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PLASMA SURFACE INTERACTION PROCESSES AND POSSIBLE SYNERGISMS

R. Behrisch and J. B. Roberto

SOLID STATE DIVISION
OAK RIDGE NATIONAL LABORATORY
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Rainer Behrisch
Max Planck Institut für Plasmaphysik
EURATOM-Association
D-8046 Garching/München,
Federal Republic of Germany

and

J. B. Roberto
Solid State Division
Oak Ridge National Laboratory*
Oak Ridge, TN 37831 USA

The processes determining the plasma surface interaction in today's high temperature plasma experiments are investigated following several lines. First, in plasma devices, the particle and energy fluxes to the different first wall areas and the fluxes from the walls back into the plasma are measured and the boundary plasma parameters are determined. The surface composition and structure of the walls, limiters and divertor plates are analysed following exposure to many discharges. Secondly, the different surface processes which are expected to contribute to the plasma surface interaction (particularly to hydrogen particle balance and impurity introduction) are studied in simulation experiments using well defined particle beams.

The results of these different approaches can be combined to give a qualitative picture of plasma wall interaction processes in relatively few areas. In most cases, a consistent description of the plasma wall interaction and its influence on the plasma has not yet been achieved. A two dimensional theory which is necessary for describing the boundary plasma is in an early stage of development. There is only a limited effort toward a quantitative description of recycling and of the total particle balance. It is not clear whether there

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will be major sources for impurities other than sputtering. The criteria for the selection of wall materials are not yet established. For example, carbon appears to work best in plasma experiments, but shows relatively high erosion in ion bombardment simulation studies.

A major concern in using surface data measured from well defined ion beam experiments to explain wall phenomena in fusion devices is related to the quality of the simulation. In plasma experiments, the walls are bombarded by a large variety of particles having a broad distribution in energy and in angle of incidence. The effects of these different bombarding species do not always add linearly.

Problems of nonlinear additivity of different actions have been discussed for ages in theology, philosophy, and medicine. They are given the name synergism from the greek word syn - ergos which means cooperation.[1] This word has also been adopted in fusion research to describe wall phenomena where the combined effect of independent processes is significantly different from the individual effects considered separately.[2,3]

Synergistic effects are expected to influence surface processes in several areas,[3] however, their contribution to surface effects in plasma experiments has not yet been explored in any detail. Generally all effects connected with the thermal motion of the atoms of a solid such as diffusion in the bulk or at the surface, evaporation and sublimation, and chemical reactions may be increased or decreased due to simultaneous bombardment with energetic particles. During bombardment at high temperature, free interstitials and vacancies are produced generally increasing the diffusion. Implanted gas atoms (H, D, T, He) and impurities (O, C metals) change the surface layer composition. There are further synergisms due to bombardment with ions of different energies and/or different atoms, and due to the simultaneous additional application of stresses and magnetic fields.

Synergisms have been identified in a variety of plasma surface interaction phenomena including hydrogen particle balance, impurity release, and mechanical and electromagnetic stresses. In particle balance, synergistic effects occur during simultaneous hydrogen bombardment and bombardment with other damage producing ions such as He or impurity ions. Here additional trapping centers are created which influence trapping, saturation concentrations, diffusion and surface recombination.

In impurity release, chemical or reactive sputtering has been found due to the formation of volatile hydrocarbons during implantation of carbon with hydrogen atoms at high temperatures. Similar effects are found for oxygen bombardment of carbon or some metals where the oxide sublimates at temperatures lower than the bulk material. Large chemical erosion has also been observed due to simultaneous exposure of a graphite surface to atomic hydrogen and a damaging ion flux. In addition, graphite shows an enhanced sublimation at temperatures $\geq 1000°C$ if it is simultaneously bombarded by energetic particles. On the other hand, chemical erosion of carbon with hydrogen atoms is considerably reduced by simultaneous deposition of metal atoms.

Finally mechanical stresses influence the surface topography and surface cracking due to ion bombardment. Melted surface layers can be destabilized by magnetic fields. Synergistic processes in plasma surface interactions have been reviewed in Ref. 3 and will be discussed in more detail in the contributions to this workshop.

REFERENCES

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