Influence of the material defects on the absorption and conversion capacity of the microwaves in heat

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Microwave heating, microwave absorption

1. Introduction

The paper presents some preliminary research regarding the study of the influence of material defects on the microwave absorption capacity and their conversion into heat for sintering [1]. Since ceramic materials are good microwave absorbers and a wide variety of magnetic ceramic materials are used in electrotechnical and electronic applications, a study on barium carbonate ($BaCO_3$) composites is proposed. Previous research on these nanostructured composites has shown the possibility of their sintering if certain parameters are strictly adhered to avoid thermal runaway at temperatures around 600 °C [2]. Starting from this aspect, the paper aims to optimize the heating process by creating artificial defects on crude composites.

2. Materials and heating procedure

Material samples have been pressed from the homogeneous mixture of $BaCO_3$ to achieve material defects. Defects of material consisted in performing similar drillings in several samples (figure 1).

Figure 1. Composite with defects.

The composite material was obtained by homogenizing [3] in a planetary ball mill having a grain size of 1120 nm and subsequently pressed into a mold as shown in the figure 2.

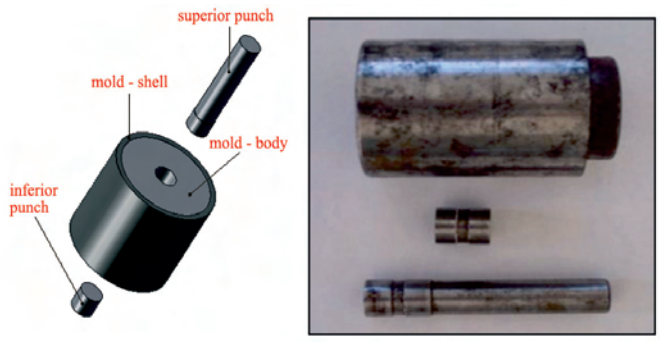

Figure 2. Cylindrical mold.

The advantages of using this process are the realization of complex shaped semi-finished products, with high quality surfaces and high dimensional accuracy and the porosity or compactness can be achieved within wide limits, varying the specific pressing force. The pressing force was set at 300 MPa. The samples obtained were cylindrical in shape with a height of 4 mm and a diameter of 12 mm. Sample punching was performed using a Proxxon MF70 drilling machine, drilling at a maximum speed of 20,000 rpm. The equipment used is shown in the figure 3.

Figure 3. Proxxon MF70 drilling machine.

The microwave heating procedure consisted of exposing the samples of a uniform and unidirectional field of high frequency electromagnetic waves according to a heating cycle at injected microwave power ranges between 100-1,000 W for 300 seconds with temperature sampling at a range for 10 seconds. Tests were performed under identical conditions with the exception that a ceramic support was used in the first experiment, and in the case of the second microwave heating it was carried out without a ceramic susceptor as a support.

Table 1. Specimens characteristics.

Sample Code	Grain Size [nm]	Pressing Force [MPa]	Height/Diameter Sample [mm]
HM	1120	300	4/12

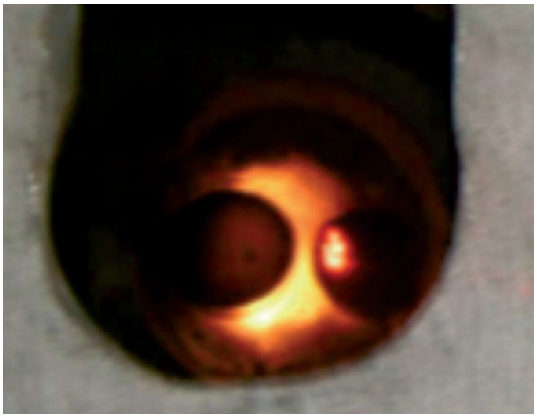

Figure 4. Snapshot during microwave heating of $BaCO_3$ composites materials.

3. Results and discussions

The experimental procedure has been applied to 3 samples with 1, 3 and 5 defects (P1, P3 and P5) with and without ceramic support. The mass of the samples was 2.5 mg and the temperature was recorded using 2 IR pyrometers with range between 250 and 1650 °C. The results obtained are presented in the figures 5 to 10.

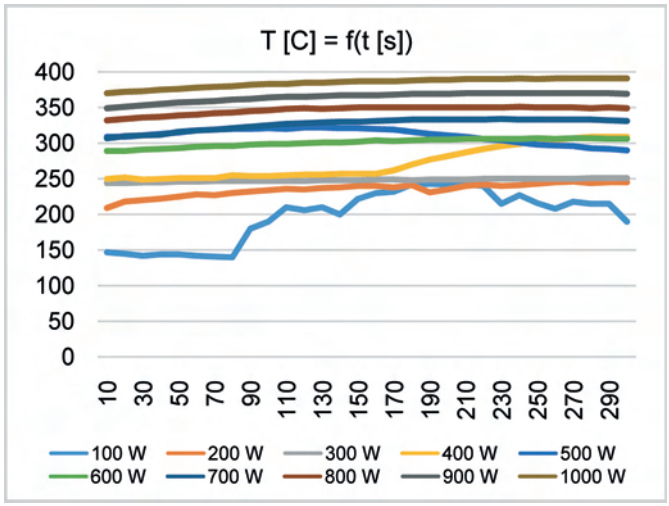

Figure 5. P1 without ceramic support.

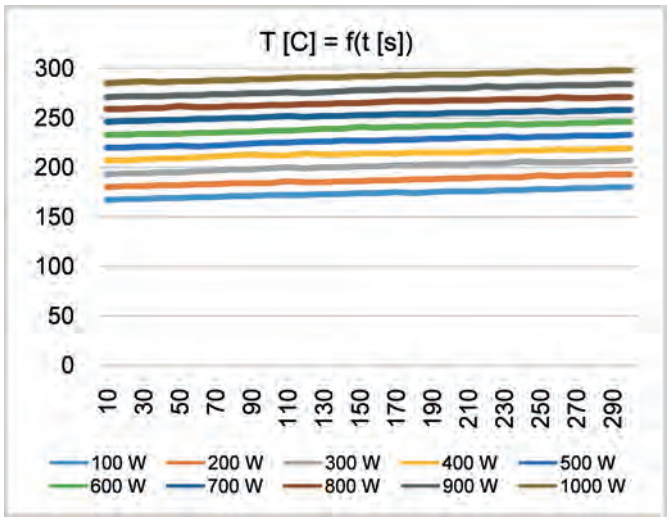

Figure 6. P1 with ceramic support.

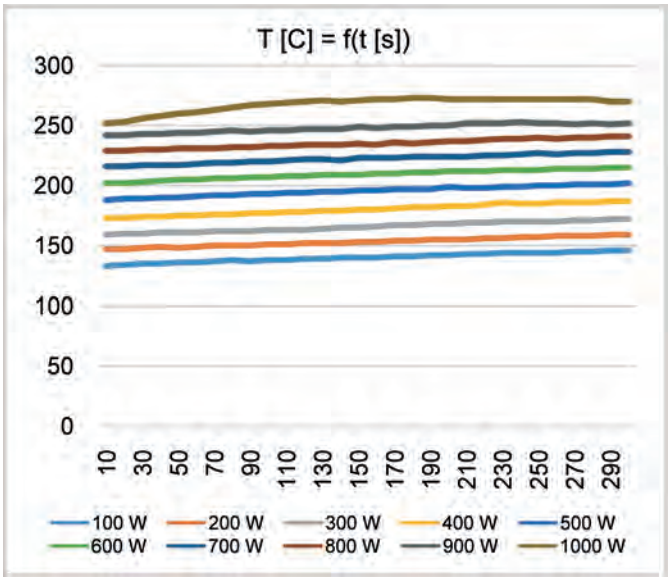

Figure 7. P3 without ceramic support.

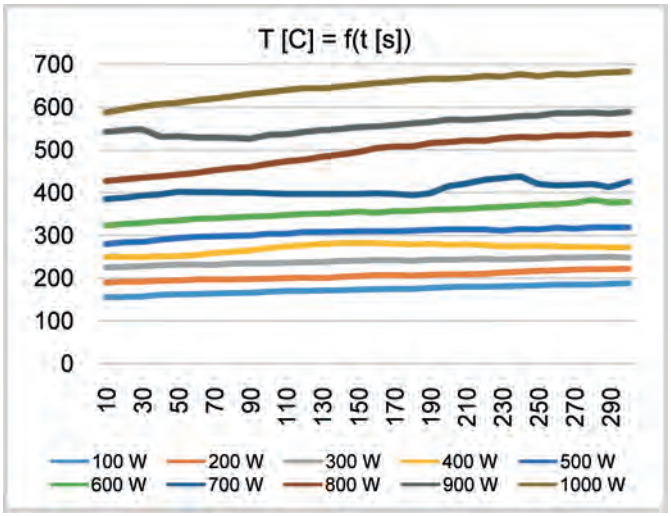

Figure 8. P3 with ceramic support.

Temperature records show different behavior for experimental studies:

- In the case of samples with 1, 3 and 5 defects and without ceramic support it is observed that the reduced number of defects leads to an increase of the absorbance and hence the conversion of microwaves into heat. The above applies to the entire injected power level without noticeable differences
- For samples with 1, 3 and 5 defects but with ceramic support it is found that the increased number of defects leads to totally inverse behavior to the first situation. At an injection power of 1000 W microwaves in the presence of the ceramic support, a temperature above 650°C is recorded, as compared to the situation where, in the single-fault sample, the temperature reached does not exceed 3000 °C.

This different behavior can be explained precisely by the presence of the ceramic support which contributes to the increase of the microwave conversion efficiency in the heat, but also the presence of material defects creates additional heating conditions due to the faster reaching of the threshold for the thermal runaway phenomenon.

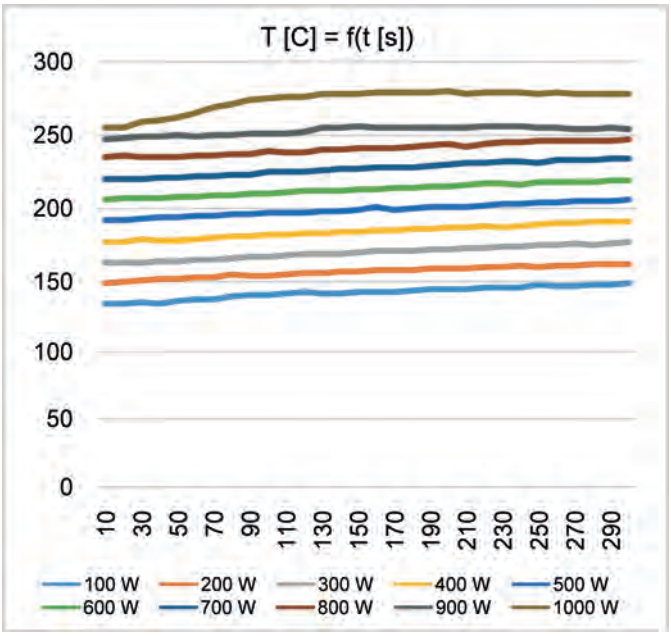

Figure 9. P5 without ceramic support.

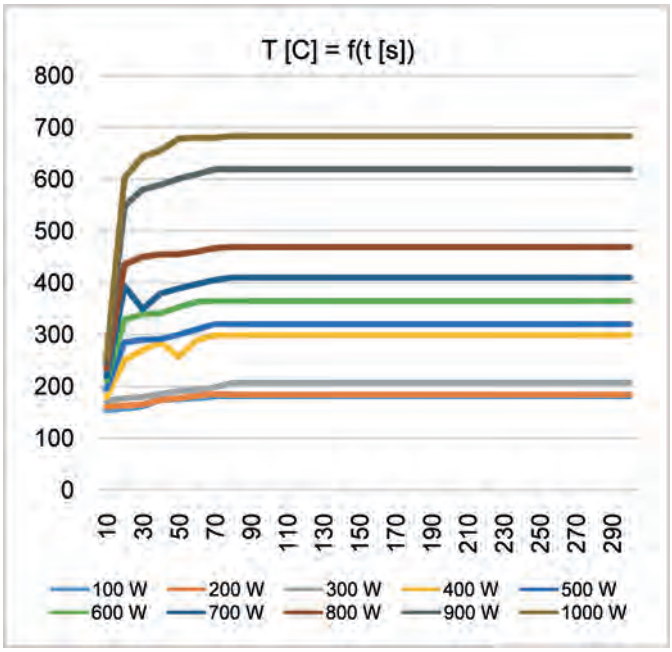

Figure 10. P5 with ceramic support.

4. Conclusions

• Material defects do not directly affect the degree of microwave absorption and conversion in the heat.

• The presence of material defects leads to an increase in the temperature inside the composite material only by means of an additional thermal intake, which facilitates a free movement of the dipoles inside the materials.

• The different behaviour at the same level of power and the same heating conditions for the same composite material cannot be explained simply by the additional heat input. The existence of voids inside the material as well as artificial defects can lead to an increase in conduction current that can generate additional heat [4] through Joule-Lenz effect.

• In the case of sample with 5 defects, it was noted that the too high number of defects led to an end of the absorption and conversion capacity of the electromagnetic energy in the heat. The maximum temperature reached in the heating process being 683^0 C. By forcing, the heating beyond this temperature has led to the phenomenon of thermal packaging and implicitly to the destruction of the sample.

• In the case of a single artificial defect sample, it was noted that the heating process is unstable when the microwave power injected does not exceed 100 W. This can be explained by the fact that the automatic load impedance generator at the microwave generator does not work at power less than 15% of the rated power of the generator. The conclusion drawn is that microwave heating has been uncontrolled, which is to be avoided in industrial processes.

References

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