Thermal Conductivity of Super Fine Structural Insulator

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According as the cost of energy is rising, there is a need for good heat insulators for saving energy that is consumed in the heat treating plants. A ceramic fiber and a super fine structural insulator appear to answer this need. Particularly, the latter material has the thermal conductivity close to that of still air, so that it will be widely used in the field requiring a large quantity of heat energy such as steel or ceramic industries. In this paper, the thermal property of this new insulator and its performance as a heat insulator at high temperatures were investigated.

This insulator having the chemical composition as shown in Table 1 is named “Microtherm” and commercially available. This was formed a board-like by filter-pressing the slurry dispersed the raw materials into solvent. To measure the thermal conductivity, two specimens sawed into a rectangular form of 25×50×100 mm. The thermal conductivity measurement was conducted by the transient hot wire method described in previous papers[1-3]. The sample with the probe composed of a hot wire (0.3 mm φ Pt-Pt 13% Rh wire) and thermocouple (0.3 mm φ Pt-Pt 13% Rh) was set in the alumina tube in order to obtain reasonable temperature uniformity along the tube furnace controlled by a PID program controller. Thermal conductivity measurements were automatically conducted by using a microcomputer.

The result of measurement of thermal conductivity for Microtherm up to 950°C limited as a

Table 1. Chemical composition of sample.

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<th>Chemical composition (wt%)</th>
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<td>SiO₂</td>
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<td>64.68</td>
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Fig. 1. Thermal conductivity of super fine structural insulator.
critical temperature for the application of this insulator is shown comparing with that of still air in Fig. 1. The black dots in Fig. 1 stand for the values measured at each temperature after measurements at 950°C have established. Although the measurements at maximum temperature were repeated 7 times for about 3 h, no hysteresis on the values obtained during heating or cooling was observed as seen in Fig. 1. This mean that the microstructure of the insulator didn't change during measurements up to 950°C. It was found that the temperature dependence of thermal conductivity of Microtherm is very close to that of still air up to 400°C.

The result obtained was compared with those of ceramic fibrous insulators⁶⁻⁷ and a calcium silicate insulator in Fig. 2. It was obvious that the thermal conductivity of Microtherm is very low in comparison with other insulation materials having lower conductivity than that of insulating bricks⁸ and the increasing rate in thermal conductivity with increasing temperature was very small.

Figure 3 shows a scanning transmission electron microscope image and an electron diffraction pattern of Microtherm observed with HITACHI H-800 electron microscope. As seen in Fig. 3, Microtherm consists of the ultra fine amorphous particles (SiO₂) cohered with a small amount of crystalline particles (TiO₂) dispersed. The size of voids or cells produced between such as fine particles must be less than about 1000 Å, i.e. less than the mean free path of an air molecule at room temperature. Therefore, the apparent thermal conductivity of still air filled up the voids or cells was to be less than that of still air and the
crystalline particles (TiO$_2$) dispersed in the insulator behaved as the reduction agent of heat transfer by radiation so that Microtherm with the ultra fine structure is a very high efficiency thermal insulation material having the thermal conductivity only one third that of most high temperature insulators such as ceramic fibrous insulators at high temperatures.

The microstructure of such a super fine structural material may easily be destroyed by sintering of fine particles during being exposed to its maximum operating temperature. Figure 4 shows the time dependence of thermal conductivity of Microtherm. It was found that its thermal conductivity increased gradually with prolonged periods accompanying with thermal shrinkage. So, it should be taken care to use such a fine structural insulation materials at their maximum operating temperature.

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References