# §12. Studies on Microwave/Millimeter-wave Absorption Measurement of Powder Materials

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We have been measured dielectric and absorption behaviors of ceramics at microwave and millimeter-wave region as a basis of developing microwave and millimeter-wave heating technology. Recently, R. Roy et al. reported that metal powders can be sintered by microwave heating[1], and many attentions have been attracted on the microwave heating of metal powders. Enlightened from their work, we started to measure microwave and millimeter wave adsorption behaviors of metal powders, and reported a measurement result for Fe powder[2]. The objective of this study is to reveal the microwave and millimeter-wave absorption behavior of powder materials both at room temperature and at high temperature. In this report, we will report measurement results of complex dielectric constant and complex magnetic permeability for Ni powder by using a microwave/millimeter-wave network analyzer.

As objective material, Ni powder (99%, <150μm) is used. Complex dielectric constant and complex magnetic permeability for Ni powder are measured by using a microwave/millimeter-wave vector network analyzer system (Agilent technology; 8510C system) with a WR42 wave guide fixture and a material measurement software (Agilent technology; 85071C). The measurement system is calibrated by TRL calibration procedure prior to measurements. Ni powder is filled up in a sample holder (i.e. 1/4λ offset parts) with an appropriate thickness for the measurement. The powder filled sample holder is set in the test fixture and S parameters are measured by using the net work analyzer at a frequency range from 18 to 26.5GHz. Obtained data are converted to complex dielectric constant and complex magnetic permeability by applying Nicolson-Ross algorithm in the material measurement software. The measurement is executed at room temperature.

Fig. 1 and 2 are measured complex dielectric constant and magnetic permeability of Ni powder at room temperature, respectively. Filling density of Ni powder is 31.9% and thickness of sample body is 0.54mm. This thickness is equal to 0.17mm of dense metal body. Usually, a dense metal body behaves as an almost perfect reflector for electromagnetic waves, therefore dielectric constant and magnetic permeability could not be measured by Nicolson-Ross method. However, measured $S_{21}$ (Transmittance) value was not 0 for Ni powder, it means microwaves penetrate into a roughly packed Ni powder body (its apparent density of measured sample is 31.9%), and dielectric constant and magnetic permeability can be calculated. Obtained dielectric constant and magnetic permeability for Ni powder (apparent density: 31.9%) are 12 and 1, respectively as shown in Figs. 1 and 2. Absorption power by matters can be estimate form value of imaginary part of complex dielectric constant or complex magnetic permeability, namely loss factor *tanδ*. Comparing *tanδ* values of both losses for Ni powder, they are almost same though magnetic loss was 3 times larger than dielectric loss for Fe powder. It means that the contribution of magnetic loss for microwave absorption of Ni powder is smaller than that of Fe powder.

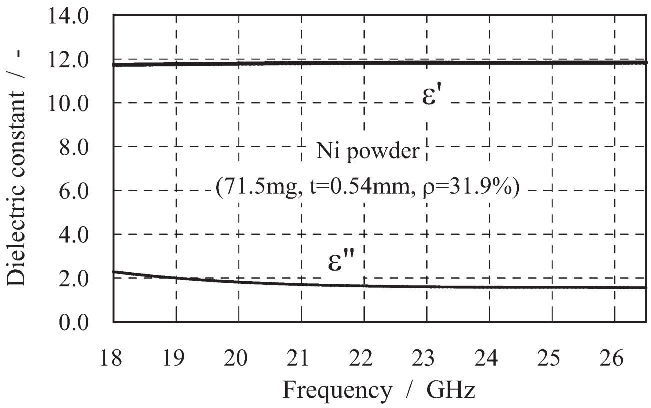


Fig.1. Dielectric constant measurement result of Ni powder.

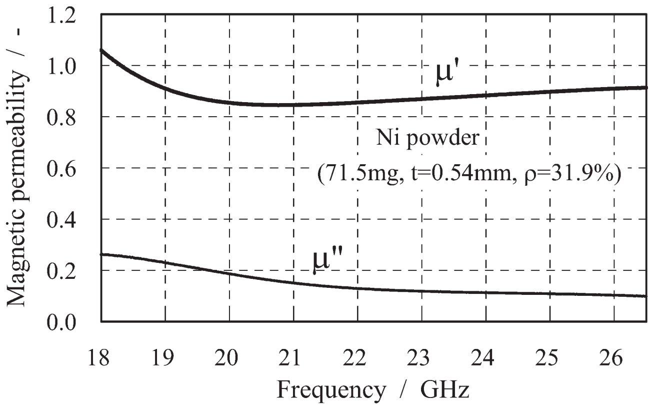


Fig.2. Magnetic permeability measurement result of Ni powder.

1) Roy, R. et al., Nature **399**, (1999), 668
2) Sano, S. et al., ISIJ International **47**, (2007), 588