§20. Evaluation of Millimeter-wave Absorption Behavior of Nitride Powders

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Studies on microwave and millimeter-wave power applications are extensively done for sintering of ceramics and metals, and also done to expand the research field to chemical reactions. As a basis of developing microwave and millimeter-wave power applications, it is important to know the microwave/millimeter-wave behaviors of object materials. For this purpose, we have been measured permittivity and absorption behaviors of oxide ceramics and metal powders at microwave and millimeter-wave region. In the previous joint research, we reported measurement results of complex permittivity of nitride powders at room temperature. In this study, millimeter wave absorbency change of nitride powders were measured under vacuum heating. Subjected nitrides were BN, which showed very low dielectric loss angle δ (tan δ), and Cr_2N, which showed high tan δ at room temperature.

The microwave/millimeter-wave absorption measurement system comprises a vector network analyzer, a circular wave-guide fixture, and a vacuum furnace. The length of the circular wave-guide fixture was 660 mm long with an internal diameter of 8 mm, and the matching frequency was adjusted to approximately 24 GHz. At this frequency, the millimeter-waves were H_{11} single mode in the circular wave-guide. A microwave/millimeter-wave vector network analyzer (Agilent Technologies: 8510C system) was used to measure the reflection spectrum from the circular wave-guide fixture. The sample powder was packed into the bottom end of the wave-guide fixture, and the reflection signal was measured at the opposite side using the network analyzer. The end of the fixture in which the sample powder was packed, was heated in a vacuum furnace to prevent oxidation of the wave-guide metal. The change in signal power from the sample during heating was measured using the time-domain mode of the network analyzer in the frequency range from 23.8 to 24.2GHz. The network analyzer was calibrated at the end of a coaxial cable prior to the measurements. The vacuum furnace was operated at a heating rate of 5°C/min to a final temperature approximately 1100°C and was subsequently cooled at the same rate. A reflection spectrum was measured every 2°C during the heating and cooling processes. The reflection power of each sample was evaluated using the time-domain-mode results.

In the previous joint research, it was recognized that tan δ at 24GHz were 0.001 for BN powder and 0.597 for Cr_2N powder at room temperature. Figure 1 shows the millimeter-wave absorption measurement results for BN powder at temperatures up to 1120°C. Blank data, measured without a sample, is also plotted as a narrow line for comparison. The BN powder data and blank data are

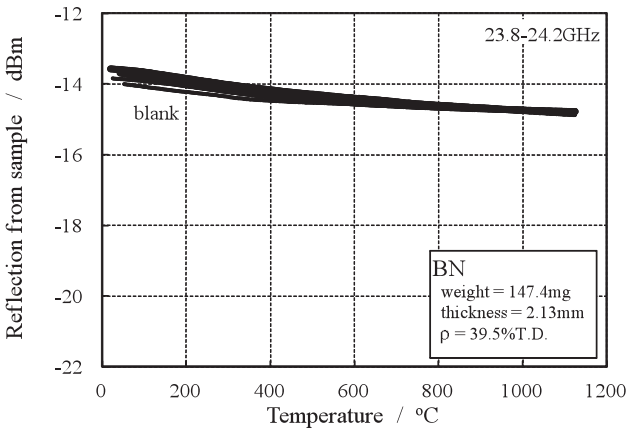

Fig. 1 Millimeter wave absorbency change of BN powder under vacuum heating.

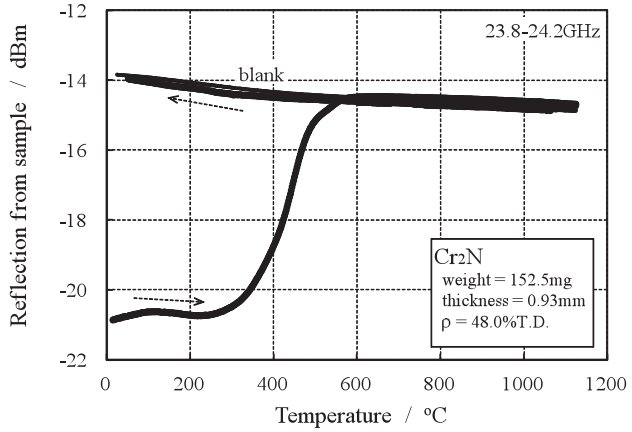

Fig. 2 Millimeter wave absorbency change of Cr_2N powder under vacuum heating.

overlapped within the measured temperature range. This result indicates that BN is not an absorber of millimeter-wave energy in the measured temperature range. Therefore, BN is a good thermal insulator for millimeter-wave heating. Figure 2 shows the millimeter-wave absorption measurement results for Cr_2N powder at temperatures up to 1120°C. Cr_2N exhibits high millimeter-wave absorbency even at room temperature as shown in the figure. During vacuum heating, its absorbency starts to decrease at approximately 250°C and eventually matches that of the blank curve; at higher temperatures, the curves for Cr_2N overlaps with that of the blank. This behavior is similar to that reported for iron [1]. The electrical resistance of the Cr_2N sample body after the absorbency measurement was very low, and its appearance was that of a well-sintered sample. On the basis of these results, we hypothesized that the Cr_2N sample body became a microwave reflector.

[1] S. Sano, S. Takayama, Y. Takao, A. Tsuzuki, Y. Makino, Microwave absorption behavior of Iron-Alumina mixed powder at elevated temperature, ISIJ International 47 (2007) 588-591