

STUDY OF THE LONG-TERM STABILITY OF MHD COATINGS FOR FUSION REACTOR APPLICATIONS -- B. A. Pint and L. D. Chitwood (Oak Ridge National Laboratory, USA) and A. Suzuki (NIFS, Japan)

OBJECTIVE

The objective of this task is to assess the long-term, high-temperature compatibility of high electrical resistance coatings with lithium at high temperatures. Electrically insulating coatings on the first wall of magnetic confinement reactors are essential to reduce the magnetohydrodynamic (MHD) force that would otherwise inhibit the flow of the lithium coolant. Experimental work is being conducted on bulk ceramics to determine resistivity, basic lithium compatibility and maximum-use temperatures of candidate ceramics such as Er_2O_3 , Y_2O_3 and YScO_3 . As the next step, coatings of Y_2O_3 are now being evaluated.

SUMMARY

In order to determine the high temperature resistivity and Li compatibility of several candidate materials, bulk specimens were fabricated for testing. Results for YScO_3 showed sufficiently low resistivity up to 800°C. Combined with the Li compatibility results, YScO_3 meets the metrics for bulk materials and should be tested as a coating. Initial characterization of the electron beam physical vapor deposited (EB-PVD) Y_2O_3 coatings shows significant deterioration after exposure to Li at 700° or 800°C.

PROGRESS AND STATUS

Introduction

Based on positive results for bulk, polycrystalline Y_2O_3 specimens, Y_2O_3 coatings were fabricated and tested.¹⁻³ However, coating delamination and/or reaction with Li was detected after static Li exposures at 700° and 800°C. Initial post-exposure characterization of the coatings is now being conducted. The problems with Y_2O_3 as well as previously reported problems with CaO dissolving with Li and lack of compatibility between AlN and V alloys indicates that none of these candidates are likely to meet the coating performance metrics⁴ for a viable MHD coating material at 700°C. Thus, two new candidates are now being considered, Er_2O_3 and YScO_3 . In bulk form, both have shown some compatibility to Li. However, no high temperature resistivity data has been found for YScO_3 to meet the bulk material performance metrics.⁴ Current work is being conducted to fabricate and test high-purity dense specimens of these materials.

Experimental Procedure

The YScO_3 specimen was made by ball milling powders, cold-pressing and then hot-pressing in a graphite die. The Y_2O_3 coatings were deposited on V-4Cr-4Ti substrates by EB-PVD at Lawrence Livermore National Laboratory and have been described previously.²⁻³ The experimental procedure for lithium exposures also has been outlined elsewhere.^{1,5} After exposure, the coatings were cleaned by submerging them in methanol for 24h to dissolve the residual Li. The coatings were characterized using field emission gun, scanning electron microscopy (SEM) with energy dispersive x-ray analysis (EDX), auger electron spectroscopy

(AES) and x-ray diffraction (XRD) with 300kV Cu K radiation. The resistance of coated specimens and bulk specimens was measured from 25°-800°C in a test rig with a vacuum pressure of 10^{-6} Torr. The vacuum system was used to avoid oxidation of the coated V-4Cr-4Ti substrate. For bulk specimens (3mm thick by 12-15mm diameter), gold electrodes were deposited on opposite sides for the resistance measurement.

Results and Discussion

Figure 1 shows the measured resistivity results for several specimens compared to literature values for Y_2O_3 .⁶ As reported previously, the as-received, EB-PVD Y_2O_3 coatings showed lower resistivity than these literature values. However, recent measurements on bulk Y_2O_3 showed considerably higher results. Measurements for bulk $YScO_3$ were very encouraging, showing a resistivity at 700°C several orders of magnitude higher than that required by the metrics (dashed lines in Figure 1).

Specimens with Y_2O_3 coatings were examined by SEM before and after exposure to Li. Figure 2a shows the as-deposited coating grain structure in plan-view. After 2000h at 700°C, only fragments of the coating remained on the V-4Cr-4Ti substrate, Figure 2b. The coatings were intact on the substrates after exposures for 100 and 1000h at 800°C but all of the coating was gone after a 2000h exposure at 800°C. Figure 3 shows the coating appearance in plan-view after the shorter exposures at 800°C. The original coating morphology is not apparent. Smooth patches (slightly darker) appeared after 100h, Figure 3a, and the entire surface appears covered by this morphology after 1000h, Figure 3b. Analysis by EDX showed significant Ti in or on the coating which may indicate a Ti-rich oxide phase is forming. Both the V alloy test capsule and substrate contain Ti that may have reacted to form a compound. However, a specific phase has not been identified by XRD. Subsequent characterization work will section the coatings for Auger and/or

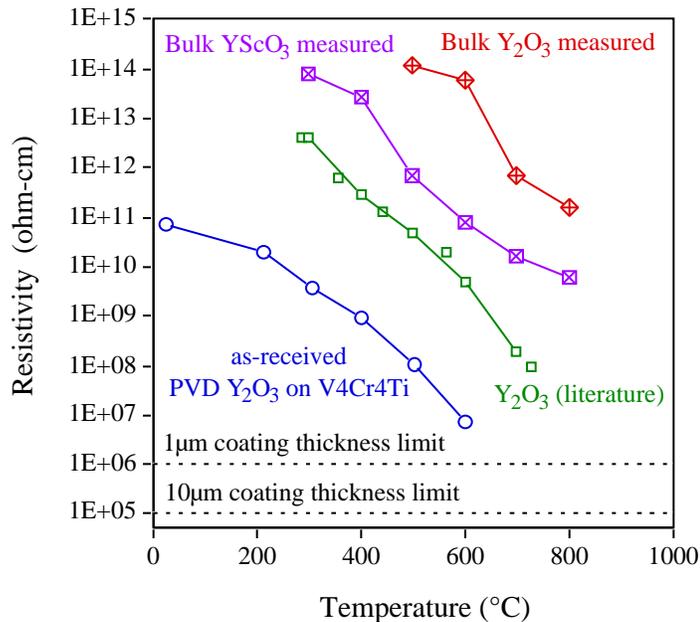


Figure 1. Resistivity as a function of temperature for bulk ceramic specimens of Y_2O_3 and $YScO_3$ and EB-PVD Y_2O_3 coatings compared to values cited in the literature.⁵

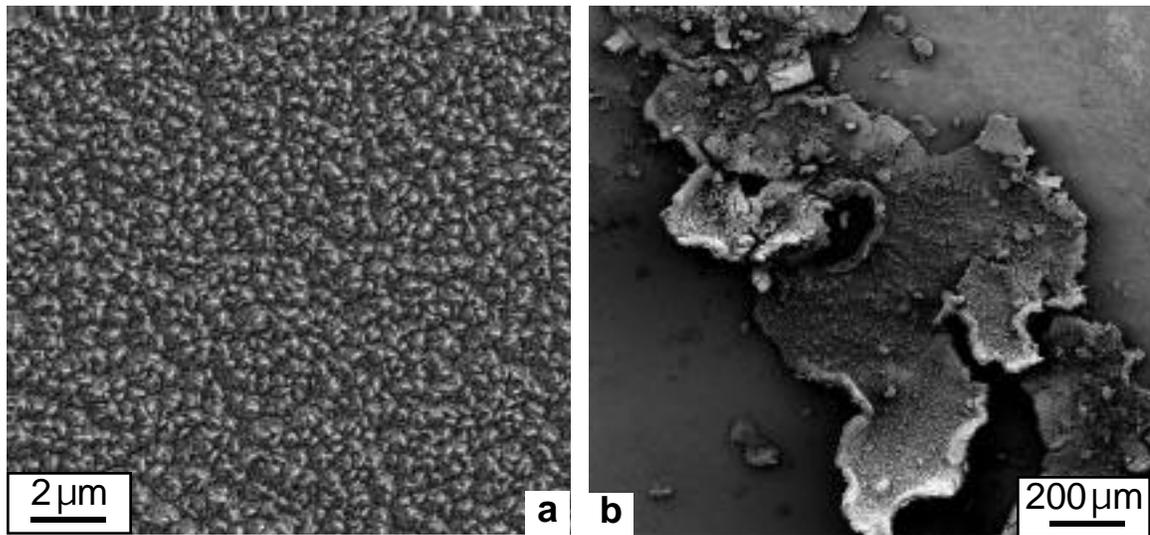


Figure 2. SEM secondary electron images of EB-PVD Y_2O_3 coatings (a) as-received and (b) after 2000h at 700°C in static Li.

TEM analysis.

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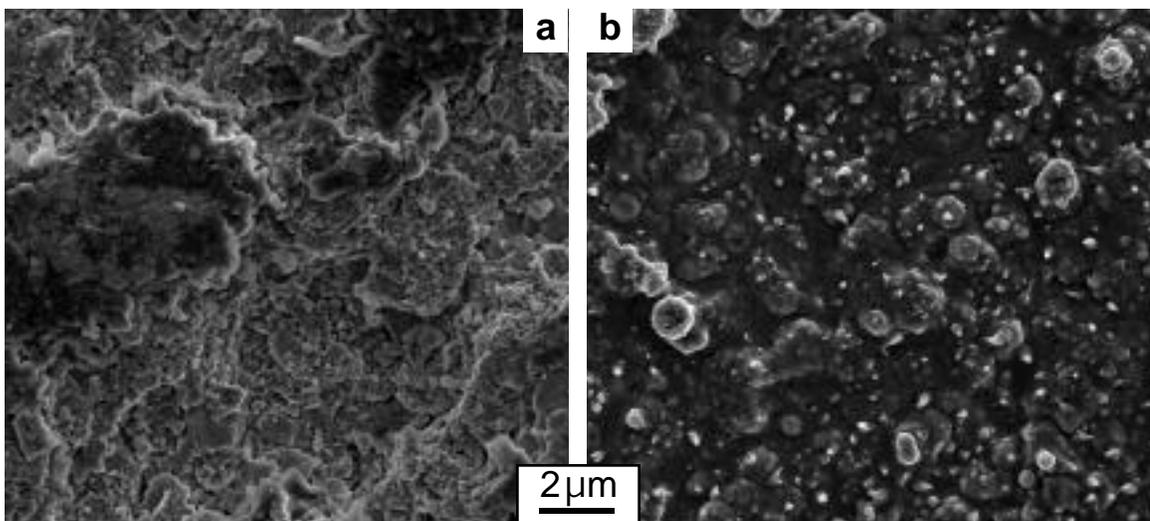


Figure 3. SEM secondary electron images of EB-PVD Y_2O_3 coatings after exposure to static Li for (a) 100h and (b) 1000h.