OVERVIEW OF MICROWAVE ANALYTIC MODELING STUDIES AT THE JET PROPULSION LABORATORY

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The microwave research program at the Jet Propulsion Laboratory (JPL) has combined theoretical modeling with experimental verification studies to evaluate the application of microwaves for processing materials. Analytic models were initially developed to predict the transient and steady state temperature behavior within spherical samples in a resonant rectangular cavity using a spherical shell approach. These initial studies supported NASA's containerless processing program that has the goal of processing unsupported molten spherical samples in a microgravity space environment. Theoretical models for using microwave forces to uniquely position a spherical sample within a microwave cavity were also developed and validated experimentally.

More recently, a new exact theoretical approach was used to calculate the transient and steady state temperature profiles in a cylindrical sample positioned along the entire axis of a cylindrical cavity. Maxwell's equations were solved exactly and the electrical conductivity of the cavity walls was accurately taken into account in the framework of a cylindrical shell model. Furthermore, the thermal emissivity of all solid boundaries and the temperature dependence of the dielectric constants and thermophysical properties were included in the calculations. The model also compared direct microwave heating with hybrid heating by including radiation from a microwave-heated tube surrounding the sample.

These exact theoretical results are now being used to test the accuracy of finite-difference calculations and the range of validity of cavity perturbation theory. A computer program was developed that could determine the cylindrical sample diameter required to obtain the most accurate complex dielectric constant measurement. These calculations could be used with simple cavity perturbation theory for small samples or with the new exact cylindrical model for larger samples.

The analytic models developed for spherical and cylindrical samples have also been applied to study the thermal runaway process. In spherical samples thermal runaway effects were calculated that are consistent with an S-shaped heating curve. However, the only thermal runaway phenomenon obtained in cylindrical sample studies did not have the S-shaped heating features.

Examples of these JPL theoretical model calculations will be presented and their implications for microwave materials processing will be discussed. [Work supported by NASA].