

論文 / 著書情報
Article / Book Information

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Title(English)	Neutron Irradiation Induced Damage of Silicon Nitride-Related Ceramics and Their Recovery Behavior
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種別(和文)	論文要旨
Type(English)	Summary

論文要旨

THESIS SUMMARY

専攻 :	原子核工学	専攻
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申請学位 (専攻分野) :	博士	(工学)
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要旨 (英文 800 語程度)

Thesis Summary (approx.800 English Words)

In this research, neutron irradiation effects on silicon nitride-based ceramics were studied. Four kind of hot-pressed silicon nitride and SiAlON ceramics were concurrently neutron irradiated up to a fluence of $8.5 \times 10^{24} \text{ n/m}^2$ at irradiation temperature of 563 K. This thesis consisted of four parts as follows.

Firstly, the changes in their macroscopic lengths and lattice parameters caused by the neutron irradiation were investigated along with their microstructural changes. Changes in macroscopic length expansion of α - and β -SiAlON ceramics and α - Si_3N_4 were similar and almost double that of β - Si_3N_4 . Lattice parameters increased on both axes for both α - and β - Si_3N_4 . On the other hand, the a -axis in SiAlON ceramics increased while their c -axis shrank. However, the unit cell volumes of both SiAlONs expanded. The macroscopic volume changes calculated from the macroscopic length changes were slightly larger than the unit cell volume changes calculated from the lattice parameter changes for all specimens. HREM observation revealed no voids, dislocation loops, or grain boundary microcracks in either neutron irradiated-SiAlON ceramics. Based on the results of swelling and microstructural changes, the low-dose neutron irradiation-induced defects in silicon nitride-based ceramics were consider to be point-like defects or point defects.

Secondly, recovery behavior of low-dose neutron-irradiated SiAlON ceramics by thermal annealing was studied. The macroscopic length changes of neutron-irradiated α - and β -SiAlON were precisely measured by *in-situ* dilatometry. The recoveries of macroscopic length of α - and β -SiAlON started slightly above the irradiation temperature, and continued up to 1473 K. In addition, for α -SiAlON, recovery rate decreased at temperature ~ 1123 -1273 K, might be related to the presence of the Sr and/or Y in the interstitial sites. These interstitial atoms may need higher energy to annihilate in appropriate lattice sites. There were at least two stages of recovery up to 1473 K for both SiAlONs. Activation energies of macroscopic volume recovery of α - and β -SiAlON at lower temperature range were 0.09 and 0.06 eV, respectively, and those at the higher temperature range were 0.49 and 0.33 eV, respectively. The activation energies of α -SiAlON were slightly larger than those of β -SiAlON. At thermal annealing temperatures lower than 1123 K, the recombination, which may be caused by annihilation of closely-separated Frenkel pairs, occurred easily. On the other hand, at high

temperatures (>1223 K), the recovery may be governed by the recombination of separated Frenkel pairs along with migration of not only interstitial atoms but also vacancies.

Thirdly, two polymorphs of Si_3N_4 ceramics, very similar crystal structures with polymorphs of SiAlON, were selected to study the recovery behavior of defects in different crystal structures, and compared to those of α - and β -SiAlON. Macroscopic length of α - and β - Si_3N_4 was mostly recovered to their original length, i.e., most of defects induced by neutron irradiation were recovered. The recovery rate tendencies of α - Si_3N_4 and α -SiAlON resembled each other, as did those of β - Si_3N_4 and β -SiAlON. However, recovery characteristics of α - and β -polymorphs were different in both crystals, maybe due to the difference in crystal structures. There were two stages of recovery processes from 673 K to 1473 K. The activation energies at the higher temperature range of both compounds were almost double of those at lower temperature range. Furthermore, the activation energies of Si_3N_4 were larger than those of SiAlON in both polymorphs. It may be due to the difference in atomic bonding strength, i.e. that of the covalent bonds in Si_3N_4 would be higher than covalent/ionic bonds in SiAlON.

Finally, microstructural changes of the as-irradiated silicon nitride-based ceramics and after thermal annealing up to 1123, 1223 and 1473 K were observed with a high-resolution transmission electron microscope (HREM) in order to clarify the feature of defects and their thermal stability. HREM micrographs of the as-irradiated specimen revealed that the atomic configuration projected onto the basal plane was similar as a perfect crystalline arrangement without lattice distortion. This result confirmed that only point defects or point-like defects were generated during the neutron irradiation of the present condition. HREM micrographs of four neutron irradiated specimens after thermal annealing at 1123 K and 1223 K did not reveal dislocation loops or voids/bubbles formation in grains or along grain boundaries, or triple junctions. There was no evidence to support the difference in recovery tendencies of α - and β - Si_3N_4 and SiAlON polymorphs at 1123 - 1223 K. In addition, HREM micrographs of the irradiated Si_3N_4 polymorphs after thermal annealing up to 1473 K did not show any dislocation loops or voids/bubbles formation in grains or along grain boundaries, respectively. This observation suggested that there were no defects agglomeration in grain or at grain boundaries and neutron irradiation induced defects were mostly annihilated by thermal annealing up to 1473 K. It was still not clear that the reason for the difference in macroscopic length recovery during thermal annealing between α - and β -polymorphs of silicon nitride-related compounds. In conclusion, the difference in recovery tendencies of α - and β -phases should be related to the kind of point or point-like defects in each compound.

備考：論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1 copy of 800 Words (English).