§22. Heat Removal Enhancement of Plasma-Facing Components by Using Nano-Particle Porous Layer Method (I)

Kunugi, T., Ueki, Y., Kawara, Z. (Kyoto Univ.),
Sagara, A.

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[1-3]. Two fabrication methods have been developed such as a "Nano-Particle Layered Surface (NPLS)" method and a "Fine Precipitate (FP)" method. Another fabrication method with combining previous 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.

In the previous studies[1-3], the scanning electron microscopic (SEM) observation of the nano/micro porous layer was performed. The SEM images showed the plate-like or needle-like crystals of the nano-particles are chemically formed on the bare plate surface, i.e., the nano/micro porous layer. The pore size is 0.01-10 μm, the layer thickness is 70-100 μm. The pores are almost connected to one another. The porous layer material made of the copper oxide has poor thermal conductivity, but the pores show very good wettability of liquid. Owing to this feature of the porous layer, it considers that the porous layer filled with liquid can be like a "fluid wall" which reduces the thermal resistivity in spite of the poor thermal conductivity of the porous layer. Moreover, since this surface roughness is very small compared to the laminar boundary layer thickness, the additional pressure rise cannot be expected.

In this study using the fundamental apparatus as shown in Fig. 1, the net amount of the input energy from the porous layer plate to the water was increased 20-25% in comparison with the bare plate. It was found that this enhancement was independent on the base-plate material and the thickness. In order to investigate the heat transfer enhancement mechanism using nano/micro porous layer, the effect of the Reynolds number on the heat transfer of the porous layer was examined as shown in Fig. 2. The Nusselt number calculated from the overall heat transfer coefficient was measured with varying the Reynolds number. This experiment revealed the heat transfer performance of the porous layer was high in the experimental range of the Reynolds number based on the test plate diameter, and the gradient of the Nusselt number with the variation of the Reynolds number in case of the porous layer was a little gentle than that in case of bare plate. This means the heat transfer performance of the porous layer tends to be degraded with increase of Reynolds number

Based on the SEM observation of nano/micor porous layer, an unsteady one-dimensional thermal conductivity analysis was conducted. This showed the porous layer filled with water will be heated up to the same temperature as the heated base-plate within msec, and if the fluid with the temperature as high as the heated base-plate is removed a little bit from the pore near the porous layer surface, the temperature recovery by transferring energy from the heated base-plate is quite immediately, in order of μsec.

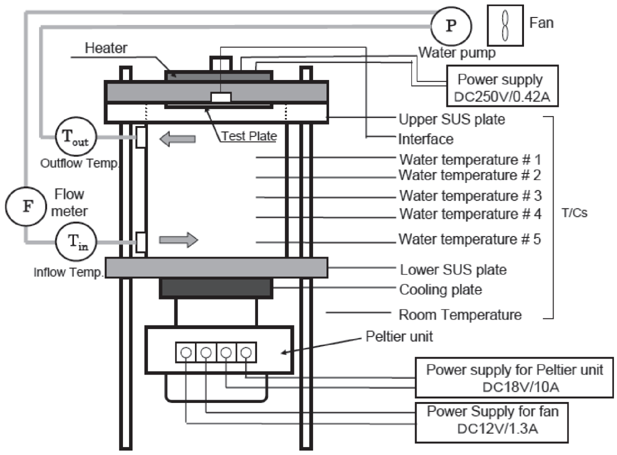

Fig. 1 Experimental apparatus

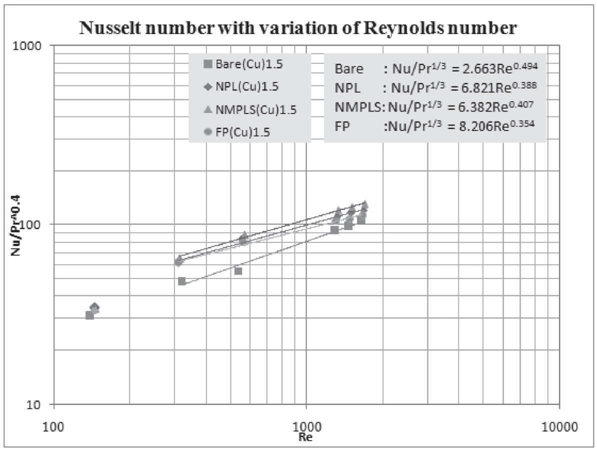

Fig. 2 Effect of Reynolds number on heat transfer performance

The temperature fluctuation at low frequency (around 0.10 Hz) was also measured on the porous layer surface[5], and the same fluctuation was not obtained near bare-plate surface. At this moment, this fluctuation can be considered as the result of a "new behavior" of heat and fluid flow from the porous layer. It is necessary to investigate this flow behavior in the near future.

Taking all experimental and analytical results into consideration, the transferring energy by the new heat and fluid flow behavior from the heated base plate during the temperature recovery is considered as main contribution to the heat transfer enhancement mechanism at present.

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