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

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We have been measured microwave and millimeter-wave permittivity of ceramics and metal powders as a basis of developing microwave and millimeter-wave heating technology. In those measurements, mainly oxide ceramics were subjected for measurement. In this study, nitride powders were subjected for measuring millimeter-wave permittivity by using a wave-guide fixture. As nitride samples, Si_3N_4, BN, AlN, ZrN, Cr_2N, TiN and GaN powders were used.

The millimeter-wave permittivity measurement system is consist of a network analyzer (Agilent Technologies; 8510C), a materials measurement software (Agilent Technologies; 85071C) and a WR42 wave-guide (K-band) fixture. Fig. 1 shows the measurement system (left side) and a magnified view of wave-guide fixture (right side). 1/2λ offset plate was used as the sample holder which inner size is 10.7 x 4.3mm and 4.5mm in height. Sample powder was poured into the hole of sample holder and pressed under a slight pressure by human hand using a pressing rod. The measurement system was TRL calibrated prior to measurements. The S parameter measurements were done at a frequency range of 18-26.5 GHz, and obtained data were converted to complex permittivity by using e fast algorithm in the software.

Figs. 2 and 3 show complex permittivity measurement results of BN and Cr_2N powders, respectively. As seen in figures, BN shows flat curves of ε' (real part of complex permittivity) and ε" (imaginary part of complex permittivity) in the measured frequency range and ε" value is almost zero, it means BN is a low loss material for millimeter-wave. However, ε' and ε" values of Cr_2N shows trend of decreases in increase of frequency and ε" value is very high. It means Cr_2N is a high loss material for millimeter-wave.

Sample's apparent density and complex permittivity measurement results are summarized in table 1. ε' and ε" values are average at frequency range of 23.8-24.2 GHz, and loss tangent (tan δ) was calculated by an equation tan δ = ε" / ε". As seen in table 1, Si_3N_4 and BN have very low tan δ values (<0.01), ZrN and Cr_2N have high tan δ values (about 0.6). AlN shows a little higher tan δ value (0.018) than Si_3N_4 and BN. It means Si_3N_4 and BN are almost transparent for millimeter-wave though ZrN and Cr_2N are high performance millimeter-wave absorbers. TiN and GaN showed intermediate tan δ values. As a view point of electrical conductivity, GaN and AlN are treated as semi-conductor though occasionally AlN treated as an electrical conductor. Usually, Si_3N_4 and BN are treated as electrical insulators. Millimeter-wave permittivity of nitride maybe related to their electrical conduction.

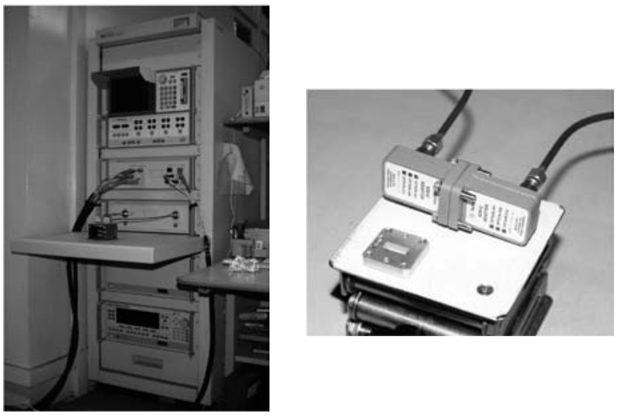

Fig. 1 Appearance of measurement system (left) and wave-guide fixture (right)

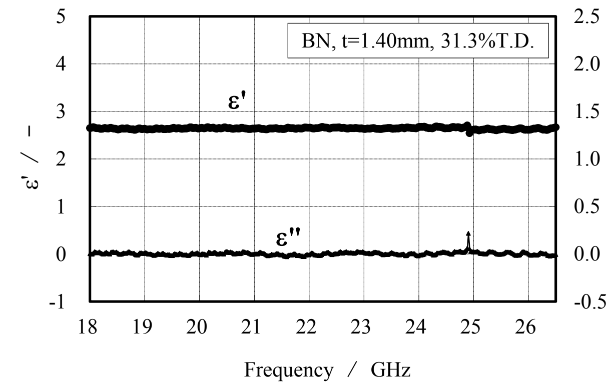

Fig. 2 Complex permittivity of BN at K-band

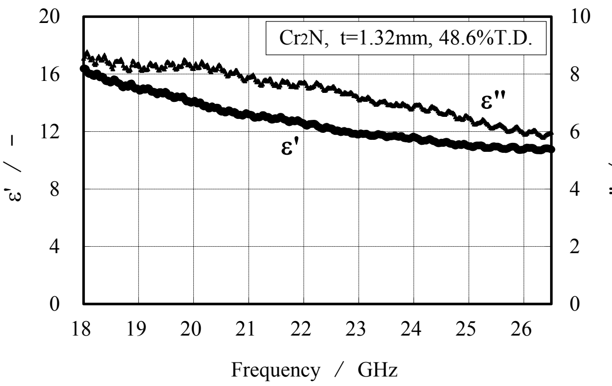

Fig. 3 Complex permittivity of Cr_2N at K-band

Table 1 Complex permittivity of nitride powders measured at 24GHz

	Apparent density %	ε' (at 24GHz)	ε" (at 24GHz)	tan δ
Si_3N_4	46.2	3.15	0.011	0.004
BN	31.3	2.66	0.003	0.001
AlN	44.1	3.00	0.053	0.018
ZrN	50.5	9.70	5.937	0.612
Cr_2N	48.6	11.50	6.863	0.597
TiN	47.8	17.74	1.571	0.089
GaN	20.7	7.57	1.663	0.220