Conductivity Measurement Using Fabry-Perot Resonator

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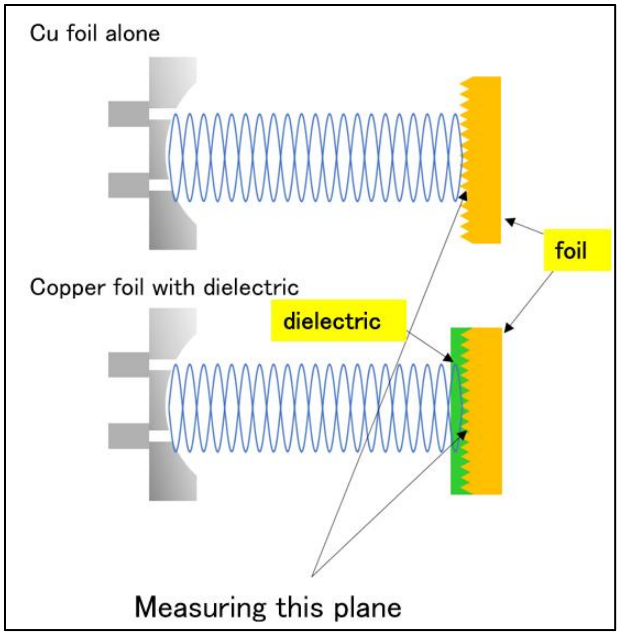
Introduction

With the shift of electronic devices to higher frequencies, evaluation of conductivity of conductor materials such as copper foil has become increasingly important. In the millimeter-wave band, conductivity decreases markedly due to the skin effect, and surface roughness and processing of copper foil strongly affect conductivity. The Fabry-Perot resonator has emerged as a powerful method to quantitatively evaluate such effects.

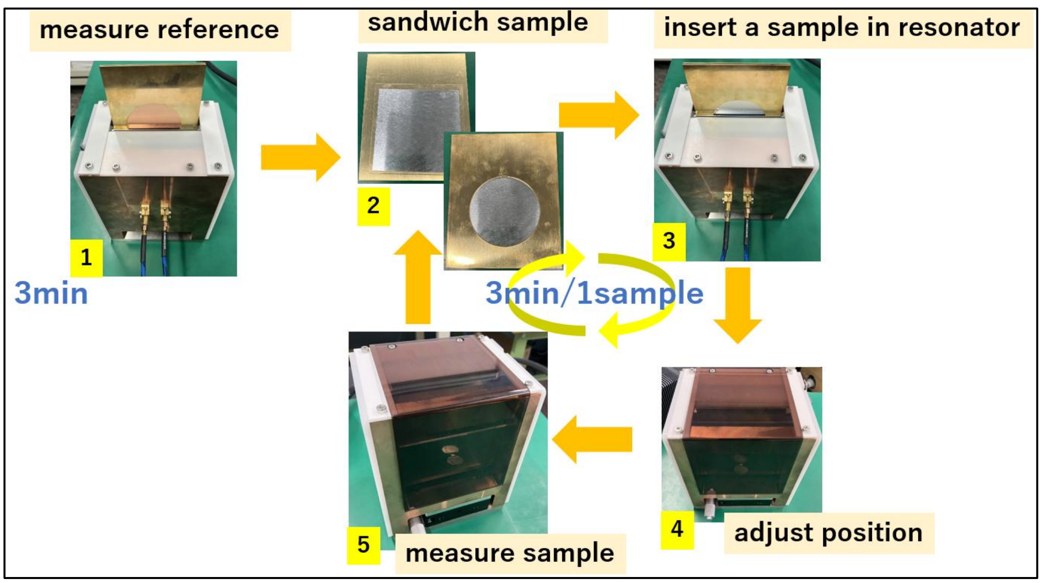
Conventional conductivity measurement instruments required long measurement times and produced large variations, so the results were rarely used in development. With the Fabry-Perot resonator developed by EM Labs, measurement precision at millimeter-wave frequencies has dramatically improved, enabling evaluation that was not possible before.

1. Measurement Principle

The Fabry-Perot resonator consists of two parallel spherical mirrors that cause multiple reflections of electromagnetic waves. While generally used for dielectric measurement, it can also be applied to conductivity measurement by replacing one of the reflecting plates with the test sample (Fig. 1). By first measuring a pure copper reference and then inserting the test sample, the Q-factor can be measured. The difference from the reference allows high-precision determination of conductivity. This mechanism enables direct measurement of copper foil conductivity without etching or processing.



【Fig. 1: Schematic diagram of Fabry-Perot resonator】

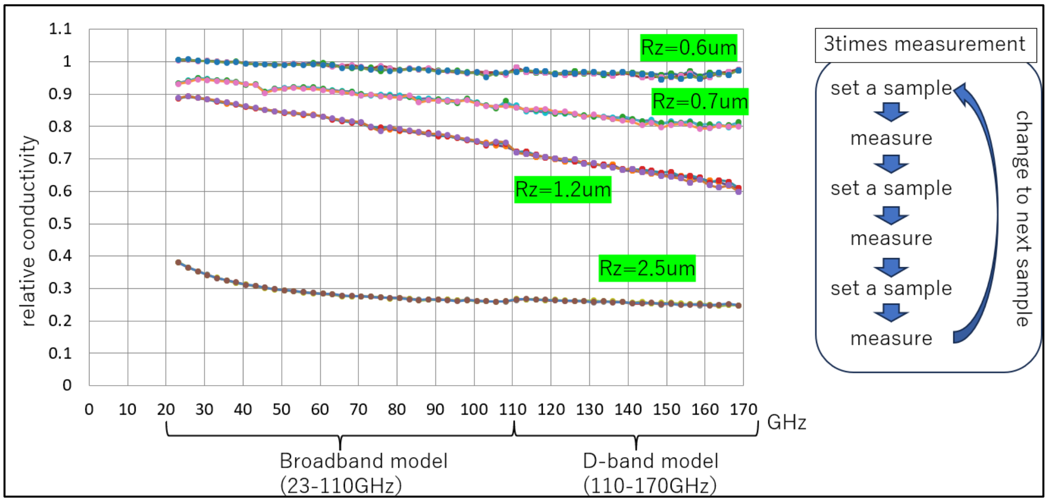


【Fig. 2: Conductivity measurement procedure using Fabry-Perot resonator】

2. Features

- Broadband coverage: 23–110 GHz and 110–170 GHz
- High-speed measurement: about 4 seconds per frequency point
- High reproducibility: variation less than ±2% for repeated measurements of the same sample
- Capable of evaluating interface conductivity of copper foil bonded with dielectric materials

Figure 3 shows conductivity measurement results for four types of copper foils with different roughness. As frequency increases, copper foils with larger roughness exhibit a decrease in relative conductivity. Even with repeated mounting and measurement three times for each sample, excellent reproducibility was obtained.

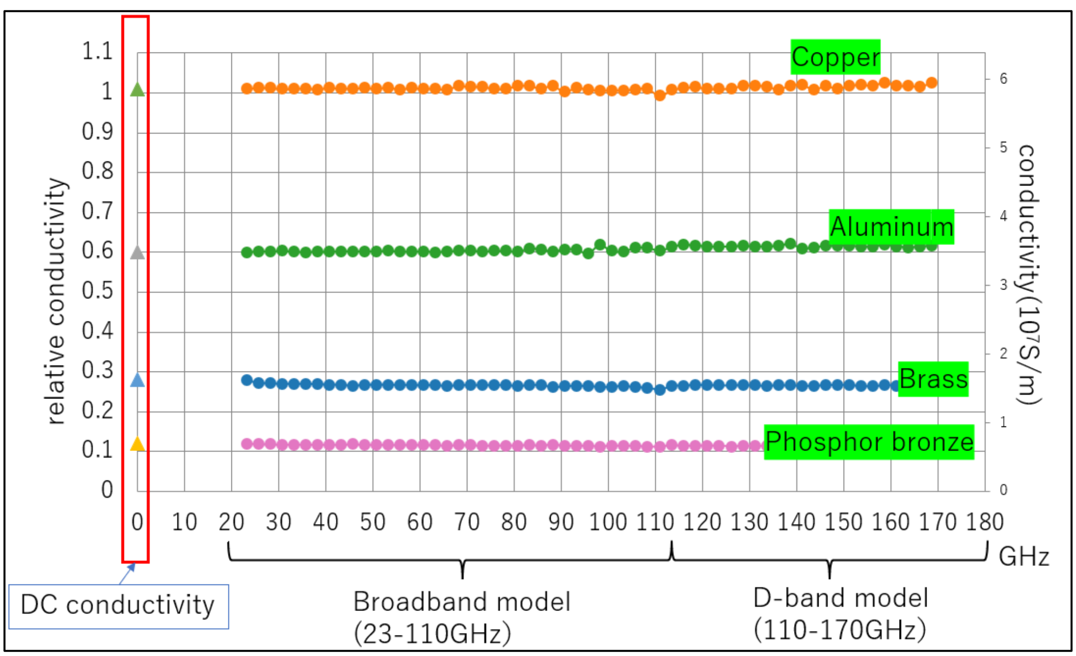


【Fig. 3: Reproducibility data for copper foils with different roughness (three repeated measurements each)】

3. Application Examples

3.1 Measurement of different metals

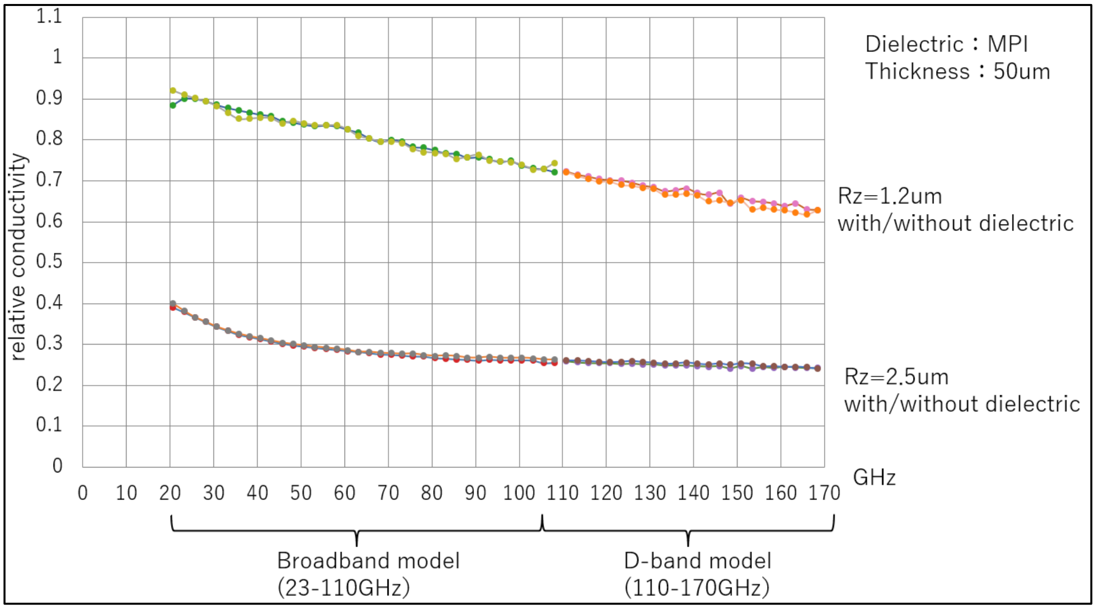
As shown in Fig. 4, four types of metal plates were polished to mirror finish so that surface state would not affect conductivity. Conductivity was measured up to 170 GHz, and the results confirmed that conductivity remained constant from DC to 170 GHz, consistent with the theoretical prediction that metal conductivity does not change up to over 1 THz.



【Fig. 4: Measurement results of different metals using Fabry-Perot resonator】

3.2 Measurement of copper foil bonded with dielectric

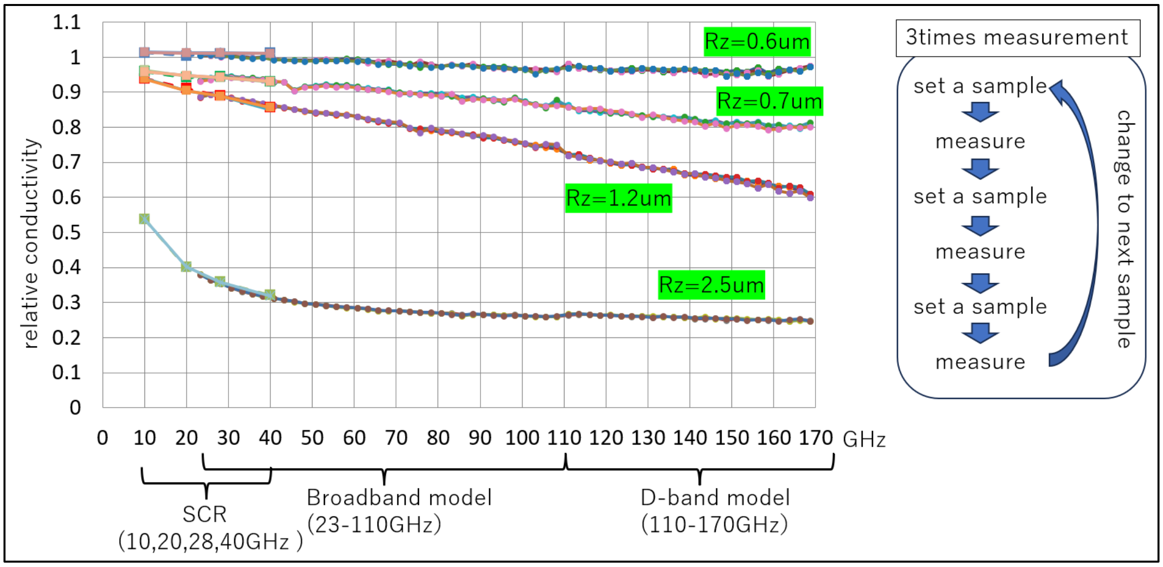
As shown in Fig. 5, measurement is also possible in the state where copper foil is bonded with a dielectric. Modified polyimide (MPI, 50 μm) was bonded to copper foil, and conductivity was measured before and after bonding. The conductivity of the copper foil alone and the interface conductivity of the bonded MPI–copper foil were identical. This enables evaluation of conductivity at resin–metal interfaces formed by deposition or sputtering.



【Fig. 5: Conductivity measurement example of copper foil bonded with dielectric】

4. Comparison with Other Methods

The Fabry-Perot resonator is effective for measurements in the 23–170 GHz range, where it supports multi-point frequency measurement. In contrast, the split-cylinder resonator covers 10–40 GHz and measures only one frequency point per fixture. Its advantage is simplicity and very short measurement time—about 15 seconds per sample. Because there is an overlapping frequency range, the same sample can be measured with both resonators to confirm measurement reliability (Fig. 6). Such cross-validation across different fixtures is an important factor when selecting measurement instruments.



【Fig. 6: Comparison of Fabry-Perot resonator (Broadband and D-band) with Split-Cylinder Resonator (SCR)】

5. Key Points in Instrument Selection

When using a Fabry-Perot resonator for conductivity measurement, the following should be carefully checked:

- Whether frequency characteristic data are published
- Whether measurement results of different metals show no frequency dependence
- Whether stable measurement is possible even for highly conductive samples
- Whether there are examples of measurements with dielectric-bonded samples
- Whether reproducibility data are provided
- Whether correlation with other measurement methods has been demonstrated

Conclusion

The Fabry-Perot resonator from EM Labs enables high-precision, high-speed, and high-reproducibility conductivity measurement in frequency ranges where such evaluation was previously difficult. It supports measurement of copper foils, different metals, and dielectric-bonded samples, making it an indispensable evaluation method for next-generation communications and high-frequency IC packaging design.

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