

学校编码: 10384

分类号_____密级_____

学号: 19820081153015

UDC_____

厦 门 大 学

硕 士 学 位 论 文

微波炉加热均匀性研究

Research on New Methods of Improving
Microwave Oven Heating Uniformity

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专业名称: 无线电物理

论文提交日期: 2011 年 5 月

论文答辩时间: 2011 年 月

学位授予日期: 2011 年 月

答辩委员会主席: _____

评 阅 人: _____

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摘 要

随着社会进步和微波能利用技术的发展，微波炉的使用越来越普及。因微波具有良好的穿透性，能直接将微波能量送入被加热物体内部，实现了对物品内部和外部同时加热，因而极大地缩短了加热时间，提高了加热效率。此外，微波加热食品既不产生油烟、一氧化碳等有害物质，又能够最大限度地不破坏食品的营养成分，真正体现了现代人健康饮食的理念。

本文介绍了微波炉的发展过程，突出了传统微波炉加热不均的缺点及现用的常规克服方法：一种是在微波炉加热腔底部放置由电机带动旋转的食品托盘，另一种是在微波炉加热腔顶部放置由电机带动旋转的场搅拌器。此两种方法能在一定程度上克服微波炉加热的不均匀性，但都需要在微波炉加热腔中放置额外器件，给使用带来了不便，也增加了微波泄漏的风险。

深入研究微波加热的机理后发现，决定微波炉加热均匀性的主要因素是电场分布的均匀性。而微波炉中电场的分布与微波炉加热腔的形状、加热腔中微波的谐振模式、磁控管频率的波动和介质对微波炉腔体的扰动等因素有关。本文对微波在介质中的传播特性、微波多模谐振腔理论、介质谐振器理论、谐振腔的微扰理论等进行了深入研究。非谐振态的介质能够起到聚集微波能量，提高多模谐振腔谐振模式数的作用，且其介电常数越高，其聚集微波能量的能力越强，谐振态微波介质具有明显的谐振峰，能够起到俘获微波能量，提高介质内部和附近空间电磁场能量密度的作用，两种状态互补，就可在微波炉中获得较好的匀场效果。

本文结合微波加热理论和上述结论，提出了两种新的改善微波炉加热均匀性的方法，一种是在现有的微波炉中放置合理设计的微波陶瓷，另一种是将微波炉磁控管改成变频工作状态。根据第一种方法研制出了柔性快速解冻板、非谐振态匀场板和谐振态匀场板，根据第二种方法设计出了具有匀场功能的变频微波炉。

文中采用 HFSS 软件，对上述两类改善微波炉加热均匀性的方法进行了仿真，并制作出样机进行了实验。仿真和实验结果都验证了这两种方法的可行性和合理性，本文的研究成果现已在小范围推广使用。

关键词：微波炉；微波陶瓷；变频；HFSS；

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Abstract

Along with social progress and continuous improvement of microwave energy utilization technologies, the use of microwave ovens is becoming increasingly popular. Because of the good penetrability of microwave, microwave energy can be sent into the objects directly, and food can be heated from both internal and external. Thus, the heating time is greatly reduced and the heating efficiency is improved. Besides, heating food by microwave not only produces no soot, carbon dioxide, and other harmful substances, but also can minimize the loss of nutrients in food, which truly embodies the modern concept of healthy diet philosophy.

This paper introduced the development of microwave oven, traditional microwave oven's shortcoming of uneven heating and the two commonly used methods to overcome this shortcoming. One is to place a rotatable food tray driven by a motor at the bottom of the microwave oven cavity and the other is to place a rotatable field mixer driven by a motor at the top of the microwave oven cavity. The two approaches can overcome the shortcoming of the microwave uneven heating to some extent, but additional devices should be placed into the microwave oven cavity, which not only bring inconveniences, but also increase the risk of microwave leakage

After in-depth study of the mechanism of microwave heating, it is founded that, the electric field distribution is the main factor that determine the uniformity of microwave. The electric field distribution is mainly determined by the shape of the microwave cavity, resonant mode, frequency fluctuation of the magnetron, and medium disturbance to the microwave oven cavity. This paper had in depth research of characteristics of microwave propagation in media, multi-mode microwave cavity theory, the dielectric resonator theory and resonant cavity perturbation theory. It is found that microwave dielectric in non-resonant state can gather microwave electromagnetic field and improve the number of multi-mode resonant cavity modes , The higher the dielectric constant is, the stronger the capacity of microwave energy gathering is. And microwave dielectric in resonance state has obvious resonance peak which can capture microwave energy to enhance the strength of microwave electromagnetic field in and around them. The two states are complementary, which helps achieve good field shimming effect of the microwave oven.

Combining the theory of microwave heating with the above findings, this paper

presented two new methods to improve the uniformity of microwave heating. One is to introduce reasonable designed microwave dielectric ceramic to the existing microwave oven cavity, and the other is to change the working state of microwave oven magnetron from fixed-frequency to sweep-frequency. According to the first method, fast flexible defrosting plates, un-resonant state and resonance state field shimming boards are developed while according to the second method the sweep-frequency microwave oven is invented.

The feasibility and rationality of these two methods are proved by simulations in HFSS software and experiments on real samples. The research achievements of this paper have already been promoted and applied in a small scale.

Key Words: Microwave oven; Microwave ceramic; Variable-frequency; HFSS;

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