§3. Development of High Power CW Milimeter-Wave Vacuum Windows Using a Silicon Nitride Composite

Shimozuma, T., Sato, M., Takita, Y., Kubo, S., Idei, H., Ohkubo, K., Watari, T.

Development of millimeter-wave vacuum barrier windows is one of the most important subject to accomplish windows of both high power, CW gyrotrons and ECRH systems of LHD.

Recently, Kyocera Corporation developed new material (silicon nitride composite so called SN-B), which shows low loss tangent at low frequency ranges (7-30GHz). The silicon nitride has higher thermal shock resistance, higher flexural strength and better thermal conductivity than sapphire. Metalizing and brazing with some metals is possible, though it is more difficult than sapphire because of its small thermal expansion characteristics.

We fabricated an SN-B disk with the diameter and thickness of 161mm and 1.96mm, respectively. This disk is metalized and brazed with a molybdenum flange for welding. This assembly was heat-cycle tested up to the temperature of gyrotron baking several times and no vacuum leak was observed after the testings.

We measured the loss tangent of this material by observing temperature rises of a disk during high power (80kW level) millimeter wave transmission from an 84GHz gyrotron. Assuming the rf profile on the disk to be gaussian with the beam waist radius of 18.7mm which is a designed value, we compared observed behaviors of temperature rise with calculated ones and determined the loss tangent. As the disk could be heated by a resistive wire which was wound around the disk in the thermal insulator support, we measured the loss tangents at several temperatures of the material. Figure 1 shows the temperature dependence of the loss tangent. At room temperature, it is estimated to be 1.5×10^{-4}, which is comparable to sapphire. The temperature dependence of the loss tangent is weak and proportional to T.

Low power measurements of the loss tangent were performed on another frequency range (140-145Gz) with a sophisticated high Q Fabry-Perot resonator in collaboration with FZK in Germany. The loss tangent in this frequency range was assured to be 2.4×10^{-4}. Figure 2 summarizes the frequency dependence of the loss tangent of the silicon nitride composite. Frequency dependence of $\tan\delta$ is weak ($\sim f^{0.3}$).

Easiness of manufacturing large size disks, superiority of mechanical property and comparable rf characteristics give it possibility to become the rf window material instead of sapphire.

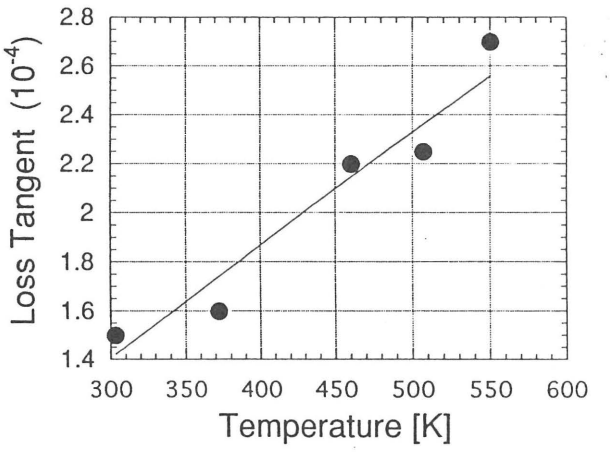

Fig. 1 Measured temperature dependence of the loss tangent.

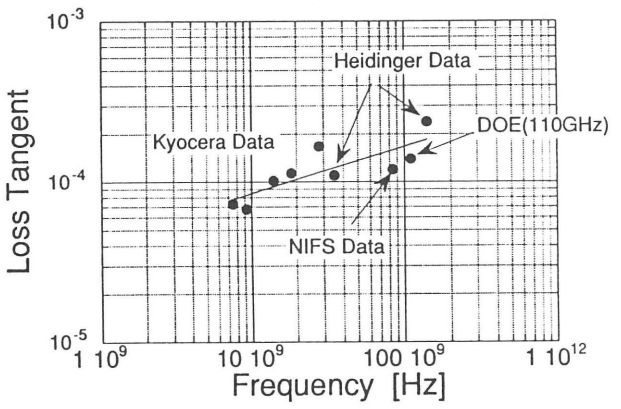

Fig. 2. Frequency dependence of the loss tangent