Microwave Drill with Compact Solid-state Microwave Sources

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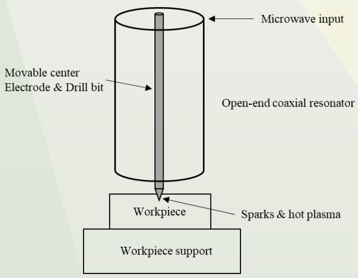
INTRODUCTION

Compared to mechanical drilling, microwave drilling has the advantages of no noise, no dust debris, and no vibration. Compared with most microwave heating systems that use magnetrons as feeding sources, compact solid-state microwave sources can reduce the size, weight, and operating voltage of the local heating system, making it more suitable for delicate operations. This paper presents a simulation and experimental study of a microwave drill implemented by a solid-state source; the realization mechanism and experimental setup are shown in Figure 1.



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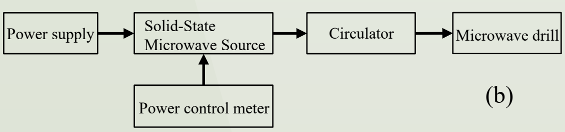
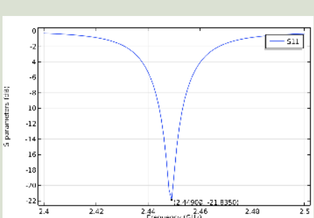


(b)

Figure. 1. (a) Schematic diagram of the microwave drill
(b) Structure diagram of the experimental setup

METHODS

We build a micro-zone heating and processing device containing a homogeneous lossy open coaxial antenna model, which is optimized in COMSOL Multiphysics v5.5 in terms of energy feed efficiency, cavity size, and center electrode geometry; three physical phenomena (electromagnetic field, thermal conduction, and heat convection) are coupled in both frequency and time dimensions. Figure 2 shows the numerical simulation results of the open-end coaxial antenna resonator by 30-W microwave power at 2.45 GHz. (the load is 1mm×6mm(Φ) soda-lime glass, using a perfectly matched layer (PML) to absorb scattered waves, and perfect electric conductor (PEC) boundary conditions are applied to the metal).



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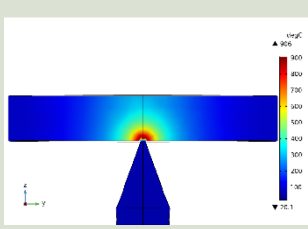
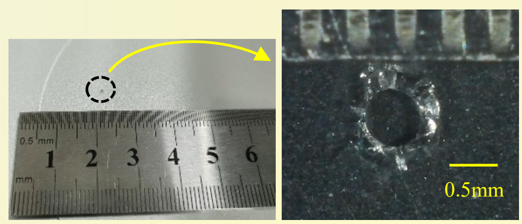


(b)

Figure. 2. Numerical simulation results of open-end coaxial antenna resonator by 30-W microwave power at 2.45GHz.
(a) S11 Parameter (b) Distribution of temperature

RESULTS

The experimental setup consists of a solid-state microwave source, a 1.2mm(Φ) microwave drill with removable electrodes, a circulator, and other devices, verifying the feasibility of the local microwave heating effect through experiments on 0.55mm×10cm(Φ) soda-lime glass in the power range of 30~100w.The material of the drill bit is stainless steel with gold outside plating to ensure both good electrical conductivity and high-temperature resistance. As the drilling progresses, the molten glass with the drill inserted cools down, and around the drill forms porous glass; figure 3 (a) shows the holes drilled in the glass with little mechanical help in less than 45s at 30w power; local cracks are observed by microscopy in the range of 1~2mm around the holes, which are caused by thermal stress and the properties of brittle materials like glass. then (b) shows the different power is used to obtain different drilling times as well as different levels of carbonization.



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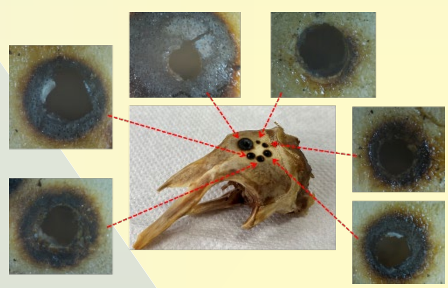

(b)

Figure 4. Microwave drilling pictures based on different materials

CONCLUSIONS

As the drilling progresses, Morphological changes in the drill bit and the workpiece can lead to an impedance mismatch, and this effect will diminish as the drill bit makes complete contact with the workpiece. In addition, the increase in dielectric loss or decrease in the material's electrical conductivity due to the temperature increase will also impact the microwave reflection.

The experimental results provide a new idea to reduce the total power required for the heating system to achieve the same performance by adaptive impedance matching system and accelerate the heating process at a given power.

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