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Deuterium retention and melting behavior in Toughened, Fine-Grained Recrystallized Tungsten

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Toughened, Fine-Grained Recrystallized Tungsten (TFGR W) has been developed at Tohoku Univ., Japan [1], in order to improve poor mechanical properties of W such as brittleness at low temperature and embrittlement following neutron irradiation. TFGR W has an average grain size of ˜1 μm with a small amount of TiC and TaC dispersoids. These features of the microstructure serve to improve ductility. Here we report the performance of TFGR W under hydrogen isotope irradiation conditions and its applicability as a plasma-facing material, with respect to hydrogen isotope retention and melting behavior.
First, deuterium (D) retention was investigated. Two types of TFGR W specimens were prepared; TFGR W-1.1wt%TiC and TFGR W-3.3wt%TaC (referred to as W-TiC and W-TaC, respectively). For comparison, pure W specimens were also investigated. D irradiation was conducted using HiFIT at Osaka Univ. [2]. D fluence of ˜1 x 10^24 m^-2 was implanted at temperatures of 473 - 873 K. The D retention was determined by TDS.
At temperatures above 473 K, D retention in TFGR W is systematically higher than in pure W. The difference is about one order of magnitude at ˜573 K, which is close to the water coolant temperature of the W divertor of a recent DEMO concept [3], suggesting that the use of TFGR W could greatly increase tritium retention. At a temperature of 773 K, retained amount of W-TiC is higher than W-TaC. At ˜800 K, which corresponds to about surface temperature of ferritic-martensitic steel blankets, W-TaC should be used for reduced retention.
Secondly, in order to study their melting behavior, TFGR W specimens were exposed to TEXTOR edge plasmas at temperatures above the melting point. The D plasma parameters were I_p = 350 kA, B_t = 2.25 T and n_e = 3.5 x 10^19 m^-3. Specimen surfaces were molten at the roof limiter position of 46.4 cm.
The re-solidified layer of W-TiC has many small pores with size of ˜ 1 μm, while that of W-TaC has a dome-like structure with a height of ˜500 μm and a few cracks with ˜ 1 cm long. These rough layers could lead to increased erosion when loaded by repeated exposure. Therefore, TFGR W should be more improved to mitigate surface roughening under extreme heat flux conditions.
[1] H. Kurishita et al., Phys. Scr. T159 (2014) 014032
[2] Y. Ueda et al., Fusion Eng. Design 62 (2002) 255-261
[3] K. Tobita et al., Nucl. Fusion 49 (2009) 075029

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Primary author: Mr OYA, Makoto (JpUOsaka)

Co-authors: Dr KRETER, Arkadi (DeFJ); Dr DE TEMMERMAN, Gregory (ITERFr); Dr LEE, Heun Tae (JpUOsaka); Dr KURISHITA, Hiroaki (International Research Center for Nuclear Materials Science, JpUTohoku); Dr

COENEN, Jan Willem (DeFJ); Dr IBANO, Kenzo (JpUOsaka); Dr OYAIDZU, Makoto (JpIFERC); Dr HAYASHI, Takumi (JpIFERC); Dr MORGAN, Thomas Warwick (NIFOM); Prof. UEDA, Yoshio (JpUOsaka)

Presenter: Mr OYA, Makoto (JpUOsaka)

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