

UNIFORMITY OF TEMPERATURE FIELD VIA MICROWAVE ENERGY PULSING: A MATLAB-BASED ILLUSTRATION

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It has long been known that microwave (MW) heating thermal processing is inherently non-uniform, and hot and cold spots arise in the load in practically unpredictable locations. It has been also realized that in order to simultaneously bound the maximum temperature (occurring at the hot spots) and still sufficiently heat the rest of the load, one should somehow change the way that energy is diffused through the load. This has traditionally been done by changing the physical location of the load (e.g., using turntables) or by changing the way microwaves are distributed in the cavity (e.g., using mode stirrers). An alternative less studied approach features a MW pulsing regime, in which periods of thermal relaxation are allowed between periods of heating.

Heating with MW energy produces temperature extremes much more quickly than thermal diffusion can eliminate them; so because of the difference in time scale on which MW heating and thermal diffusion operate the effects of thermal diffusion are more useful when MW power is off. This study is motivated by the fact that industrial applications of microwave energy usually require simultaneously achieving uniformity of heat release and minimizing the time that it takes to achieve this uniform heating. To address this need, we consider parameters of the MW pulsing regime as design variables in minimizing time-to-uniformity.

In this contribution, we present a model of this concept in one dimension, along with corresponding MATLAB codes designed for computation of temperature fields produced by MW (or combined convective-MW) heating with the source of MW energy operating in a pulsing regime.

The model is based on the solutions of the fully coupled electromagnetic-thermal problem with temperature-dependent electromagnetic (dielectric constant and the loss factor) and thermal (heat conductivity, heat capacity and density) parameters. The problem in 1D can be handled analytically under the assumption that material properties are temperature-independent; in our model, the temperature dependencies and coupling are implemented with a numerical finite-difference scheme.

These computational experiments have confirmed the general efficacy of pulsing in distributing hot and cold spots more evenly. However, in order to completely even the spatial temperature distribution by pulsing, one may need a substantial time; indeed, the growth rate of the minimum temperature in the load remains low because it is practically conditioned only by thermal conductivity.