論文 / 著書情報
Article / Book Information

題目(和文)	強磁場下における高配向B4Cセラミックスの作製とその特性
Title(English)	Fabrication of highly oriented B4C ceramics under strong magnetic field and their properties
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種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
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論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	Materials Science and Engineering, Nuclear Engineering 系 コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of （Engineering）
学生氏名： Student's Name	Muhammad Fajar	指導教員（主）： Academic Supervisor(main)	Assoc. Prof. Katsumi Yoshida
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Boron carbide (B_4C) pellets have been used as neutron-absorbers for fast reactors due to their high neutron absorbability, high melting point, thermal stability at high temperature, and low induced radioactivity after irradiation. However, the lifetime of B_4C pellets has been limited due to swelling effect and thermal stress leading to cracking and fragmentation of neutron-absorbers. High-performance B_4C pellets with excellent mechanical and thermal properties have been considerably required to extend their lifetime and enhance the safety of fast reactors. Generally, the properties of ceramics depend on the crystal orientation. Therefore, it is expected that their properties can be enhanced by achieving highly crystal orientation. In this study, highly oriented B_4C ceramics with/without alumina (Al_2O_3) as a sintering additive were prepared under a rotating strong magnetic field followed by spark plasma sintering, and their mechanical and thermal properties were evaluated. In addition, the effect of crystal orientation on the properties of B_4C ceramics was discussed.

Initially, suspensions with low viscosity and well-dispersion were prepared by mixing polyethilimines (PEI), and B_4C with/without Al_2O_3 powder. The pH of the suspension was adjusted to be 6. The slip casting was performed under normal condition (random) and rotating strong magnetic field of 12T (high orientation) to produce green bodies, followed by densification of the green bodies by spark plasma sintering (SPS) and hot pressing (HP), at 1700-1800^{o}C and 1950^{o}C, respectively.

Al_2O_3 addition to B_4C ceramics successfully enhanced densification (97.8%) compared to specimens without Al_2O_3 addition. The X-ray diffraction (XRD) and Rietveld analysis results found that aluminum borate (Al_5BO_9) was formed in B_4C with Al_2O_3 as secondary phase as much as 1.9-2.6%. It is considered that the formation of Al_5BO_9 assisted the densification of B_4C ceramics during sintering. The degree of orientation of highly oriented B_4C was evaluated by the calculation of the Lotgering factor (*f*). Highly oriented specimens indicated the highest diffraction peak of XRD pattern related to the (003) plane of B_4C (*c*-axis orientation), and the *f* values were ranging from 0.4-0.7. These *f* values indicated that the high *c*-axis orientation of B_4C was successfully achieved. The presence of Al_2O_3 as a sintering additive lowered the *f* values of oriented specimens (around *f*=0.4). Observation of electron backscattered diffraction (EBSD) map on the top plane, the specimen prepared without strong magnetic field showed random orientation. In contrast, the highly oriented specimen grains on the top plane of the EBSD map indicated the (0001) plane and the plane at a small angle with the (0001) plane. In this EBSD map, the (0001) plane is along with *c*-axis orientation. From the results, the effect of Al_2O_3 addition successfully increases the densification of highly oriented B_4C ceramics at the same time, reduces the degree of orientation.

Flexural strength measured on the top plane or along the *c*-axis was 547 ± 18 MPa, and the value along the *c*-axis was higher than the value perpendicular to the *c*-axis (452 ± 15 MPa). The result could be explained by the cleavage plane in B_4C crystal, located along (012) plane. The hardness, elastic modulus, and fracture toughness along with the *c*-axis orientation were 30 ± 1 GPa, 460 ± 36, GPa and, 3.5 ± 0.2 MPa·$m^{-1/2}$, respectively. The values were the highest properties and indicated that mechanical properties depended on the *c*-axis orientation. It could be related to the C-B-C bonds, which are intrinsically arranged along the *c*-axis and the stiffest bonds. Additionally, the energy of C-B bonds is found to be more

extensive (286 kJ/mol) than the energy of B-B bonds (149 kJ/mol). The crystallographic orientation increased the flexural strength by 23% and hardness by 14% compared to the sample without orientation (random). From these results, highly crystal orientation for polycrystalline B_4C effectively improves the mechanical properties of B_4C ceramics.

The specific heat varied depending on the test temperature and increased with an increase temperature. Subsequently, thermal diffusivity and conductivity were evaluated by LFA thermal analysis. The thermal conductivity (κ) of oriented B_4C with and without Al_2O_3 were 24 W/m·K and 19 W/m·K, respectively. These values increased compared to the specimens without the highly crystal orientation. It could be considered that the thermal conductivity is dominantly influenced by the transfer of vibrational energy through inter-icosahedral C-B bonds. The effect of Al_2O_3 addition reduced the thermal conductivity of B_4C ceramics. The thermal conductivity of all specimens depended on temperature due to phonon scattering at higher temperatures. Also, thermal expansion measured perpendicular to *c*-axis orientation on B_4C with Al_2O_3 addition is the lowest coefficient thermal expansion of 5.0 $10^{-6}\cdot K^{-1}$. From the results, it is suggested that highly crystal orientation improves the thermal properties of B_4C ceramics.

In conclusion, fabrication of highly oriented B_4C ceramics with Al_2O_3 under strong magnetic field followed by sintering has successfully been achieved and improved both mechanical and thermal properties compared to the random orientation of B_4C ceramics.