Modeling and Measurements of Susceptors for Microwave Heating Applications

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The presentation addresses three issues related to microwave susceptors.

1. Analytical investigation of susceptor behaviour in a microwave heating scenario from the viewpoint of reflection, transmission and absorption

Typical susceptors are manufactured as thin metal sheets. The sheets are thin enough to be semitransparent to electromagnetic waves used for microwave heating. To analyze their influence on the electromagnetic fields, we need to consider their reflecting as well as absorbing properties. Susceptors are often characterized by just one value: the resistivity per square $R_s = 1/(\sigma l)$, where σ is metal conductivity and l is the thickness of the metal layer. The question arises if such a description of a thin metal sheet is complete. In other words, if two susceptors of the same surface resistance but different thicknesses, may have different properties for microwave heating applications. In the presentation we first derive the equations showing that the reflection of a wave incident on a conducting sheet of the thickness much smaller than the penetration depth depends only on R_s. We show the formal limits of l needed to make such an approximation accurate. Then we consider the transmission properties of the wave, showing that the amount of power transmitted through such a conducting sheet also depends on R_s only. Power balance enforces the dependence of the power dissipated in the susceptor on the R_s of the susceptor, independently of its thickness.

2. Measurements of susceptor parameters, with focus on a newly developed resonator method

Exact knowledge of susceptor properties is essential in the process of designing food packages using them. Moreover, such properties need to be carefully controlled in the manufacturing process. Microwave food packages are very high volume consumer products and any error in manufacturing may lead to high economic losses of the companies involved. Thus there is a high need for a precise, simple and fast method of measurement of the properties of susceptors.

The transmission-reflection method was traditionally the most popular technique used to estimate surface resistance of thin films. It was used a few decades ago [1], [2] and apparently has not lost its appeal as exemplified by recent works [3], [4]. It has an advantage of providing relatively wide-band results, but has its well known drawbacks. The thin film sample must be placed across a transmission line (waveguide or TEM). Classically, this is done by placing a thin conducting film on a dielectric background between two flanges. However, the slot between the flanges introduces dielectric discontinuity of the guide caused by the dielectric background. Moreover, there is a problem of assuring a good contact between the guide wall and the measured film. This was solved in [1] and [2] by using a silver paint.

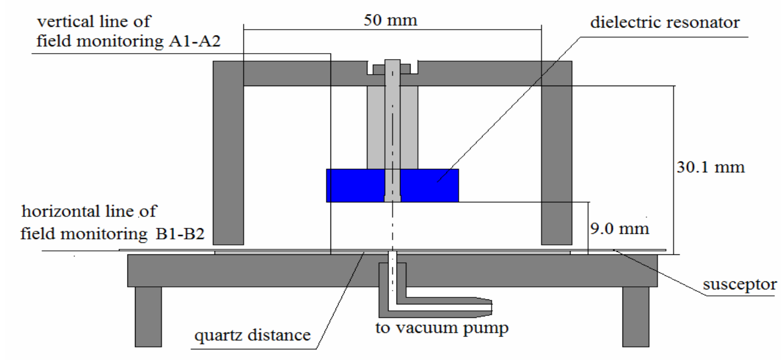

Fig. 1 Single post dielectric resonator intended for measurements of the surface impedance of microwave susceptors

In this presentation we will report a theory and practical implementation of a method based on a specifically designed dielectric resonator. Such a resonator is prepared to work with a typical microwave network analyzer. Software prepared to extract the susceptor parameters from measurements is run on a standard. It gets the network analyser measurements as the input and immediately displays the resistance and reactance per square of the susceptor. It is very important that the susceptor is inserted into the resonator through a slot without any assembling or mounting operations. Thus the entire (high accuracy) measurement process takes just a few seconds. Fig.1 shows a section of the resonator fabricated by the authors and used for a series of practical susceptors available on the food market.

3. Efficient modelling of thin susceptors in the FDTD software

For various reasons FDTD software packages are well suited for modeling of microwave heating scenarios and thus they currently seem to dominate the modelling market in such applications. However, good modelling of a susceptor in such a scenario is a challenge. The physical thickness of the metal layer of the susceptor is very small (often below 1 micrometer). We cannot introduce a cell of such a size into a practical FDTD scenario. This would cause impractical computing times. Thus we need to approximate the physical situation by a plate of a reasonable thickness (of the order of a fraction of a millimeter). The plate is made of an artificial medium chosen so that the physical properties of the electromagnetic fields in the approximate scenario are as close as possible to the physical reality. In the presentation we will show possible models of the susceptors in the FDTD scenarios and discuss how they influence the overall accuracy of the simulation.

References

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