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Bio-Organism Damage under the Influence of Microwave Heating

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Abstract

In this paper, we setup a simple model to understand the damage of bio-organism under the influence of microwave heating based on the bio-heat transfer equation and Arrhenius equation. Detailed information of temperature distribution and fraction of damage is presented. Results show that microwave heating is effective in the damage of bio-organism.

Keywords

Bio-Heat, Microwave, Bio-Damage

1. Introduction

Radio frequency (RF)/microwaves has applied in monitoring public health and in medicine as well as being a therapy method [1] [2] [3]. Modern electronic science and technology have seen rapid technological advances and enormous influence on our everyday lives [4]. They have laid the foundation for an unprecedented drive toward the improvement of existing medical devices and for the development of new ones. In particular, the advances in RF/microwave technology, among others, set the way for novel therapeutic and diagnostic methods. Microwave with frequencies from hundreds of MHz to several GHz is of primacy research field being investigated for medical and diagnostic applications in various areas such as cancer therapy, organ imaging, cardiology, surgery, etc. [5] [6] [7] [8] [9]. On the other hand, RF/microwave radiation with high power raised safety concerns on the biological effect. Lots of research has been performed over radio station, television, and digital mobile phone systems [10].

In this manuscript, we study the bio-heating effect of a bio-organism under the illumination of microwave. We set up the microwave and input the bio-heat equation. We setup the bio-organism inside of the microwave, to simulate the bio-organism heated. The temperature increase and fraction of damage are both investigated in details. Results show that after 60 s of microwave illumination, the bio-organism will be 95% damaged.

2. Theory and Assumptions

The heat transferred from the microwave to the bio-organism and the heat dissipation inside the bio-organism is governed by the following heat transfer equation [11].

$$K\rho C\cdot\partial T/\partial t+\rho C\boldsymbol{u}\cdot\nabla T+\nabla\cdot\boldsymbol{q}-Q=0$$

where T is the temperature in unit of K, ρ is the density in unit of kg/m^3, C is the heat. Capacity in unit of J/kg/K, $\boldsymbol{u}$ is the fluid velocity in unit of m/s, $\boldsymbol{q}$ is the heat flux in unit of W/m^2 and Q is the volume heat generation rate in unit of W/m^3.

Here, we also compute the fraction of tissue damage. This parameter gives a quantified evaluation about the degree of tissue injury (β) during the process. The calculation is based on the Arrhenius equation [12].

$$\frac{\mathrm{d}\beta}{\mathrm{d}t}=A\exp\left(-\frac{\Delta E}{RT}\right)$$

where ΔE is the activation energy for irreversible damage reaction (in unit of J/mol), and A is the frequency factor (in unit of Hz). These two parameters are dependent on the type of tissue under study. The fraction of damaged tissue (η) is represented by: $\eta = 1 - \exp(-\beta)$.

3. Results and Discussions

The setup of the simulation under study is shown in **Figure 1**. The isolated box is 40 cm long, 40 cm wide and 20 cm high, used for confining the microwave inside. Besides, the box is made of copper, a good material for being low loss in the microwave range under study. The bio-organism is represented by an ellipsoid with three semi-axes being 8, 5 and 3 cm long. Specifically, we choose three points in the central plane for measuring the detailed information in the bio-organism. They are denoted by A, B and C as the inset of **Figure 1**. The microwave is sent from the port on the left side to excite the simulation.

Figure 2 is the temperature distribution of the bio-organism at different times (a) 10 s, (b) 30 s, (c) 45 s, and (d) 60 s. At 10 s, the bio-organism stays mostly at its initial temperature since there are not enough energy being absorbed. The temperature increases gradually as the absorbed energy increases. At 60 s, the highest temperature rises to 305 K, 5 degrees higher than its initial value.

This study is simulation the bio-organism damage under the bio-heat. In life, skin scald and cooking are example of bio-organism damage.

Figure 3 gives the temperature as a function of time at the designated points. The temperature increases at a much higher rate for Point B as a microwave hot spot is formed around Point B, offering much more energy density.

Finally, we study the fraction of damaged bio-organism according to the Arrhenius equation discussed above. **Figure 4** shows the fraction of damage for the

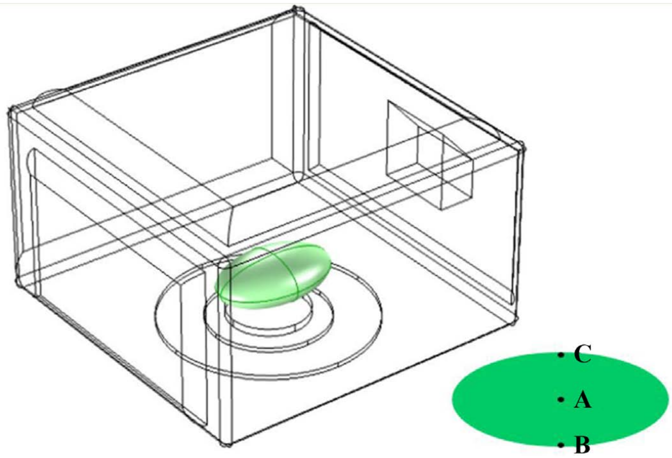

Figure 1. The bio-organism is located inside a metal box under the illumination of microwave. Three points located at the central plane of the bio-organism (shown in the lower right inset) are chosen to monitor the temperature and fraction of damage. (C point is center point of the upper surface, B point is center point of the surface below. A point is the central of whole bio-organism.)

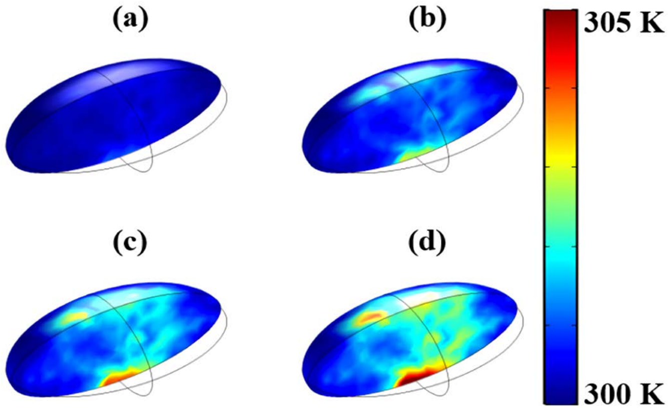

Figure 2. Temperature distribution of the bio-organism at different times: (a) 10 s, (b) 30 s, (c) 45 s, (d) 60 s.

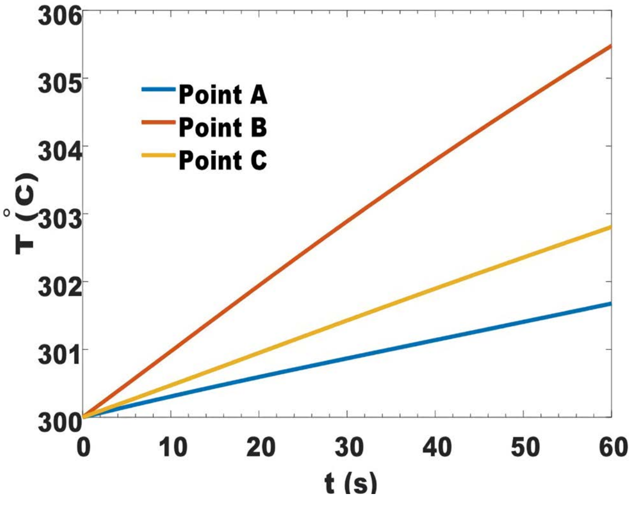

Figure 3. Temperature as a function of time at designated points.

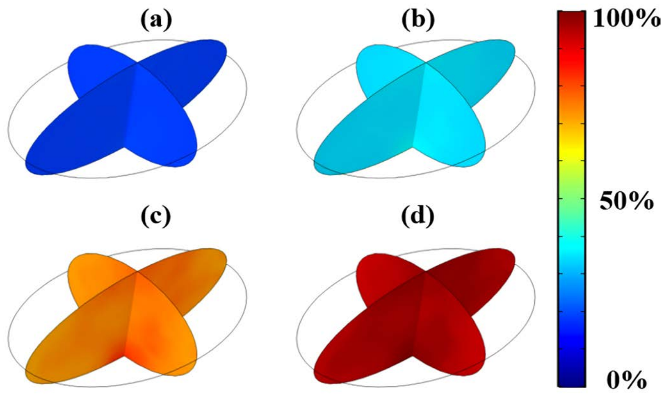

Figure 4. Fraction of damage for the bio-organism at (a) 5 s, (b) 10 s, (c) 30 s, and (d) 60 s.

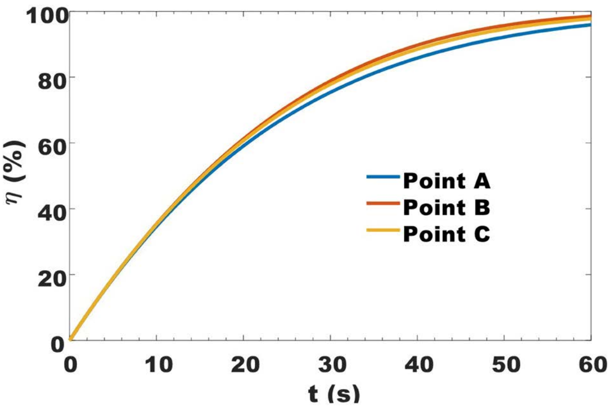

Figure 5. Fraction of damage for the designated points as a function of time.

bio-organism at different times for the two cross sectional view long the central line. The corresponding values are 15%, 35%, 75% and 95%. Note that the damage is relatively uniform on the planes displayed. Fraction of damage for the designated points as a function of time is shown in Figure 5. The value increases quickly in the first 30 seconds and slows down thereafter, gradually saturates towards 100%.

4. Summary

In conclusion, we have established a model for studying the bio-heating effect under microwave. The model simulation is based on the heat transfer equation and Arrhenius equation. Simulation results reveal that the bio-organism will rise 5 degrees in temperature and 95% will be damaged by the microwave radiation.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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