§40. Sintering Density Dependence on the Thermal Diffusivity of the Carbide Materials for Shielding Blankets

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Some carbides, for example, Tungsten Carbide (WC) and Boron Carbide (B_4C), and metallic hydrides are considered as candidate materials of thermal shield of the blanket system for Force Free Helical Reactor (FFHR). There are few published data on thermophysical properties, for example, thermal conductivity, thermal diffusivity, and specific heat capacities of carbides and hydrides comparing those of metals and oxides. Especially, there are no data which is validated whose reliability. In order to contribute to thermal design of the blanket system from the view point of thermophysical properties field, we measured and reported thermal diffusivity of WC and B_4C last year[1)].

This year, we evaluated uncertainty of these thermal diffusivities of WC and B_4C. Thermal diffusivity is obtained from specimen thickness and heat diffusion time by the laser flash method[2)]. It also depends on temperature. Uncertainty factors are mainly as follows; uncertainty of specimen thickness, uncertainty of estimation of heat diffusion time, uncertainty of temperature where the measurement is carried out. Thickness variation in a specimen and uncertainty of micrometer are included in the uncertainty of specimen thickness. The heat diffusion time uncertainty consists of time scale of the temperature rise curve, time delay of the detector, finite pulse width of the laser, heat loss effect and analysis uncertainty of the temperature rise curve. The uncertainty of temperature is estimated from stability of temperature and temperature scale of the calibrated thermometer. It is exchanged to a factor of thermal diffusivity uncertainty considering the temperature dependence. Uncertainty attributed to gold thin film and graphite spray coating is additionally considered as 3 %. Combining these four factors, uncertainty of thermal diffusivity measurement was 4.8 % - 9.6 % in the case of WC with the coverage factor k=2 that means 95% reliable range. In the case of B_4C, it was evaluated as 8.9 % - 17.1 %. Large uncertainties more than 10 % mainly was caused by large uncertainty of temperature. Here, we obtained reliable thermal diffusivity of WC and B_4C. These data with uncertainty were opened in the thermophysical properties database[2)]. We made presentations at conferences in the thermophysical properties field[3)].

Another object is an investigation of density effect of thermal diffusivity for carbides. We prepared a low density specimen of B_4C and measured. Figure 1 shows thermal diffusivity of sintered B_4C specimens with different density. The thermal diffusivity of dense B_4C which consists of natural boron is measured last year expressed with uncertainty error bar. The density of it is about 2.5×10^3 kg/m^3. We measured thermal diffusivity of a low density B_4C specimen which is 10 mm in diameter and 5 mm in thickness. It had 1.3×10^3 kg/m^3 density as a half of that of dense specimen. The specimen was coated by about 100 nm thick Au thin film and about 10 μm thick graphite spray coating for the laser flash measurement. The measurement was carried out at room temperature and 200 ^oC. It was found that thermal diffusivity of a low density specimen is smaller than that of a dense specimen. Thermal diffusivity is sensitive to structure of materials. This result is reasonable. Note that thermal diffusivity of a low density specimen measured in vacuum is 14 % smaller than that measured in air at room temperature in Fig. 1. It is known that a porous material shows atmosphere dependence of thermal diffusivity and thermal conductivity. We observed a similar phenomenon for a low density B_4C.

In summary, it was found that thermal diffusivity of B_4C varies by density. We confirmed that thermal diffusivity depends on environmental atmosphere in the case of porous B_4C. The dense B_4C may be suitable rather than a low density B_4C for use as thermal conductive spreader in the view of thermal design. If low density B_4C is used, it will be important to consider environmental atmosphere at the thermal design.

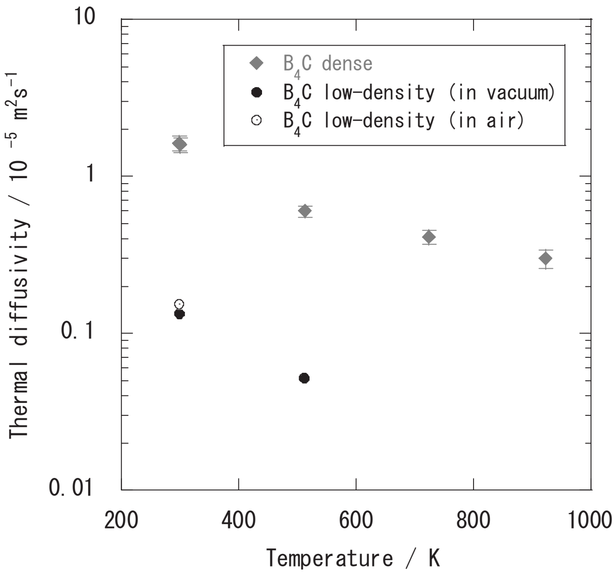

Fig. 1. Temperature dependence of thermal diffusivity of sintered B_4Cs. ◆: dense specimen, ●: low density specimen measured in vacuum and ○: in air.

1) Hishinuma, Y., Akoshima, M., Yamashita, Y., Tanaka, T., Sagara, A., Muroga, T., 23rd International Toki Conference (ITC-23), Toki, Japan 18-21. Nov. (2013)
2) http://tpds.db.aist.go.jp/
3) Akoshima, M., Yamashita, Y., Hishinuma, Y., Tanaka, T., Sagara, A., Muroga, 20th European Conference on Thermophysical Properties, Porto, Portugal, 31. Aug. -4. Sep. (2014) and 35th Jpn. Symposium on Thermophysical Properties, Tokyo, Japan, 22-24 Nov. (2014).