# §11. Thermophysical Properties and Microstructure of Plasma-sprayed Tungsten Coating on Low Activation Materials

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Tungsten (W) coating on low activation materials has been considered to be important technology for development of the first wall in fusion reactors. The vacuum plasma spray (VPS) process is practical for coating a large area because of its relatively high coating rate. In the present study, W coatings were fabricated on various low activation materials by the VPS process. The purpose is to characterize the coated materials from the analysis of the thermophysical properties and microstructures.

The low activation materials used for the coating substrate were F82H ferritic steel , ODS ferritic steel and NIFS-HEAT-2 vanadium alloy (NH2: V-4Cr-4Ti). In order to avoid thermal damage on the substrate, the substrate temperature was controlled at around 550 °C and 700 °C during the VPS process. The resulting thickness of the W coatings was about 0.1 mm or 0.7 mm. A 3 mm-thick W coating was also prepared on sintered W substrate, and then was peeled off for the measurement without substrate. Sintered W was also prepared as a reference bulk W.

Void and crack-type defects were observed within the coating by SEM. The void size was about 10 μm. No intermediate layer was observed by SEM at the interface between the W coating and the substrates. Tables 1 is the result of mass density measurements for the VPS-W. The mass density of VPS-W and bulk W was 17.0~17.1 and 18.8 g cm$^{-3}$, respectively, which are 88~89 % and 97 % of the reference data (19.3 g cm$^{-3}$). According to the number density of the 10 μm voids, they can explain only 0.6 % loss of mass density, while the actual reduction was 11~12 %. The crack-type defects and/or invisible smaller defects are likely to be responsible for the mass density loss.

Fig. 1 shows the thermal conductivity of the VPS-W, bulk W, NH2 substrate and VPS-W-coated NH2. The thermal conductivity of VPS-W was small and 31 % of the bulk W at RT, while it was 51 % at 800 °C. However, the VPS-W coating will not degrade the heat transfer properties of NH2, because the thermal conductivity of VPS-W is still higher than NH2, and the coated NH2 exhibited better thermal conductivity than the NH2 substrate. Assuming no heat loss at the interface between the coating W and substrate, thermal conductivity of the coated NH2 can be calculated with,

$$\lambda' = \frac{(t_1 + t_2)}{\frac{t_1}{\lambda_1} + \frac{t_2}{\lambda_2} + R} \qquad (1)$$

λ': Average thermal conductivity of the coated NH2
$t_1$: Thickness for W coating, 0.74 mm
$t_2$: Thickness for NH2 substrate, 1.26 mm
$\lambda_1$: Thermal conductivity of VPS-W
$\lambda_2$: Thermal conductivity of NH2 substrate

Table 1 Mass density of VPS-W produced at 550 and 700 °C, and its ratio to that of the bulk W in a reference.

| | Mass density at RT, $\rho(T_0)$ / g cm$^{-3}$ | Ratio to Ref. / % |
|---|---|---|
| 550 °C | 17.0 | 88 |
| 700 °C | 17.1 | 89 |
| Bulk W (present) | 18.8 | 97 |
| Bulk W (Ref.) | 19.3 | 100 |

Ref.: Data Book for Metals, 3rd Ed., the Japan Institute of Metals (1993).

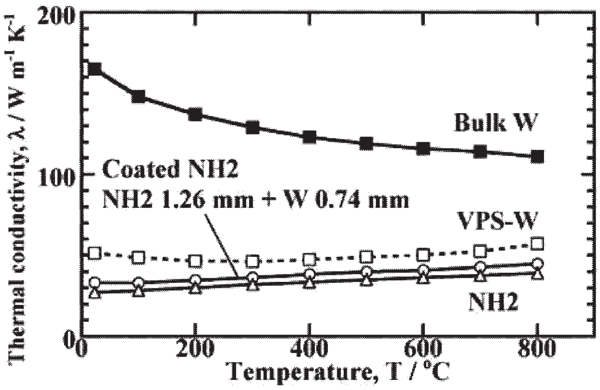


Fig. 1 Thermal conductivity of NH2, VPS-W, bulk W and coated NH2.

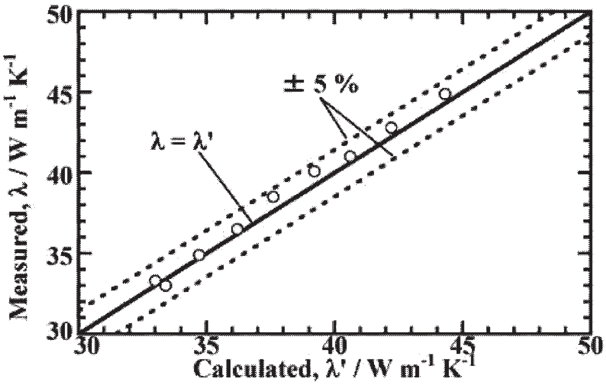


Fig. 2 Comparison between, λ', thermal conductivity calculated from those measured at VPS-W and NH2 substrate, and, λ, that measured for the coated NH2.

R: Thermal contact resistance at the interface.

Fig. 2 shows a comparison between the calculated thermal conductivity, λ', and measured one, λ, for the coated NH2, assuming R = 0 K W$^{-1}$. Calculated and measured values are consistent with each other within 5 % error. This means that there was no significant thermal contact resistance at the interface between the W coating and the NH2 substrate. The maximum thermal contact resistance, R, was estimated from these measured data with Eq. (1) as 8.4 x 10$^{-3}$ K W$^{-1}$. According to this good thermal bonding, W is considered to form direct metal bonding to NH2, or to form an intermediate layer with good thermal conductivity at the coating interface. The former agrees with the lack of intermediate layer observed by SEM.

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