§51. Heat Load Test of Divertor Plate Module of LHD

Yoshida, N., Tokunaga, K. Miyamoto, Y. Fujiwara, T. Kugimiya, M. (Res. Inst. Appl. Mech. Kyushu Univ.)
Motojima, O., Noda, N., Kubota, Y.

Carbon-copper joint materials has been developed as high heat flux components for the divertor plate of Large Herical Device(LHD) that is being constructed at NIFS. The main aims of this study are to estimate (1) resistance of joint layer for repeated heat load, (2) erosion of carbon materials and (3) mechanism of impurity emission due to erosion.

In the present study of this year, composition and microstructure of the interface of C/C and Cu joint materials by a brazing using a interlayer foil were observed as well as behavior of thermal response in according to (1). On the other hand, according to (2) and (3), amount of erosion and surface compositional change of B_4C coated C/C were evaluated by a weight loss and a AES analyses, respectively.

The test samples were high thermal conductive carbon-carbon composite(C/C) and B_4C coated C/C produced by a chemical vapor reaction that were fabricated at Toyo Tanso Co. Lid. The sample size was 20 mm x 20 mm x 10 mm. The thickness of B_4C layer was about 0.2 mm. The C/Cs were brazed to OFC(oxygen free copper) using iron and copper brazing filler metals. Mo plate with a thickness of 1mm is used as interlayer materials between the C/C and the OFC to relax to the difference of thermal expansion of the C/C and the OFC. The dimension of the brazing materials was 20 mm x 20 mm x 21 mm(10 mm C/C + 1mm Mo + 10 mm OFC). The samples were exposed to electron beam in an electron beam facility named the Active Cooling Teststand(ACT) in NIFS. The heat loading time was 30 sec and the energy of electron beam was 30 keV. The samples were placed on a block actively cooled with water. The top surface of the sample(20 mm x 20 mm) was irradiated almost uniformly by electron beam. During the irradiation, the surface temperature was measured with a pyrometer and time evolution of vacuum pressure and electric current were monitored. Emitted gases and atoms from the heated specimen surface were also monitored by a quadrupole mass spectrometer (QMS). In addition, surface morphology before and after the irradiation was observed by a scanning electron microscope (SEM). Compositional changes along cross section after the irradiation was analyzed with a scanning Auger electron microspectroscope (SAM). Microstructure and composition of interface between the C/C and the OFC of the brazing materials were examined with a scanning electron microscope (SEM) equipped with a energy dispersion X-ray spectroscope (EDS).

Experimental results of weight loss showed that the amount of erosion exponentially increased with increasing surface temperature and that of the B_4C coated materials was larger than that of the C/C. When the amount of erosion of the B_4C coated C/C was large, the pressure in the vacuum chamber decreased by gettering effect due to B evaporation, but the use at high temperature is not suitable due to high erosion. This result suggests that the B_4C coated C/C should be used at relatively lower temperature rather than the C/C.

Examination of compositional change of cross section after the irradiation showed that distribution of B became to be ununiform and content of B near surface region decreased when melting occurred. This result indicates that the composition changes due to preferential evaporation or sublimation and the effect of the B_4C coating degrades.

Alloys were formed by melting of brazing materials on the interface of the brazing using a Mo interlayer. It is expected that the formation of alloys as well as increase of thickness by multiple layer structure results in decrease of the thermal conductivity. Porous phase was also observed. This may cause degradation of strength about the interface of the brazing layer.