Coupled Electromagnetic and Heat Transfer Simulations for RF Applicator Design for Efficient Heating of Materials

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Abstract

Conventional radiation bases heating of material wastes energy during heating and limits the quality due to inherent radiation, conduction and convection based heating mechanism. Alternate efficient heating methods are actively researched for improved efficient and quality. Radio frequency based electromagnetic heating is increasingly used for efficient heating in place of conventional radiation based heating. This paper briefly summarizes available heating method. The radio frequency based heating, which requires coupling of electromagnetics and heat transfer for performance evaluation is used for design of an RF electromagnetic applicator. The methodology, material properties used and simulation results are reported. The uniformity of heat application or electromagnetic energy distribution is used as metric to evaluate the efficiency of the RF heating applicator. The virtual design, physical fabrication and heating results and comparison with experiments are reported. The multiphysics coupling and parametric modeling capability of COMSOL for optimal design of applicator will be highlighted.

RF based Electromagnetic heating method provides opportunity for efficient heating of materials and improved quality. The energy and cost efficient designs are required as a competitive differentiator for new product and process development. Electromagnetic heating provides an alternative to conventional radiation based heating. This paper details about an RF applicator design for electromagnetic heating. The coupled electromagnetic heat transfer formulation methodology and implementation of the model in COMSOL Multiphysics is given. An formulation was developed to predict the overall performance and is compared with COMSOL Multiphysics simulations. The overall design methodologies, simulation details, fabrication of prototype, heating experimental results are reported. A special focus is given to the applicator design for uniform field and hence heating. The numerical DoE related to applicator design is detailed. The parameters contributing to the uniformity is highlighted and calibrated against the physical fabrication limitation. The optimal and finalized configuration and the results will be reported. A Typical RF applicator in an enclosure along with simulation results are shown in figure 1.

Keywords: Heating, RF heating, Electromagnetic heating, dielectric heating, coupled heat transfer, uniform heating.

Reference

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Figures used in the abstract

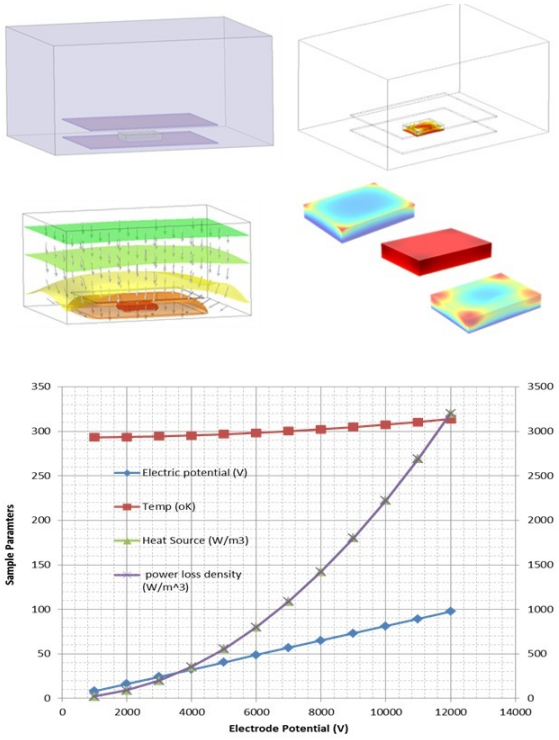

Figure 1: Typical Electromagnetic and Thermal heat transfer simulation configuration and results for a typical RF heating setup