# Radiation Induced Conductivity for $Er_2O_3$ coatings on EUROFER under 1.8 MeV electron irradiation

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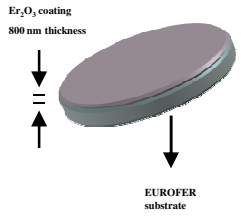
**The use of some type of electrical insulating ceramic coating will be necessary in order to mitigate MHD (magnetohydrodynamic) pressure drop of liquid Li breeder/coolant in future blanket systems. Previous studies have shown that $Er_2O_3$ coatings mantain the chemical compatibility with highly corrosive high temperature liquid Li. However it is expected that during operation under the influence of an intense radiation field the electrical behaviour of the insulating coating will be severely modified.**

**In this work, enhancement of the electrical conductivity of cubic phase $Er_2O_3$ coatings due to RIC (Radiation Induced Conductivity) and RIED (Radiation Induced Electrical Degradation) have been examined by irradiating with 1.8 MeV electrons at 700 Gy/s (≈ $10^{-10}$ dpa/s on the O sublattice), 450 ºC.**

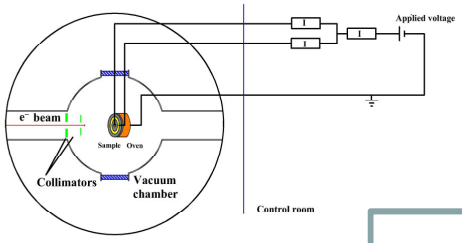
## $Er_2O_3$ coatings on EUROFER:

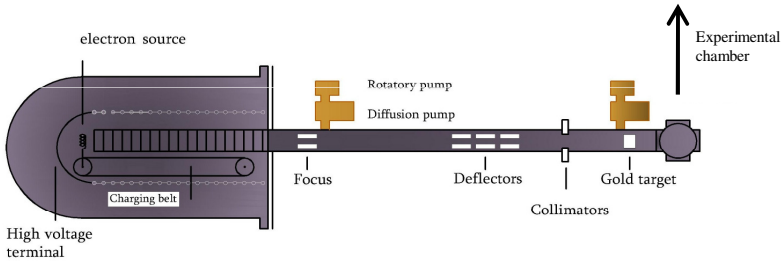
**Cubic phase $Er_2O_3$ coating on EUROFER substrate was produced at IPP (Garching) using the method of cathodic arc deposition, at 700ºC.**



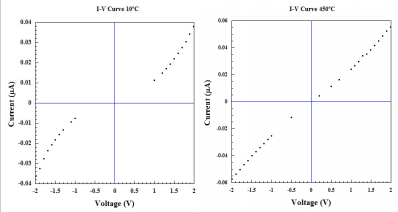

## Electrical insulating behaviour measurement before, during and after e⁻ irradiation:

**Electron irradiations were carried out in a special chamber in the beam line of a Van de Graaff accelerator. The system permits electrical measurements to be made during irradiation at controlled temperatures between 15 and 1000 ºC. The usual conductivity measuring system requires the use of sputtered central and guard electrodes on one face of the sample, with a common electrode on the opposite face, but due to the porosity of the coating this was not possible. Instead a single 10 mm diameter thin Al covered steel electrode was pressed onto the $Er_2O_3$ surface, the Eurofer substrate serving as the other ground electrode in contact with the oven, allowing an electric field to be applied to the sample. Conductivity measurements were made applying 1 V to the sample, corresponding to 1.3 MV/m, high enough to produce RIED.**



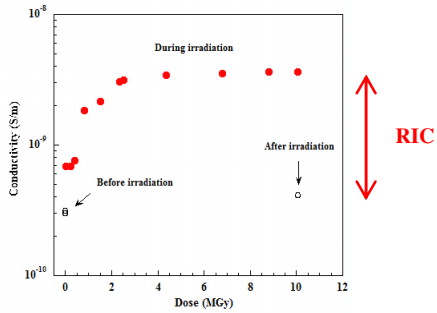

**I-V curves were measured at 10 and 450 ºC for voltages between ± 2V. At low temperature the curves were non-linear (semiconductor), however at 450 ºC the behaviour was almost Ohmic.**




## Results:

### RIC

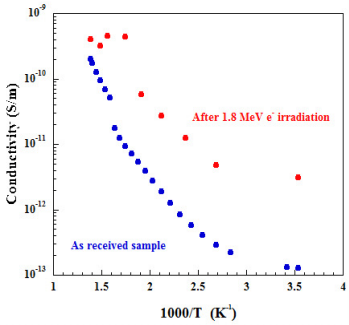
***A transient effect due to radiation excitation of valence electrons***




**The initial conductivity rapidly increases at the on-set of irradiation from 3 to 7 x $10^{-10}$ S/m, and then more slowly reaching 3.6 x $10^{-9}$ S/m by 10 MGy. The measured RIC at 10 MGy (3.2 x $10^{-9}$) is small and suggests a high concentration of defects and/or impurities in the material, which act as carrier recombination sites.**

### RIED

***Permanent degradation related to structural changes that only occur for irradiation with an applied electric field within a narrow temperature range***




**Electrical conductivity of the $Er_2O_3$ coating was measured from 10 to 450ºC, before and after 4 hours (10 MGy) of 1.8 MeV electron irradiation at 450ºC. An increase is observed in the electrical conductivity, more pronounced at low temperatures. This type of increase is typical for RIED.**

## Conclusions

**These initial results indicate that Arc-PVD $Er_2O_3$ coatings on Eurofer have the potential to provide an insulating barrier with sufficiently low electrical conductivity to resolve any MHD problem. Extrapolated results for 1 fpy operation indicate a degradation of the conductivity to ≈ 4x$10^{-7}$ S/m, still many orders of magnitude below the limiting value of ≈ $10^{-1}$ S/m. However further work needs to be done at higher temperature and to considerably higher total doses.**