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The microwave processing of foods

Edited by Helmar Schubert and Marc Regier



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The microwave processing of foods

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Part I

Principles

Introducing microwave processing of food: principles and technologies

M. Regier and H. Schubert, University of Karlsruhe, Germany

1.1 Introduction

This chapter treats the physical background of microwaves and the corresponding physical theory but also makes some general remarks on the setup of microwave applications. It starts with the definition of the frequency covered and the corresponding wavelength range and legislative regulations, before introducing the basic equations: Maxwell's equations and those that cover the interaction between electromagnetism and matter. Starting with these basics, the wave equation and some example solutions are derived, so that the important concepts of penetration depth and power absorption, which are useful for the estimation of thermal interaction between microwaves and matter can be introduced. After covering the general setup of microwave applications including microwave sources, waveguides and applicators, the chapter is completed by useful links to further literature.

1.2 Definitions and regulatory framework

Microwaves are electromagnetic waves within a frequency band of 300 MHz to 300 GHz. In the electromagnetic spectrum (Fig. 1.1) they are embedded between the radio frequency range at lower frequencies and infrared and visible light at higher frequencies. Thus, microwaves belong to the non-ionising radiations.

The frequency f is linked by the velocity of light c to a corresponding wavelength λ by eqn 1.1:

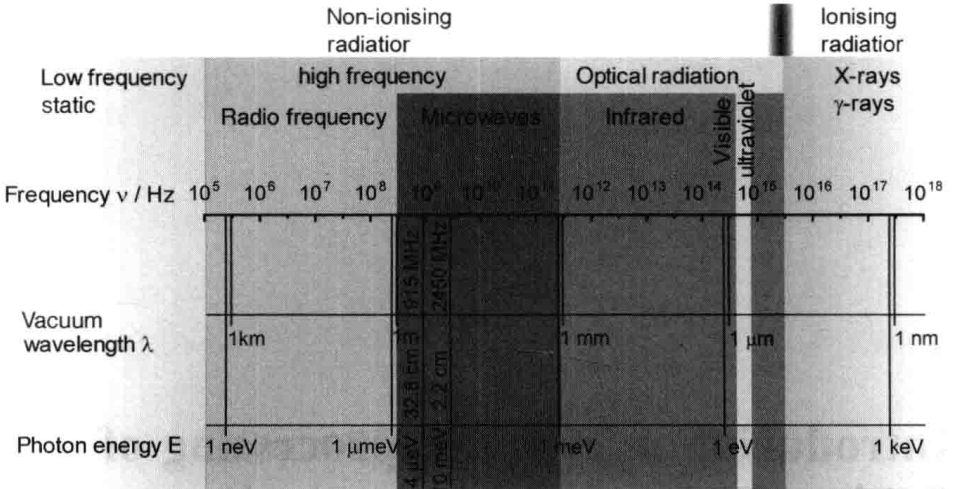


Fig. 1.1 Electromagnetic spectrum. Additionally, the two most commonly used microwave frequency bands (at 915 MHz and 2450 MHz) are sketched.

$$c = \lambda \cdot f \quad [1.1]$$

In this case the velocity of light as well as its wavelength within matter are dependent on the material. For the speed of light in a vacuum ($c_0 \approx 3 \times 10^8$ m/s) the corresponding wavelength of microwaves is between 1 m and 1 mm, so that the term ‘microwave’ is a little misleading. The name rather points to their wavelength within the matter, where it can indeed be in the micrometre range.

1.2.1 Regulations

As already shown in Fig. 1.1 the frequency range of microwaves adjoins the range of radio frequencies used for broadcasting. But the microwave frequency range is also used for telecommunications such as mobile phones and radar transmissions. In order to prevent interference problems, special frequency bands are reserved for industrial, scientific and medical (so-called ISM) applications, where a certain radiation level has to be tolerated by other applications such as communication devices. In the range of microwaves the ISM bands are located at 433 MHz, 915 MHz and 2450 MHz; the first is not commonly used and the second is not generally permitted in continental Europe. Outside the permitted frequency range, leakage is very restricted. Whereas 915 MHz has some considerable advantages for industrial applications, for microwave ovens at home the only frequency used is 2450 MHz.

Apart from the regulations concerning interference, there exist two types of safety regulations:

- the regulation concerning the maximum exposure or absorption of a human, working in a microwave environment,
- the regulation concerning the maximum emission or leakage of the microwave equipment.