

## §14. Basic Study on Self-Healing of $\text{Er}_2\text{O}_3$ Coating for Vanadium-Lithium Blanket System

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A self-cooled liquid lithium/vanadium-alloy blanket system is attractive from the viewpoint of energetic conversion efficiency and tritium breeding ratio. One of the critical issues involved in this system is magneto-hydrodynamics (MHD) pressure drop, which is induced by liquid metal flowing across strong magnetic fields. In order to reduce MHD pressure drop to acceptable levels, fabrication of thin insulating coatings at inner wall of duct tubing has been proposed. In the previous studies, erbium oxide ( $\text{Er}_2\text{O}_3$ ) was selected as one of the best candidate oxide materials for the MHD coating from the point of view of compatibility with lithium [1]. And recently  $\text{Er}_2\text{O}_3$  coatings fabricated by PVD method showed high electrical resistance and high compatibility with liquid lithium [2]. In-situ formation of  $\text{Er}_2\text{O}_3$  coatings was also explored to show that oxygen in the V-alloy substrate and Er dissolved in lithium could react to form thin  $\text{Er}_2\text{O}_3$  layer at the interface [3]. In this report, feasibility of self-healing of  $\text{Er}_2\text{O}_3$  coating is explored by observing its in-situ formation at cracks on the coatings fabricated by PVD method as indicated in Fig. 1.

V-4Cr-4Ti substrates were oxidized at 973 K for 6-12 h in flowing argon (99.9999% purity;  $\text{O}_2 < 1\text{ppm}$ ) and mass of each sample increased at 4000-6000 ppm-O. Subsequently, oxidized substrates were annealed in vacuum (about  $10^{-5}$  Pa) at 973 K for 16 h to homogenize oxygen into bulk and mass change was not occurred. Then  $\text{Er}_2\text{O}_3$  coatings were deposited on these substrates at room temperature (R.T.) and 873 K. The coatings deposited at 873 K had peeled off at most area. On the contrary, the coatings deposited at R.T. were uniformly flat. After introducing cracks on  $\text{Er}_2\text{O}_3$  coatings by heating at 773 K for 50-100 h in argon, the samples were exposed in liquid lithium doped with Er at 873-973 K for 100-200 h to heal the cracks. At the large peeled-off area, no in-situ formation was observed, while small cracks were healed. If oxygen had remained in the substrates,  $\text{Er}_2\text{O}_3$  would have generated under coating deposited by PVD method and peeled off. Therefore, there is a high possibility that the substrates have lost oxygen when coating had been peeled off.

To ascertain mechanism of peel-off and healing, depth profiles of elements in  $\text{Er}_2\text{O}_3$  coatings were analyzed by X-ray photoelectron spectroscopy (XPS) with Ar sputtering. As shown in Fig. 2, Er and O drastically and V increased near the surface in case of the sample deposited at R.T.. In contrast, those of samples deposited at 873 K and heated after deposition at R.T. showed gradual decrease of Er and O and gradual increase of V. These indicated heating during or after deposition contributed to form Er-V-O intermediate layer between the coating and the substrate. It was suggested Er-V-O layer were formed by taking oxygen from substrate in case of oxidized substrates as well. It is considered

Er-V-O layer itself has been peeled off and substrate without oxygen was remained on the surface, and therefore in-situ formation had not been observed at peeled-off area. At the small cracks which have healed, it is considered the oxygen was supplied from Er-V-O layer from the remained coatings at surroundings as indicated in Fig. 3. Thus, oxygen supply in the system, especially Er-V-O layer, is a key investigation point to control the healing of cracks on  $\text{Er}_2\text{O}_3$  coating at Li/V-alloy blanket.

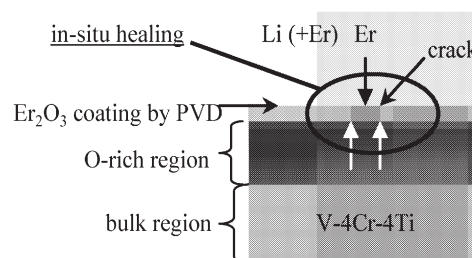


Fig. 1 The scheme of self-healing coating.

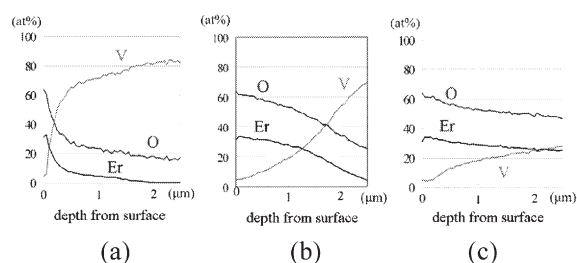


Fig. 2 Depth profiles of elements by XPS deposited by arc source plasma assisted deposition. (a) deposited at R.T. (b) deposited at 973K (c) annealed for 3h at 873K after deposition

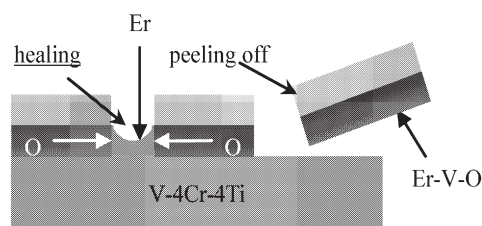


Fig. 3 Process of healing cracks and peeling V-Er-O layer.

### References

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