Modeling Dielectric Heating: A First Principles Approach

R. W. Pryor[1]

[1]Pryor Knowledge Systems, Inc., Bloomfield Hills, MI, USA

Abstract

INTRODUCTION: Dielectric heating is an important, widely used heating technology employed by consumers, small business and industry. Specific frequency bands have been allocated, by international agreement [1], for use in the exploration, development, and application in operating devices. For example, commercial, consumer microwave ovens have an operating frequency of 2.45 GHz. In this paper, I will use a First Principles Model to explore the physical differences manifested when different frequencies are chosen to heat similar geometries. Figure 1 shows an example employing 2.45 GHz to whey [2] for heating into the pasteurization range (71.7 C for 15 seconds).

USE OF COMSOL MULTIPHYSICS® software: This model employs the AC/DC Module and the Heat Transfer Module of COMSOL Multiphysics. The complex permittivity of the whey was added as a separate equation, with the majority of the characteristics of the whey being composed of water. A separate additional equation was developed for the loss characteristic of the whey, based on the complex permittivity values as a function of temperature. The Multiphysics calculation was solved in a two step-process. First, the current flow was solved and next the heat transfer.

RESULTS: Preliminary results show that the applied RF voltage needs to be significantly increased as the frequency of the applied RF is decreased. Figure 2 shows an example employing 27 MHz to whey for heating into the pasteurization range (71.7 C for 15 seconds).

CONCLUSION: Using COMSOL Multiphysics and a First Principles Approach is a powerful tool that allows the modeler to easily evaluate the concepts proposed for a new experiment. In this case, this model easily compares the relative efficiency of the dielectric heating process at different frequencies for the same geometry. When the modeler so desires, the geometry can be altered to explore other considerations, such as skin-depth, etc.

Reference

1. Radio Regulations, 2012, ITU-R
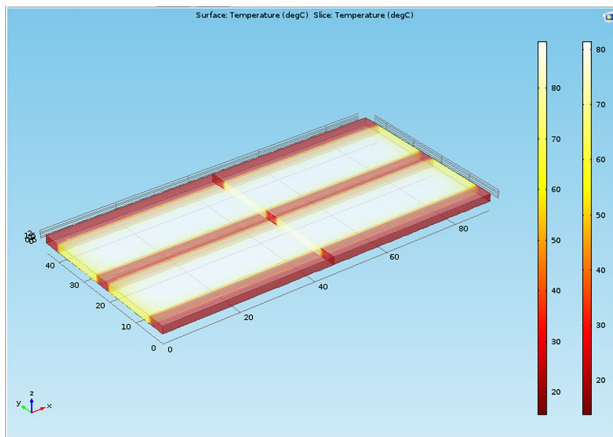2. Yifen Wang, et.al., J. Food Eng., 57 (2003), pp. 257-268

Figures used in the abstract

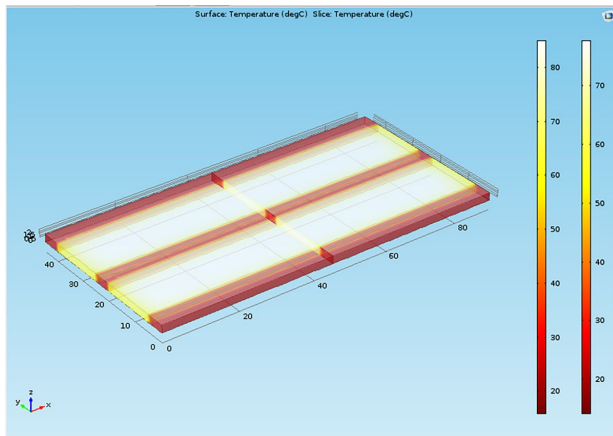
Figure 1: Dielectric Heating at 2.45 GHz

Figure 2: Dielectric Heating at 27 MHz

Figure 3

Figure 4