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First Wall Materials Problems in Fusion Reactors *

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Fusion reactors will utilize the reaction D + T → n (14.1 Mev) + He^4 (3.5 Mev) to generate heat for electric power production. Intense bremsstrahlung radiation as well as charged particles and neutrons will emanate from the burning plasma. Charged particles include fuel ions, alpha particles, and possible heavy ions previously ejected from the walls of the plasma chamber. First wall materials, which will operate at ~ 900-1500 K, must retain their structural integrity in this severe thermal and radiation environment. In the case of the theta-pinch reactor first wall, which requires an insulating inner liner, electrical integrity must also be retained.

First wall structural problems can be divided into surface and bulk phenomena. Surface phenomena may include such effects as sputtering, blistering, chemical erosion, and impurity desorption. 14 Mev neutron sputtering may prove to be a major problem; Kaminsky et al. (1) have found that niobium suffers extensive chunk-type sputtering under such bombardment. This phenomenon is not yet well

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characterized, however, and so the extent of the problem is uncertain. The formation and ablation of surface blisters due to ion bombardment has been studied by several investigators. It has been found that the implantation of monoenergetic, unidirectional hydrogen or helium ions can result in severe blistering of some materials, but the extent of the problem under reactor conditions has not yet been investigated. Chemical erosion (the formation and loss of new surface species under ion irradiation) is a potential problem area just now coming under investigation (2). A common characteristic of all surface effects (including desorption) is that accompanying material loss may result in plasma poisoning. Vernickel (3) has concluded that plasma contamination will be a more critical problem than wall thinning, at least in Tokamak fusion reactors. Ejection of eroded wall materials from the plasma back to the walls may prove to be a major problem, but its seriousness has not yet been evaluated in detail.

Bulk first wall structural damage may be manifested as swelling, embrittlement, or other structural degradation, with loss of dimensional control or fracture as the possible consequence. Although the specific radiation environment of a fusion reactor first wall is not currently available to experimenters for swelling studies, projects are underway to develop irradiation techniques which simulate this environment. Progress in the development of swelling-resistant fission reactor metals by control of composition and microstructure (4) offers hope that swelling can also be alleviated in fusion reactor materials.

Embrittlement is primarily a consequence of impurity pickup, either from transmutation or diffusion effects. Proposed first wall materials vary in their embrittlement tendencies; austenitic stainless steel, a metal under consideration for this application, is quite susceptible (5).

Electrical problems for the first wall insulator of the pulsed theta-pinch reactor can also be divided into surface and bulk effects. Dielectric breakdown could be enhanced by local electric fields resulting from surface charging by the plasma or from differential Compton scattering. However, the increased conductivity of insulators at elevated temperatures may preclude this possibility. Also, a neutral gas blanket between plasma and first wall is planned, to protect the wall from ion bombardment. Chemical reaction with hot fuel gases, structural metals, or coolants might result in formation of new surface or interface species with inferior dielectric properties. Electrical and structural surface effects for the theta-pinch reactor have been considered by Krakowski et al. (6). Bulk electrical degradation may result from the generation of free charge cariers by neutron or bremsstrahlung irradiation, or from changes in the concentration of traps and recombination centers. Because of the sequence of events during a plasma burn cycle, the insulator is not required to show good electrical properties during irradiation (6). Thus the kinetics of recovery of these properties after damage from the previous pulse (ten seconds earlier) must be determined before the magnitude of

electrical damage problems can be assessed.

References

1. M. Kaminsky, J. H. Peavey, and S. K. Das, Phys. Rev. Lett. 32, 599 (1974).
2. D. M. Gruen, personal communication.
3. H. Vernickel, "First Topical Meeting on the Technology of Controlled Nuclear Fusion", April 16-18, 1974, San Diego, CA (to appear in the Proceedings, USAEC Conference Series, CONF-740402).
4. R. S. Nelson, New Sci. Sci. J. 49, 664 (1971).
5. G. L. Kulcinski, R.G. Brown, R. G. Lott, and P. A. Sanger, Nucl. Technol. 22, 20 (1974).
6. R. A. Krakowski, F. W. Clinard, Jr., F. L. Ribe, and T. A. Coultas, J. Nucl. Mater. 53 (1974)(to be published).