Electromagnetic and Thermal Modeling of Microwave Furnaces

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Introduction: Microwave furnaces, which are used to melt metals should be designed so that in a given time, as much of material as possible can be heated to an uniform temperature desirably with the least possible cost. Therefore, finding the most appropriate design can highly increase the share of energy, which is dissipated into heat. To achieve this end, a slotted design came into question. A slotted waveguide has no reflector but emits directly through the slots. The size and spacing of the slots is critical and is a multiple of the wavelength used. Therefore, as shown in Figure 1, two differently slotted waveguides have been studied.

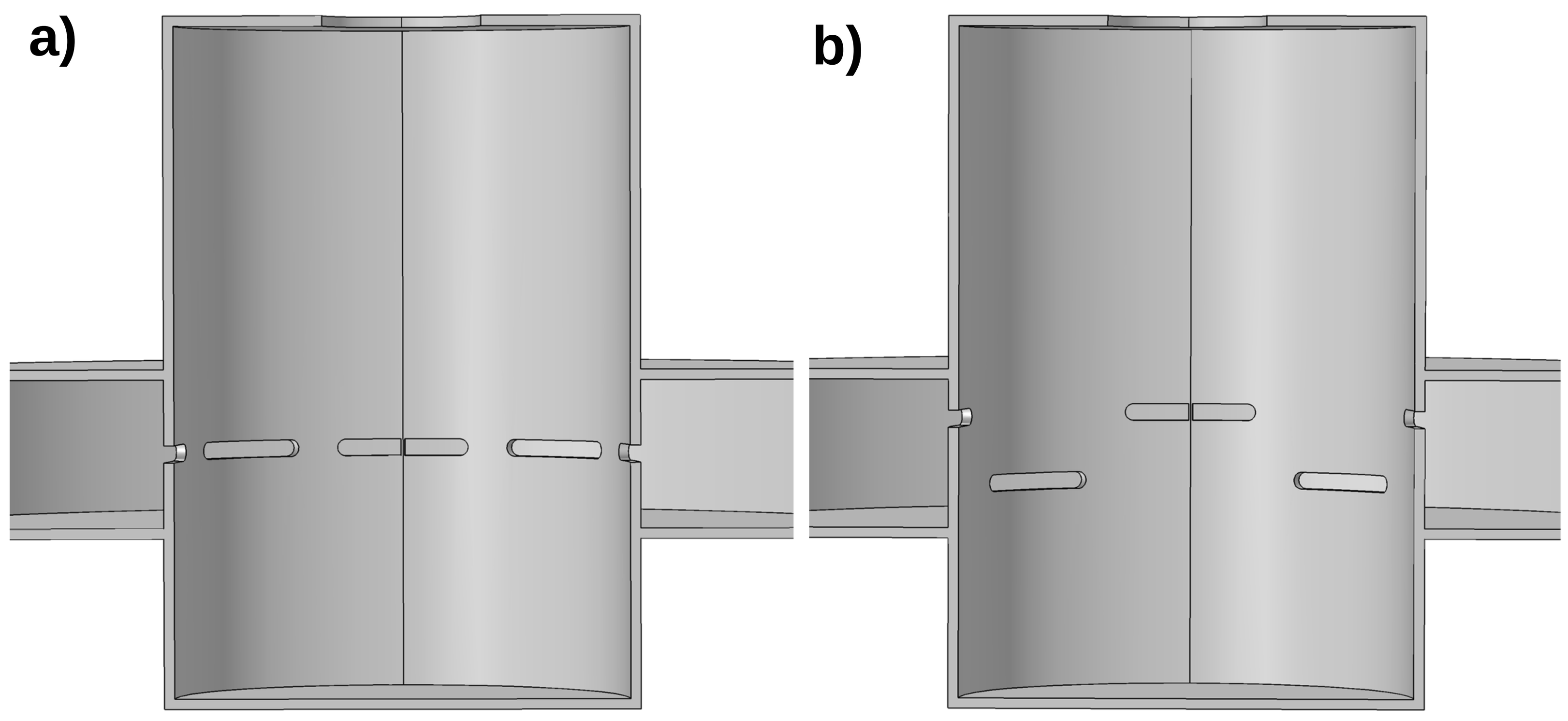

Figure 1. a) evenly, b) unevenly slotted waveguide.

Computational Methods: The coupled electro thermal model solves the Maxwell's equations in frequency domain and the Fourier heat transfer equation in steady state. The radio frequency interaction with material for heating is related to the permittivity (ε) of the material, which is a complex number: $\varepsilon = \varepsilon' + i\varepsilon''$. The density of the dissipated power can be integrated over any domain according to the equation: $P = \varepsilon_0 \cdot \varepsilon_r'' \cdot \omega \cdot E^2$, where only the imaginary part of the permittivity is responsible for energy losses, dissipating into heat. Therefore not only the effect of the slotted waveguide but also the materials' layout based on their intrinsic permittivity should be considered in order to reach an optimum inside out heating performance.

Results: To decide for the best inside out heating profile, the dissipated power within the reacting material is calculated for both cases, that is 739 W for the evenly and 825 W for the unevenly slotted waveguide. As shown in Figure 2, the unevenly slotted waveguide results in a stronger electromagnetic field and more power dissipation within the reacting material, leading to higher temperatures.

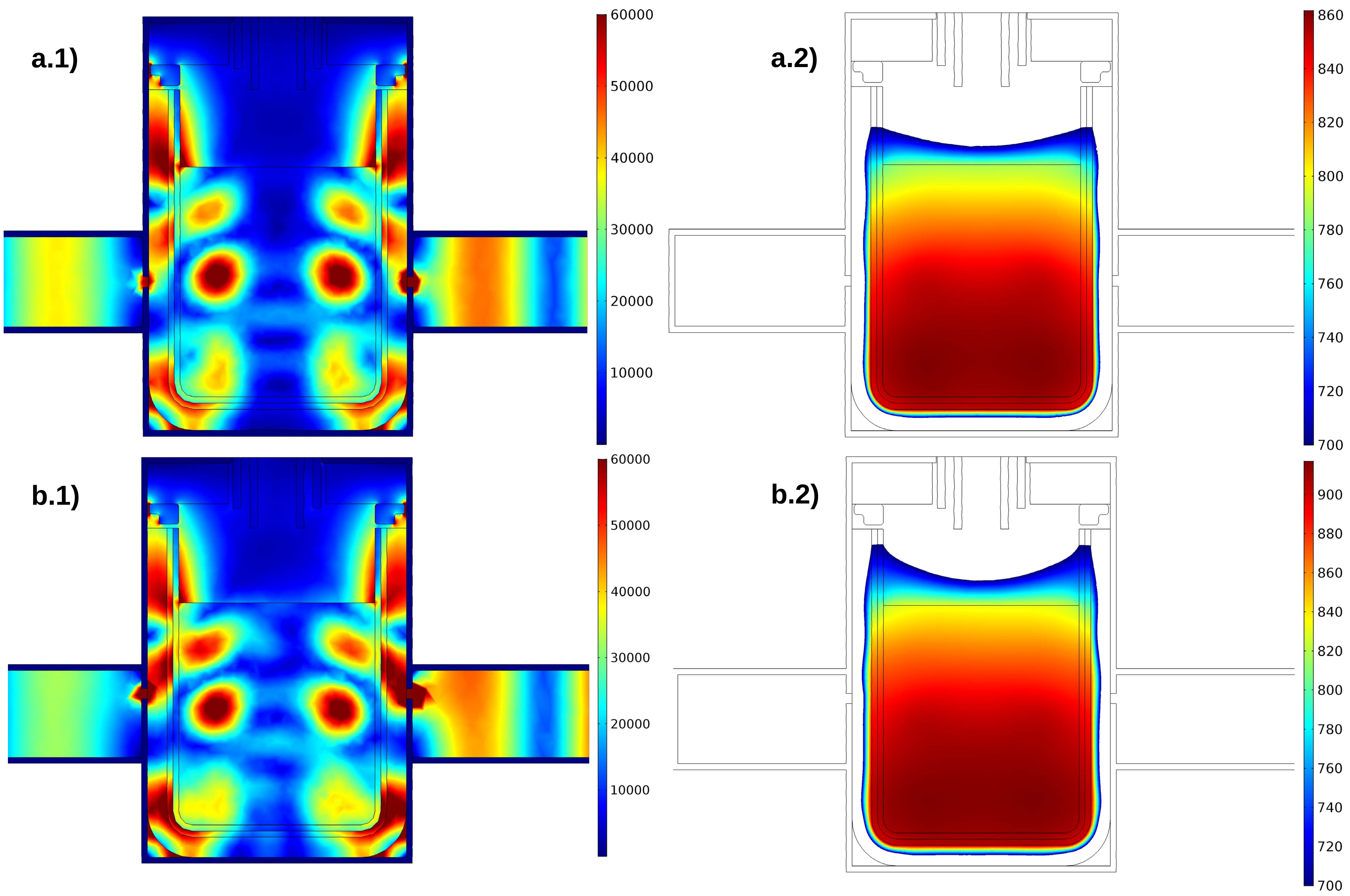

Figure 2. 1) the electric filed strength (V/m) and 2) the temperature profile (°C) inside the chamber of an a) evenly, b) unevenly slotted waveguide.

Conclusions: Based on simulation results a new design concept of microwave furnaces has been developed. The impact of material selection in combination with size and spacing of the slots on thermal behavior of the system has been studied, which has resulted in saving time, costs, and lots of effort.

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