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

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i) Nano- and Microscale Porous Layer Experiment

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.

An ultrahigh 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: the maximum increase of heat transfer performance was around 160~180%. A nano-porous layer formed on the heat transfer surface by a chemical etching with some acids or alkalis including nano-particles can provide an ultrahigh convective heat transfer performance. This method was named as a "Nano-Particle Layered (NPL)" method. This nano-porous layer formed on the substrate was confirmed by a scanning electron microscope (SEM). Moreover, we developed a new porous layer fabrication technique, named a "Fine Precipitate (FP)" method. This porous layer also showed a good heat transfer performance, but this layer has a little weak feature because of the adhesion of the stains contained in the fluid flows. In order to examine the applicability of these methods to the real size heat exchanger, some experiments for a parallel flowing heat exchanger consisted of hot and cold water-channels making from an acrylic double open-ended box and a thin copper partition plate were conducted and got a very high performance: over 200% increase compared to the bare heat transfer surface. Combining two methods: NPL and FP, we develop a new "nano- and micro-scale porous layer surface (NMPLS)" method and confirm the heat transfer enhancement feature as same as that of NPL and FP methods.

In the present study, in order to investigate the temperature profile near the wall, we have made a small test channel: 500 mm in length, 50mm in width and 5mm in height as shown in Fig. 1 and have been conducting a fundamental heat transfer test for two cases: case-1) a bare copper plate was installed as the top wall with heating and the bottom wall is adiabatic, case-2) the top wall covered by the NMPLS or FP with heating. We used three types of thermometer: Platinum resistance thermometer, 25 and 250 μm thermo-couples, and measured the temperature profiles near the wall. Figure 2 shows the comparison of the temperature profiles between both cases. However, it is difficult to evaluate whether the effect of nano- and micro layer on the heat transfer is obvious or not. This is because the thermal boundary layer could be too thin to realize the nano- and micro-scale porous layer effect. We are planning to make a larger test section at Kyoto University in 2005.

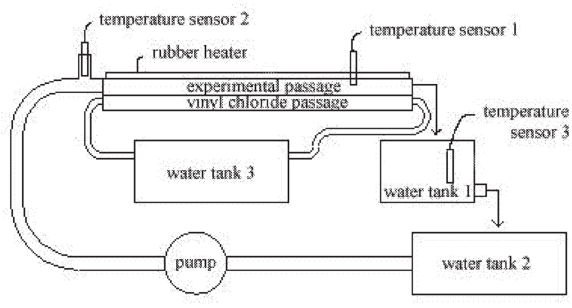

Fig.1 Preliminary heat transfer test section for nano- and micro-scale porous layer 1000.

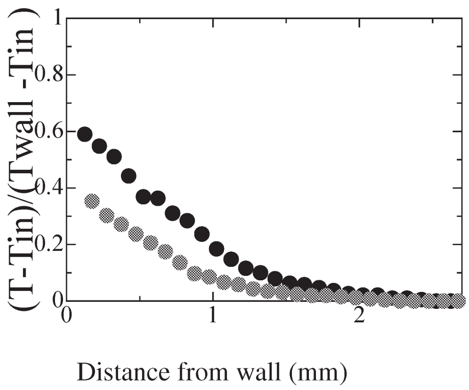

Fig.2 Normalized temperature distribution from the wall Reynolds number is around 1000.

ii) Approach to the Mechanism of these phenomena

In order to investigate the mechanism of this ultra-high heat transfer process, we have been conducting the molecular dynamic (MD) simulation. Until today, the MD results show that the surface to be the maximum was not to be the maximum energy transfer because the fluid molecule could not flow in/out through such a very narrow clearance between the nano-scale obstacles. The results suggest us the effect of the nano-structure on the thermal properties of the fluid could be large.

As for the macro-scale simulation via a direct numerical simulation, we have examined several types of wall conditions such as low friction wall. However, it is not clear to clarify the effect of the low friction on the heat transfer. It would be necessary to develop a new type wall boundary condition to match the experimental results.

iii) Experiment of Molten Salt Flow and Heat Transfer

In order to investigate the enhancement of the molten salt for the FFHR application, we have reconstructed the TNT-loop at Tohoku University to keep the experimental area and make a test section. The basic experiment has been conducting to check the loop performance such as ordinary heat transfer test and pressure drop measurement.