MEETING REPORT

SUMMARY OF SEVENTH INTERNATIONAL WORKSHOP ON CARBON MATERIALS, STOCKHOLM, SWEDEN, SEPTEMBER 21–22, 1995

The International Workshop on Carbon Materials, held in Stockholm, Sweden, on September 21 and 22, 1995, was the seventh meeting in the series designed to highlight recent progress in studies and development of plasma-facing materials for controlled fusion devices. The meeting was organized through the close cooperation of groups from the Royal Institute of Technology, Stockholm, and Forschungszentrum Jülich (KFA), Jülich, Germany. This was the first time that the workshop was organized outside Germany; all previous meetings of the series were held at KFA. The workshop was sponsored by the Royal Swedish Academy of Sciences through its Nobel Institute of Physics, the Swedish Natural Science Research Council, the Royal Institute of Technology, and the city of Stockholm.

The symposium gathered 48 registered participants, including 15 from Germany; 12 from Sweden; 6 from Japan; 3 each from France, the United States, and Russia; 2 each from Italy and the United Kingdom; and 1 each from Poland and India. The scientists came from the leading plasma physics and fusion-related materials research laboratories.

The presentations included 16 invited talks and several oral presentations given both by the researchers and the representatives of industrial companies developing plasma-facing materials and components. Moreover, Toyo Tanso, Ltd., Japan, organized an exhibition of its products. Ample time was allowed for discussions and "hot topic" presentations.

The program consisted of three major topics:

1. neutron irradiation effects in materials
2. hydrogen interaction with materials and tritium inventory
3. comparison of carbon materials with beryllium for fusion applications.

The speakers presented both an overview and details of the field.

T. Tanabe (Japan) discussed the sp^2-sp^3 transition in neutron-irradiated graphites and its influence on volume expansion under high dose irradiation. That issue and the change in thermal conductivity and strength were addressed in T. Burchell's (United States) and J. P. Bonal's (France) presentations for a number of carbon-fiber composites (CFCs) irradiated at elevated temperatures with neutron doses of up to 4.7 displacements per atom (dpa). The recovery of thermal conductivity due to annealing was also demonstrated. The influence of neutron-induced damage on the increase of tritium retention in carbon-based materials was presented by R. A. Causey (United States), who stressed that for all the irradiation conditions studied, the retained tritium was less than that measured in earlier studies for different types of graphites. The results suggest that carbon composites should be preferred over graphites for use in fusion reactors where both tritium and neutron irradiation exist. H. Werle (Germany) also observed the increased tritium retention in carbon composites. Moreover, his results for beryllium indicated a gradual increase of tritium retention by a factor 10, with increasing fast neutron fluence, in the range of up to 40 dpa, which was assumed to be caused by irreversible changes in the microstructure of beryllium. S. Kanashenko's (Russia) presentation dealt with a thermodynamic analysis of hydrogen interaction with beryllium and graphites.

T. Yamashina (Japan) summarized the ongoing studies in Japan on development of materials for high heat flux components capable of removing fluxes of up to 30 MW/m^2. In addition, the progress of divertor concepts, such as a local island divertor and ripple limiters, was reported. The results for the testing of candidate plasma-facing materials, including different CFCs, beryllium, and tungsten, under thermal shock conditions were presented by M. Rödig (Germany). At heat loads of up to 5.3 MJ/m^2, CFC and tungsten showed much lower erosion (weight loss) than that measured for beryllium. Concerning beryllium, the best resistance to the thermal shocks was found for S 65-C and TPG-56 grades.

R. Castro (United States) reported on the progress in the production of high thermal conductivity beryllium coatings obtained in the plasma-spray process. The investigations have focused on optimizing the process for depositing the coatings on damaged beryllium surfaces and on thermal cycle tests. Castro also gave a summary of contributions presented during the Second International Workshop on Beryllium for Fusion Applications held in Idaho Falls, Idaho, in September 1995.

Laboratory experiments on deuterium-induced erosion of carbon composites doped with silicon or titanium, presented by J. Roth (Germany), showed the preferential removal of carbon and enrichment of the surface with the dopant; pronounced surface topography development was observed following the ion bombardment. The thermally activated hydrocarbon emission was already reduced at low D^+ ion fluences. A paper reviewing the erosion behavior of several candidate materials exposed to the deuterium plasma in the PISCES-B facility was submitted by Y. Hirooka (United States). The influence of impurities and materials mixing on the erosion effects was also discussed in that paper.

Several presentations concerned erosion of the first-wall components in fusion devices: Tokamak Experiment for Technology Oriented Research (TEXTOR) and Joint European Torus (JET). Chemical erosion of carbon materials, leading to the formation of CH_4, higher hydrocarbons, and CO, was compared by V. Philipps (Germany) for different wall conditions. It was found that the siliconization of the walls reduced the CH_4 formation only slightly compared with the carbonized or boronized surrounding but significantly suppressed the formation of higher carbon-hydrogen compounds. Composition and distribution of thick codeposits (layers containing hydrogen isotopes together with plasma impurity species) formed on the JET divertor components and the impact of such codeposits on the operation of future devices were discussed by M. Rubel (Sweden). Results proving a high accumulation of hydrogen isotopes, $>10^{19}$ cm^{-2}, in the deposition zones of the divertor were shown. A thorough comparison of carbon and beryllium, based on operational experience at JET, was delivered by M. Pick (United Kingdom). High-power-handling capabilities and resistance to thermal fatigue were underlined for CFCs, whereas reduced plasma radiation levels, increased dynamic wall pumping, and good density control were stressed for beryllium.

The present status of the design of the International Thermonuclear Experimental Reactor (ITER) first wall and blanket was presented by K. Ioki from the ITER Team. Lifetime assessment of the divertor armor and other in-vessel components for ITER was discussed by C. H. Wu from the NET Team.

Invited papers will appear in the topical issue of *Physica Scripta*, Vol. T-64.

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