Thermal Conductivity Estimation of Fully Ceramic Microencapsulated Pellets with ZrO_2 as Simulated Particles

*Ariyani Kusuma Dewi[1,2], Souichirou Yamaguchi[1], Takashi Onitsuka[1] and Masayoshi Uno[1]
[1]University of Fukui, [2]National Nuclear Energy Agency (BATAN) Indonesia

Abstract

Thermal conductivity of fully ceramic microencapsulated (FCM) fuel estimation is important to provide accurate prediction of fuel performance and safety aspect of nuclear fuel. ZrO_2-SiC pellets with FCM fuel concept were fabricated using SPS, and characterize using laser flash analysis to measure thermal conductivity. Maxwell-Eucken model that was modified by considering the parameter of matrix-particle interaction was in good agreement with the measured thermal conductivity of ZrO_2-SiC pellets.

Keywords: Fully ceramic microencapsulated, thermal conductivity, ZrO_2-SiC pellets

1. Introduction

FCM fuel consist of tri-structural isotropic (TRISO) particles embedded in dense silicon carbide (SiC) matrix. TRISO fuel particle technology has been developed and optimized for high temperature gas-cooled reactor (HTGR) over the past five decades[1], while in conventional HTGR fuel these TRISO particles are embedded in graphite matrix. The replacement of matrix material based on the consideration of tremendous merits of SiC.

Most of previous studies[2,3] on estimation of FCM thermal conductivity focused on the particle volume fraction inside the matrix. Present work deals with the estimation of thermal conductivity with considering the interaction between components forming fuel pellet. In this work, ZrO_2 (5%Y_2O_3) particles were chosen as simulated of TRISO particles.

2. Experimental

The ZrO_2-SiC FCM fuels with ZrO_2 volume fraction of 0% to 30% and with ZrO_2 particle size of 400 µm were prepared by spark plasma sintering (SPS) method at 2073 K under uniaxial pressure of 92 MPa for 15 min. The SPS pellet then was characterized by laser flash analysis (LFA) to obtain thermal conductivity data, and by scanning electron microscopy with energy dispersive spectroscopy (SEM-EDS) to observe the pellet cross-sectional microstructure.

3. Result and discussion

The existences of pores in the SiC matrix, interfacial layer and gaps between ZrO_2 particles and SiC matrix observed by SEM-EDS (Figure 1a, 1b, 1c) were suspected as the cause of decreasing the pellet thermal conductivity. The formulas were obtained to correct thermal conductivity values for the matrix porosity and particle matrix interface and gaps. These corrections then inserted to the basic equation of Maxwell-Eucken to obtain effective thermal conductivity and plotted with the measured value as shown in Figure 1d in the case of volume fraction of ZrO_2 of 30%.

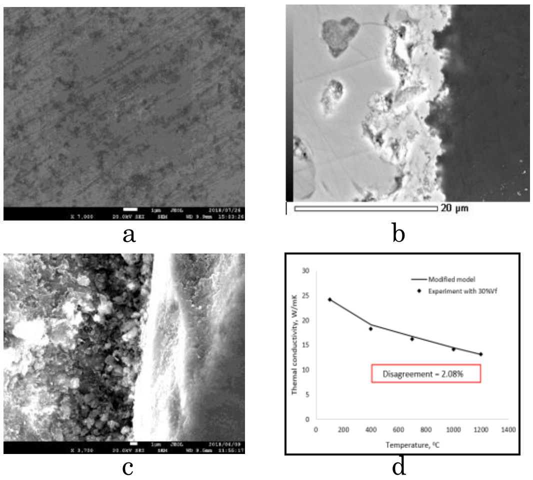

Figure 1. a. SiC matrix pores; b. Interfacial layer; c. gaps between ZrO_2 particles and SiC matrix; d. estimated and measured thermal conductivity ZrO_2-SiC pellet.

4. Conclusion

The simulated FCM pellets were fabricated by SPS in order to obtain the densified samples. The estimation model considering matrix porosity, interfacial layer, and gas conductivity inserted to the basic equation resulting in close agreement between the measured and estimated thermal conductivity.

References

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