§14. Studies on Microwave/Millimeter-wave Absorption Behavior of Metal Powders

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After R. Roy et al. reported that metal powders can be sintered by microwave heating[1], many attentions have been attracted on the microwave heating of metal powders. They also reported that Fe powder is more effectively heated in the H field than in the E field[2]. This result suggests that microwave heating of Fe powder is accomplished mainly by magnetic loss. Accordingly, Fe powder probably losses microwave absorbability above Curie temperature since Fe losses magnetism at the temperature. The objective of this study is to reveal the microwave absorption behavior of Fe powder at elevated temperatures especially around the Curie temperature. Fe particles may make electric contacts each other, so alumina powder was added to Fe powder to isolate Fe particles. Fe powder and Fe-alumina mixed powder inserted in a circular wave-guide fixture were heated in a vacuum furnace and microwave absorbability was measured by using a microwave vector network analyzer.

As objective materials, Fe powder (99.9%, <45μm) and high purity alumina powder (99.99%, 0.6μm) are used. The powders are mixed with a mortar at a designated ratio and used for measurements. The high temperature microwave absorption measurement system consists of a microwave vector network analyzer (Wiltron; 37269A), a circular wave-guide fixture and a vacuum furnace. The circular wave-guide fixture is made of stainless steel tube with an inside diameter of 16mm and length of 760mm. Cut-off frequencies of the fixture are 10.98GHz for H_{11} mode and 14.34GHz for E_{01} mode. Therefore, electromagnetic wave transmits in the circular wave-guide by H_{11} single mode at a frequency range from 10.98 to 14.34GHz, namely, the fixture can be operated as a single mode cavity in the frequency range. At the upper end of the fixture it is connected to the network analyzer through a semi-rigid coaxial cable. The mixed powder is inserted in a sample holder made of stainless steel and uni-axially pressed with a rod under a slight pressure, namely, with human hand. Sample holder is set at the bottom end of the circular wave-guide fixture. Then the fixture is set in the vacuum furnace to prevent oxidation of sample and metal fixture at high temperature. When the reflection power is measured with the time domain mode, two broad reflection peaks around 0 and 5ns are appeared. These peaks correspond to reflections at upper and bottom ends of the circular wave-guide fixture, respectively. If a high loss material for microwave is inserted in the bottom of fixture, reflection power of the bottom end is decreased since electromagnetic power is absorbed by the material. Microwave absorbability change of sample powder during heating and cooling is evaluated by measuring peak power for sample in this study. The measurement frequency range was set from 13 to 13.8GHz as can measure by H_{11} single mode microwave.

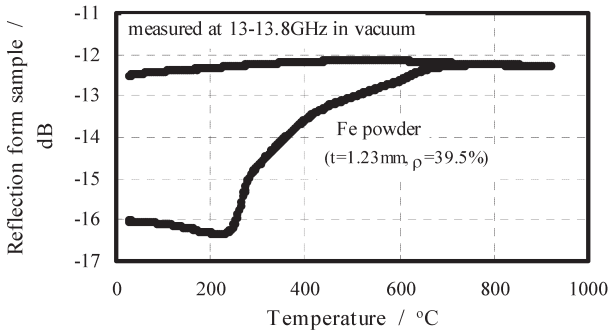

Fig.1. Microwave absorption measurement result of Fe powder.

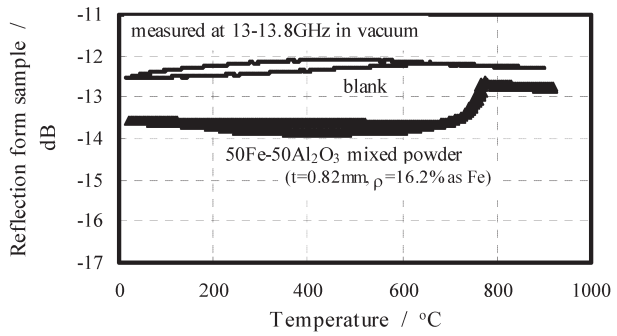

Fig.2. Microwave absorption measurement result of Fe-alumina mixed powder.

When Fe powder is inserted in the wave-guide fixture, the microwave reflection power from sample decreased about 3.5dB as shown in Fig. 1. It means that Fe powder absorbs microwave power. During the vacuum heating, reflection power start to increase around 230°C, and it reaches almost same value with the value of empty fixture at 700°C. It is thought that, Fe particles are electrically isolated at room temperature, and start to make electrical connects each other at 230°C. At 700°C, almost all particles are electrically connected each other and it shows a behavior similar to bulky metal surface. However it could not obtained the microwave absorbability change around Curie temperature because of above mentioned reason. To retain electrical isolation of Fe particles, Fe-alumina mixed powder was used as the object material. Fig. 2 shows the microwave reflection power change of Fe-alumina mixed powder during heating and cooling. This figure obviously shows the decrease of microwave absorbability at Curie temperature (770°C). This technique thought to be very useful for the evaluation of microwave absorbability of metal powders.

Reference

1) Roy. R. et al., Nature **399**, (1999), 668
2) Roy, R. et al., Mat. Res. Innovation **6**, (2002), 128