

§9. Compatibility of Low Activation Ferritic Steels with Liquid Lithium

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One of the primary requirements for the development of fusion as an energy source is the qualification of materials for the first-wall/blanket system that will provide high performance and exhibit favorable safety and environmental features. Both economic competitiveness and the environmental attractiveness of fusion will be strongly influenced by the materials constraints. A key aspect is the development of a compatible combination of materials for the various functions of structure.

Fe-Cr-W base low activation ferritic steels (RAFM) have been identified as a leading candidate structural material for fusion blanket applications. Liquid lithium is an attractive breeding material. For the combination of RAFM and liquid lithium for the use as a breeding blanket, compatibility of the two materials could be the issue. However, since previous compatibility researches between ferritic steels and liquid lithium almost focused on the Fe-Cr-Mo steels, the data of compatibility of Fe-Cr-W low activation ferritic steels in lithium is quite limited.

In this study, compatibility of the three kinds of materials, pure iron, Fe-9Cr and low activation ferritic steel JLF-1(Fe-9Cr-2W), was investigated to elucidate the corrosion mechanism and find out the influence of different elements by means of exposure to static lithium at high temperature. Corrosion rate, microstructure and hardness change in the near-surface region were investigated after lithium exposure at 973K.

JLF-1 specimen was cut into 22×5×0.25mm from a block and grinded by sand papers and finally electro-polished. Fe-9Cr and pure iron was prepared by rolling to 0.25mm, cutting into the same size as JLF-1 specimen, followed by the same surface treatment as that for JLF-1 and annealing at 973K for 1hr. The purity of lithium was 99.99%, and during whole experiment, the lithium was isolated from air. All assembling work and preheat was done in glove box filled with Ar. The lithium exposure experiment was performed at 973K for 100hrs in molybdenum cup and the cup was heated in a stainless steel autoclave. After experiment, all specimens were cleaned by ammonia to remain the corrosion product.

After 100h lithium exposure at 973K, the etching appearance was observed on JLF-1, 9Cr and pure iron, some surface of specimen was covered by corrosion product. Normally there were three kinds of corrosion product on the surface of specimen after ammonia clean identified by their appearance, the big particle made up by Li₂O, porous layer and Ni rich crystal attaching firmly on the surface. The Ni rich crystal didn't dissolve in ethanol or water when cleaning the specimen by ultrasonic.

EDS result indicated Cr dissolution on the surface of JLF-1 and 9Cr. The average composition of Cr on the

surface reduced from 9% to ~5% both for JLF-1 and Fe-9Cr. For pure iron, some Cr and Ni were detected on the surface.

The phase transition, from martensitic to single ferritic phase, was observed on the surface of JLF-1 specimen after lithium exposure, which was not observed in the specimen with identical heat history in vacuum. It seemed that the phase change was induced by carbon dissolution during the experiment. The phase transition and Cr depletion resulted in dramatic surface hardness reduction on JLF-1, dropping to 123Hv from 210Hv as shown in figure 1. The softening was observed to the depth of about 20μm. The reduction of surface hardness also happened on the Fe-9Cr, probably due to the Cr dissolution. On the other hand, there was almost no change appeared on pure Fe.

The dissolution rate of JLF-1 in liquid lithium was obtained by the weight loss for 100hrs. The average dissolution rate of JLF-1 was 0.012mm/yr at 973K.

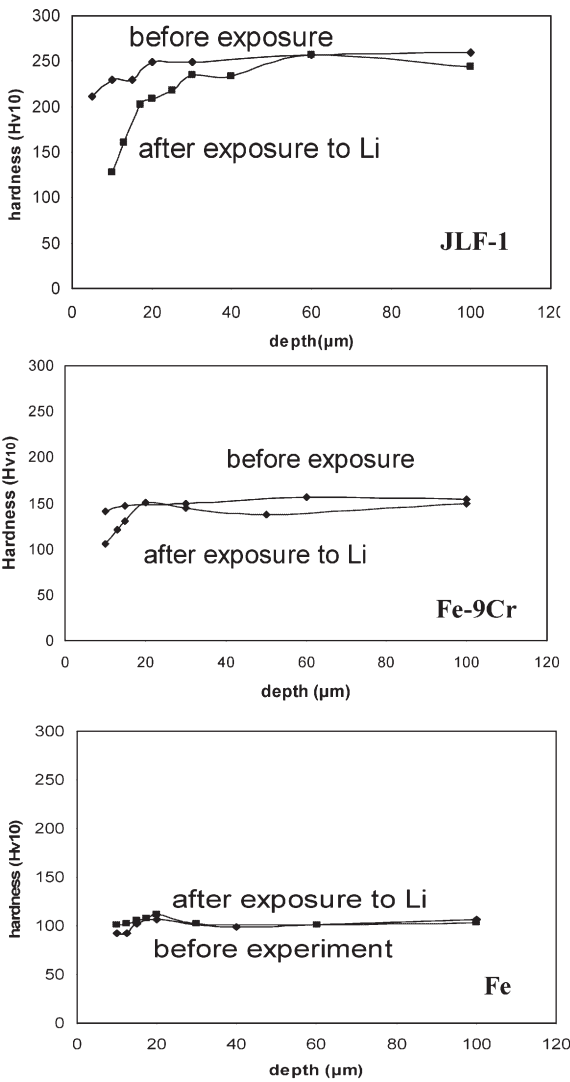


Fig.1 Depth dependence of hardness for JLF-1, Fe-9Cr and pure iron before and after lithium exposure for 100h at 973K