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Journal of Nuclear Materials 343 (2005) 368–369
journal of nuclear materials
www.elsevier.com/locate/jnucmat

Reports on summary session

# Radiation damage in general

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In total about 30 papers were presented on radiation damage which will be categorised in terms of phenomena, materials and methods (for statistical purposes, numbers of presentations dealing with the different topics are given in parenthesis).

With respect to *phenomena*, the topic of '*Production + agglomeration of defect* (5)' was mainly covered by computational work, mostly dedicated to particular source configurations. Considering the limited number of papers on basic topics, it was emphasised, that the fundamental aspects should not be neglected, giving a basis for material improvement and development. Presentations on '*Effects of transmutation products* (5)' concentrated on helium, mainly in experimental investigations (3) but also by simulation (1). The common supposition that hydrogen (2), irrespective of its much higher production rate, will be less detrimental, needs further experimental justification. The most frequently addressed topic was '*Effects of irradiation on mechanical properties + deformation + dislocation dynamics* (12)', examined mostly experimentally and in one paper by modelling. A subset of these studies dealt with *welds* (3), indicating that irradiation may pose no additional hazard. The dominance of technical oriented work in comparison to more basic ones reflects the increasing maturity in the development of spallation sources. Other phenomena such as '*Precipitation + segregation* (0)' and '*Chemical interaction + corrosion* (2)' were clearly under-represented. Up to now it was not possible (or not intended) to attract a larger number of people from these fields to the IWSMT meetings. Attempts should be made to integrate these activities, as especially the fields of pitting, liquid-metal embrittlement (LME), IASCC, and fatigue, vastly intersect with chemical and corrosion effects.

The *materials* covered in the presentations concentrated on '*Austenitic stainless steels* (12), mainly AISI 316LN, 304L, being the favoured candidates for target structures in SNS and J-PARC, and on '*Martensitic* 9–12%Cr *steels* (11)', e.g. T91, HT9, DIN1.4914, 1.4922, 1.4926, which included also reduced-activation ferritic/martensitic (RAFM)-steels, e.g. F82H, EUROFER, etc. The latter steels may be of interest to spallation sources, less for their potential of reduced activation, but for their superior fracture behaviour. '*Refractories* (7)', e.g. W, Ta, Mo, attracted interest for application in solid targets of small sources or of back-up solutions for the large liquid-metal sources. With respect to tungsten, as the preferred candidate, the most frequently addressed question was improvement of chemical resistance, e.g. by coating. On the other hand it was recognised that also mechanical properties need improvement, e.g. by fabrication technology. It was indicated that basic studies on radiation damage and of material development of W in the material programmes for fusion may be relevant to spallation targets. Investigations on candidates for beam windows dealt with '*High*-Ni *alloys* (2)', e.g. IN718, and with '*Al-alloys* (2)', e.g. $AlMg_3$, A5052, A6061, the latter being also considered for moderator structures. Basic studies on other groups of materials, such as liquid-target, reflector, absorber and moderator materials were not presented. It was recognised that, even when the major design studies (SNS, J-PARC, ESS) have decided on prime-candidate materials for the most important structures, broadening of data base as well as alloy development should continue, as most of the highest loaded parts will be routinely exchanged, allowing continuous improvements from economical or safety points of view.

With respect to the applied *methods and techniques* there was a fruitful interaction of mechanical testing

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0022-3115/$ - see front matter 
doi:10.1016/j.jnucmat.2005.03.007

and microscopical methods (TEM, SEM, PAS, SANS, etc.), with mechanical testing emphasising on fracture properties (bending, fracture toughness, impact properties etc.). It was recommended to advance miniature methods (Small-Punch, shear-punch, micro-hardness) and miniaturised specimens for standard tests, which may be indispensable for in-service testing. Reports on fatigue properties were rather limited. The existing results which seem to indicate that fatigue effects may pose no serious problems do not yet justify this restraint. As already mentioned, work on corrosion, LME etc. and the corresponding methods were clearly underrepresented.

*In conclusion* a few results and open questions may be highlighted:

- The increasing reliability of damage and transmutation calculations gives a safer basis for comparing results from different irradiation environments.
- An impressive and increasingly consistent data base on material behaviour in spallation environments is emerging.
- The possibility to improve tensile properties of steels by post-irradiation annealing, even beyond that of the virgin material, may increase lifetime and safety of targets.
- Irradiation effects in liquid metals need more attention. Examination of specimens from STIP-I and integration of liquid Hg in LISOR could promote this topic.
- In due course such experiments would also have to include the high-cycle fatigue issue.
- Development and assessment of new window materials, based e.g. on Al, Ti, etc. seems promising.
- Irradiation stability of hard layers which are proposed to reduce pitting-erosion must be assessed.