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

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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. 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. 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. This NMPLS method also shows high heat transfer performance and would have a long lifetime because of the nature of NPL surface.

This study is to investigate the mechanism of high heat transfer augmentation with the nano/micro porous layer structure formed on the plate surface. We confirmed that the net amount of input energy through this porous surface was 20-30% increase compared to the bare plate without any porous layer by using the fundamental equipment as shown in Fig. 1. We confirmed the increase of the net input energy from the test plate to the water: the input energy for all NPL, FP and NMPLS plates is 20-25% larger than the bare copper plate and 25% larger in case of the stainless steel plate as shown in Fig. 2. We examined the plate thickness effect on the input energy and then obtained the results showed all the same (> 1mm of thickness): no effect of the plate thickness on the heat transfer augmentation as shown in Fig. 3. This means that the thermal resistance is predominant at the nano/micro-porous layer. However, since the thickness of the nano/micro-porous layer is about 100 micron meter, in general it can neglect as a thermal resistance. Moreover, since this thickness can also be so small compared to the laminar boundary layer thickness, it can also neglect as a flow agitator (i.e., turbulence promoter).

On the other hand, from the SEM image, this porous layer consisted of many particles and contacted with each other. This means that this porous layer can be considered as an adiabatic medium. Moreover, the etching layer between porous layer and the metal plate (i.e., heat transfer surface) shows very tight binding and this layer thickness is around minimum 5~10 nm. This thickness is too thin to act as an adiabatic layer.

Therefore, the heat flow can easily pass through this thin part of the etching layer. Eventually, the heat flow can increase at that thin part. The water inside the porous layer could heat up by this increased heat flow and the temperature immediately increases and finally reaches to the wall temperature. This means that this nano/micro porous layer structure filling with water might act as a fluid-like wall. This might be a possible mechanism of this heat transfer augmentation by the nano/micro porous layer structure formed on the surface.

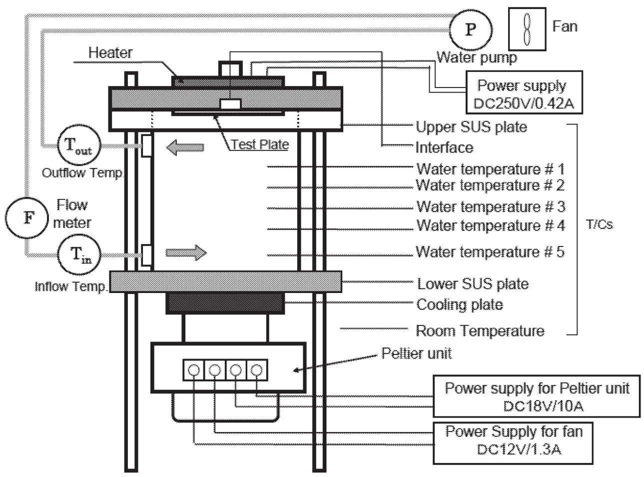

Fig. 1 Experimental apparatus

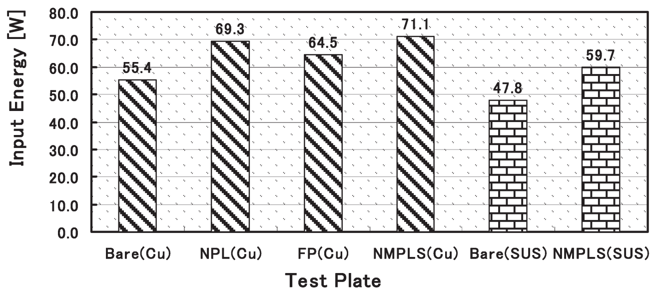

Fig. 2 Net input energy for various test plates

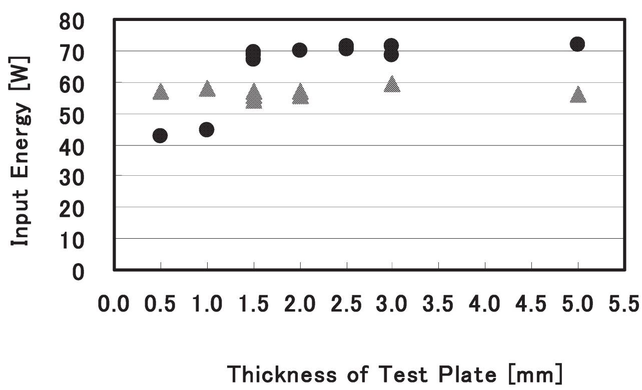

Fig. 3 Effect of Test plate thickness on heat transfer performance