§8. The Growth and Resistivity of In-situ Er$_2$O$_3$ Coating on V-4Cr-4Ti

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One of the critical issues for the self-cooled Li/V-alloy blanket is the magnetohydrodynamic (MHD) pressure drop. The insulating coatings on the inner wall of components for mitigating the pressure drop are under development. An in-situ coating in liquid Li is very attractive. The previous studies [1, 2] showed the in-situ formation and stability of Er$_2$O$_3$ coating by exposing oxygen-charged V-4Cr-4Ti in liquid Li doped with Er at high temperature. In this report, the results on the growth and resistivity of the coating were shown.

V-4Cr-4Ti sheets were oxidized in flowing argon, annealed in vacuum and exposed in liquid Li doped with Er.

Fig. 1 shows the thickness of the Er$_2$O$_3$ coating with exposure time at temperature of 500~700°C. The Er$_2$O$_3$ coating was not formed at 500°C, perhaps owing to slow diffusion of Er and O, or weak reaction between Er and O at 500°C. The thickness of the Er$_2$O$_3$ coating is a function of the exposure time. The figure indicates that the Er$_2$O$_3$ coating is stable at 600°C up to 750h of exposure to liquid Li, and stable at 650°C or 700°C up to 300h. The thickness seems to saturate at ~0.1μm at 600°C, ~0.6μm at 650°C and ~1.3μm at 700°C.

Fig. 2 shows the thickness ($T$) of Er$_2$O$_3$ coating formed on the V-4Cr-4Ti substrate (oxidized for 6h at 700°C, annealed for 16h at 700°C and finally exposed in liquid Li doped with Er) at 600°C, 650°C and 700°C as a function of the exposure time ($t$). $T' = k \cdot t + a$. Here $a=0$ was assumed, corresponding to a negligible nucleation duration observed. The figure shows the growth kinetics of Er$_2$O$_3$ coating obey a logarithmic law with high exponent (n=3 or 4) at 600°C, and 650°C, suggesting that the rate of growth to Er$_2$O$_3$ coating should be significantly low. The solubility of erbium is very low (0.15 wt%) in liquid lithium at 600°C. Thus slow delivery of either oxygen from substrate or erbium from Li to the interface is thought to be responsible for the slow growth of the coating. The growth process was expedited suddenly at 700°C exhibiting a low exponent (n=2) that almost obeys a parabolic law resulting in the quick growth of the coating.

Fig. 3 shows the resistivity×thickness of V-4Cr-4Ti coated by Er$_2$O$_3$ in vacuum (~10$^{-7}$Pa) during heating with a minimum requirement for design of fusion blanket. Up to ~550°C, the in-situ measured resistivity was over the minimum requirement. However over 550°C, resistivity starts to drop below the minimum requirement, because the electrode degraded or disconnected owing to melting or vaporization of Ag paste as a linker. Therefore, resistivity of coating is expected still over the minimum requirement up to 700°C, by improving linking of electrodes.

The study showed the growth kinetics of in-situ Er$_2$O$_3$ coating. The coating has resistivity over the minimum requirement for insulator for fusion blanket.

Reference