§26. Heat Removal Enhancement of Plasma-Facing Components by Using Nano-Particle Porous Layer Method

Kunugi, T., Okamoto, Y., Kawara, Z. (Kyoto Univ.), Hashizume, H., Yuki, K. (Tohoku Univ.), Shibahara, M. (Osaka Univ.), Satake, S. (Tokyo Univ. Of Science),
Sagara, A.

Heat transfer enhancement is one of key issues of saving energies and compact designs for mechanical and chemical devices and plants. Until today people have made effort to enhance convective heat transfer by means of the surface enlargement using obstacles such as ribs and fins and the increase of flow turbulence. However, additional pressure losses increase with increases of introducing obstacles and turbulence. A very high convective heat transfer performance compared to the well-known conventional heat transfer correlations caused by a nano-particle porous layer formed on the heat transfer surface was discovered by the authors (Kunugi, 2004a, 2004b). Two fabrication methods have been developed such as a "Nano-Particle Layered Surface (NPLS)" method and a "Fine Precipitate (FP) " method. Heat transfer surfaces treated by the NPLS or FP method showed very high heat transfer performance compare to the conventional surfaces: the maximum increase of heat transfer performance was up to 120% (Kunugi, 2003, 2004a). However, the lifetime of the high heat transfer surface was rather different between them: the surface made by the FP method covered with Silicon oil as a stain material and the surface made by the NPLS method is contradictory to maintain the high heat transfer performance. Third fabrication method with combining two methods has been developed: a "Nano- and Micro Particle Layered Surface (NMPLS)" method. This method is that the FP method applied to the heat transfer surface at first, and then the NPL method applied to the surface treated by the FP method. This NMPLS method also shows high heat transfer performance and would have a long lifetime because of the nature of NPL surface.

In this year, in order to understand these high heat transfer mechanism, the temperature profile in the parallel flow channel has been measured by using a K-type sheath thermocouple of 250μm in diameter. The experimental apparatus is shown in Fig. 1. The flow channel consists of 500mm long with 5mm in height and 50mm in width. The upper wall is made of stainless plate of 5mm thickness and a rubber heater attaches on the top to provide the uniform heating condition. A test plate attaches on the backside of the upper wall and the bottom and side walls are made of polyvinyl chloride to be insulated walls. The thermocouple can be vertically moved by a linear electromagnetic drive with 100μm intervals. The heater is set to around 200W (200Vx1A). The Reynolds number (=2UH/ν, U is mean velocity, H channel height, ν viscosity) is set to around 1200. The calorimetric balance of the experimental apparatus is satisfied within less than 10% accuracy. Figure 2 shows a scanning electron microscope (SEM) image of nano- and micro-scale porous layered surface (NPLS) on the test plate. Figure 3 shows the temperature profile in the parallel channel flow. The solid circle shows the bare plate case and the open one for the NPLS plate. The wall temperature in case of NPLS is rather lower than the bare plate case. This discrepancy leads to the heat transfer increase at the NPLS surface. The temperature profile in case of NPLS plate case is also lower than that of the bare plate case. Moreover, the temperature fluctuation very close to the wall has been measuring and shows a bit difference from that of center in the channel. In the report written in Japanese, the reasons of heat transfer enhancement mechanism are discussed.

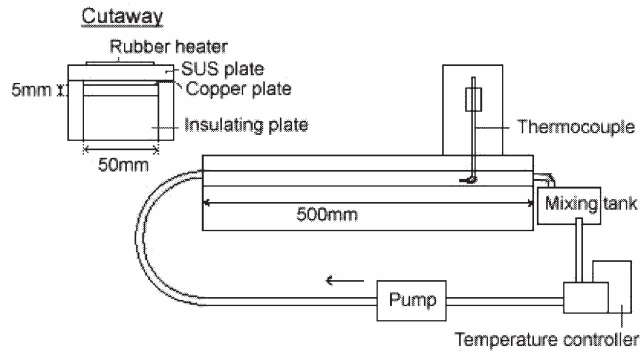

Fig. 1 Experimental apparatus

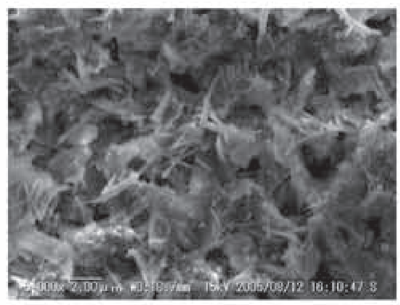

Fig. 2 SEM image of nano- and micro-scale porous layered surface: NPLS (many board- and needle-shaped crystals can be seen)

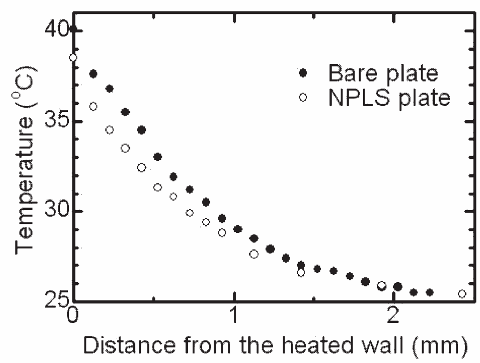

Fig. 3 Temperature profiles for bare copper plate and NPLS plate

REFERENCES

Kunugi, T. et al., Proc. Int. Sympo. Micro-Mechanical Engi., Tuchiura, Japan, pp. 129-134 (2003).

Kunugi, T. et al., Proc. 1st ISMNT, 14-17 March, 2004, Honolulu, Hawaii, USA, CDROM XXVII-3-01 (2004a).

Kunugi, T. et al., Superlattices and Microstructures, vol. 35, Issues 3-6, pp. 531-542 (2004b).