§19. W-coating on Low Activation Structural Materials

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Tungsten armor has been considered to be critical for realization of fusion reactor because it suffers severe irradiation damages by highly energetic particles irradiation together with high heat loading. The estimated thermal heat loading is more than 20 MW/m^2 for divertor of Tokamak-DEMO reactors. Since tungsten is less ductile, cyclic heat loadings may cause fatigue rupture through thermal stress applied by the difference in the coefficients of thermal expansion between W-armor and structural material. In this study, heat load tests were carried out for W-armored structure component made of vacuum plasma sprayed (VPS) tungsten with reduced activation ferritic steel (F82H) or oxide dispersion strengthened (ODS) steel[(1)].

VPS-W with 1 mm thickness was coated on a reduced activation ferritic steel, F82H, with 5 mm thickness. No surface crack was observed after 100 cycles of heat loading at 4.8 MW/m^2, while 16 cycles of the loading at 5.5 MW/m^2 resulted in cracking on the surface of W. However, the reduction of plate thickness of F82H from 5 mm to 3 mm increased cyclic heat resistance to 6.0 MW/m^2. It was found that surface cracking occurred when the surface temperature increased to higher than 1150 K irrespective of amount of heat load.

Plasma splay conditions have been examined to achieve high density and high thermal diffusivity of VPS-W. They are the size of powders, the distance between nozzle and plate, scanning speed and plate thickness. After the fabrication processes with different VPS conditions, mechanical properties such as hardness and tensile properties were investigated together with microstructure observations by transmission electron microscopy.

The obtained test results indicate that high performance PVS-W can be attained with the microstructure that has less number of pores with columnar structure, which is available when the jet-splayed tungsten powders well melted and continuously solidified with one directional grain growth.

Figure 1 shows the dependence of the density and thermal diffusivity of the VPS-W on the areal fraction (%) of columnar grains in the cross sectional area of VPS-W. With increasing the areal ratio of columnar grains, both the density and thermal diffusivity increase up to about 40 % and saturate beyond 40 %. The grain morphology with high thermal conductivity is shown in Fig. 2(A) that is rather large columnar grains with less pores, while Fig. 2(B) indicates that small and discontinuous grain structure with many pores, which are shown as black areas, is not adequate for high thermal conductivity.

(1) H. Noto, A. Kimura, H. Kurishita, S. Matsuo, Evaluation of Feasibility of Tungsten/Oxide Dispersion strengthened Steel Bonding with Vanadium Insert, Materials Transactions, Vol. 54, No.4 (2013)pp.451-455.

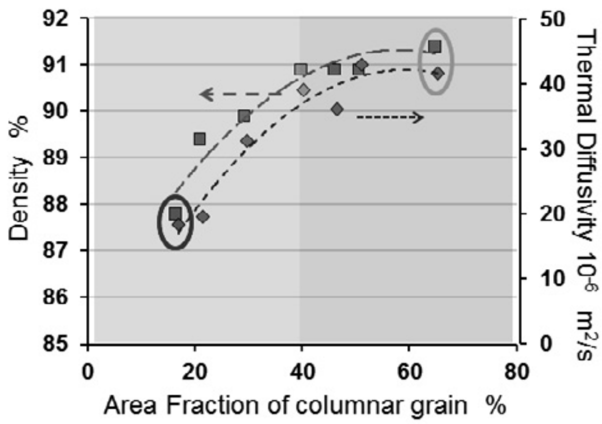

Fig. 1: The dependence of the density and thermal diffusivity of the VPS-W on the areal fraction (%) of columnar grains in the cross sectional area of VPS-W

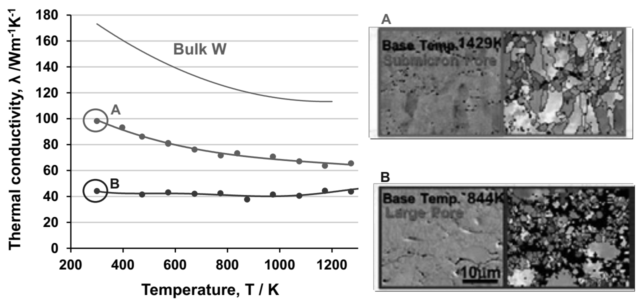

Fig. 2 : Correlation of thermal diffusivity with grain morphology of VPS-W