprised of two major phases: pure MgO and quaternary solid solution consisting of MgO, ZrO_2, Er_2O_3 and PuO_2. Pure MgO phase acts as an efficient heat conductor. It has been shown [1] that dual phase MgO-ZrO_2 ceramics have the thermal conductivity superior to that of UO_2 and have notable chemical resistance to water at the temperature of 573 K and pressure 8.6 MPa, which makes them attractive for use as an IMF matrix in LWRs.

II. DESCRIPTION OF ACTUAL WORK

Ceramics were fabricated from the oxide powder mixture using conventional pressing and sintering techniques. Oxide powders were mixed as aqueous slurry, dried, calcined, granulated, cold-pressed, and sintered in air at 1700^{o}C for 7.5 hours. The product was characterized by scanning electron microscopy (SEM), energy and wavelength dispersive x-ray analyses (EDS and WDS), x-ray diffraction (XRD) analysis and immersion density measurements.

III. RESULTS

A photograph of a ceramic sample containing 33.2% MgO, 49.8% ZrO_2, 7% Er_2O_3, and 10% PuO_2 by weight is shown in Fig. 1. Sample density determined by water immersion was 4.75 g/cm^3.

Scanning electron microscopy images (Fig. 2) revealed two major phases present in the sample: pure MgO and $Mg_{0.100}Zr_{0.761}Er_{0.069}Pu_{0.069}O_{1.865}$. The phase composition was determined from the EDS and WDS results assuming that all Er and Pu dissolved completely in the quaternary solid solution phase.

X-ray diffraction analysis (Fig. 3) reinforced the SEM results relative to the identification of the major phases present in the product. In addition, XRD detected trace amounts of the PuO_2-rich phase (<1000 ppm). The lattice parameters of the MgO and $Mg_{0.100}Zr_{0.761}Er_{0.069}Pu_{0.069}O_{1.865}$ phases were 0.4212 nm and 0.5117 nm respectively.

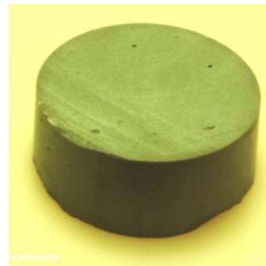

Fig. 1. A fragment of the ceramic sample obtained by sintering MgO, ZrO_2, Er_2O_3 and PuO_2 powder mixture. Density is 92% of theoretical.

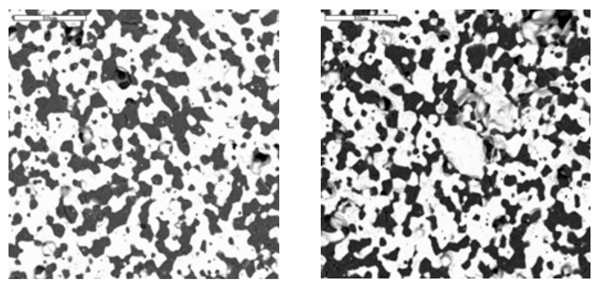

Fig 2. SEM images of the ceramic showing pure MgO as a dark phase and $Mg_{0.100}Zr_{0.761}Er_{0.069}Pu_{0.069}O_{1.865}$ quaternary solid solution as a bright phase. Note a larger agglomerate of the bright phase depicted on the left. The scale bars are 50 microns.

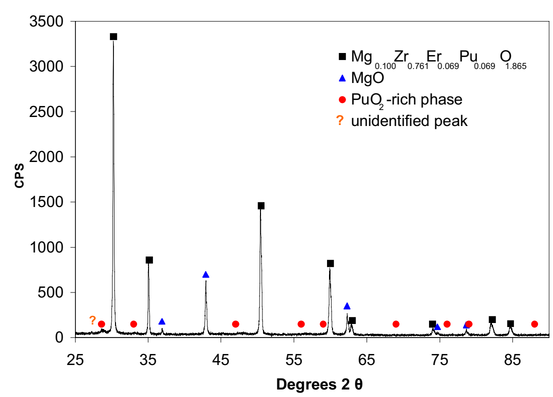

Fig. 3. XRD spectrum obtained from a ground ceramic sample.

IV CONCLUSIONS AND FUTURE WORK

The feasibility of fabrication of the innovative inert matrix fuel was demonstrated during the fiscal year 2005. Fabrication of several experimental fuel pins and their irradiation in the INL's Advanced Test Reactor as a part of the LWR-2 test [2] is planned for the fiscal year 2006 and 2007.

ACKNOWLEDGEMENT

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