Simulation research on miniature planar induction heater with cavity

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Abstract. This paper studies a new type of miniature planar induction heater through simulation. The miniature plane induction heater consists of a metal heating plate, a glass slide and a plane coil. The metal micro heating plate is designed with a cavity of a specific size. Since the cavity contains residual gas, when the micro heating plate is heated, hot bubbles will be generated in the cavity better and faster. Through the analysis of the energy density, eddy current density, and temperature distribution of the metal micro heating plate, it is found that the cavities play a very good role in the concentration of eddy current and the increase of energy. This kind of micro planar induction heater can be used for various hot bubbles to drive micro execution devices, such as micro ejectors, micro mixers and micro pumps.

1. Introduction
In recent years, bubble-driven micro-injectors [1], bubble-driven micro-mixers [2], bubble-driven nozzle diffuser pumps [3], thermal bubble-type micro acceleration sensors [4]. The bubble drive actuator has the advantages of simple structure and low working voltage, and has obtained a wide range of application prospects in the field of microfluidic systems [5].

The hot bubbles on the micro heater are usually generated by resistance heating [6-8]. Peigang Deng [6] studied micro-thermal bubbles as the drive of the microbiological analysis system and designed a micro-heater with a non-uniform width. Under pulse heating conditions, single bubbles can accurately appear in the narrow part of the micro heater. Xu Jinliang [7] studied the influence of pulse heating parameters on the microbubble behavior of platinum microheaters. When the platinum microheater is immersed in a methanol pool, microbubbles are generated. Under different heat fluxes, the growth conditions of microbubbles can be divided into Different types. Rebecca braff maxwell [8] designed a micro-heater with a micro-mechanical nucleation cavity that can accurately locate hot bubbles. This micro-heater can achieve a controllable bubble formation temperature and bubble collapse. However, due to the small size of the micro heater, the above-mentioned resistance heating micro heater can only generate small single bubbles. Therefore, the resistance heating micro heater cannot provide strong power for mechanical movement.

This paper studies a new type of miniature planar induction heater through simulation. There are cavities on the metal heating plate, which facilitates the storage of gas after increasing the cavities, increases the surrounding resistance, and can better produce bubbles. In this paper, the corresponding heating parameters, the size of the cavity, and the type of the cavity are adjusted through simulation. It is
found that the energy density, eddy current density and temperature around the cavity will increase, which can better control the growth of bubbles.

2. The structure and working principle of the micro heater

2.1. Structure
The structure of the micro induction heater is shown in Figure 1. This kind of micro heater consists of a coil, a glass plate and a metal heating plate. The circular chamber is designed on the glass plate, the disc-type metal heating plate is placed on the glass plate, and the coil is designed as a flat spiral type, placed under the glass slider, corresponding to the position of the heating plate.

2.2. Working principle
Use a high-frequency AC power supply to connect to the coil of the micro heater. When high-frequency AC power is applied, an alternating magnetic field is generated around the coil, and eddy currents are generated during heating. Due to the eddy current heating effect, the plates alternate with the magnetic field and the heating plate temperature rises rapidly. When it reaches a few hundred degrees Celsius, the liquid enters the micropump cavity for induction heating, causing some of the liquid near the heating plate to become steam. Therefore, bubbles will be generated on the metal heating plate.

3. Simulation
The simplified geometry of the miniature induction heater is shown in Figure 2. The geometric model is an axisymmetric two-dimensional model. On the RZ plane, the size, A-D section of 20×20mm is the air around the micro heater. The micro heater is placed in the middle of the air section. The radius and thickness of the micro heating plate are 4mm and 20μm, respectively. The bottom of the micro heating plate is provided with a glass slide with a radius of 4mm and a thickness of 100μm. The actual number of turns of the plane spiral coil is 14, and the coil section radius is 80μm. In order to facilitate the simulation calculation, the coil model is shown in Figure 3.

Figure 1. Micro induction heater structure

Figure 2. The geometry of the miniature induction heater

Figure 3. coil simulation model
4. Simulation results

The temperature of the heating plate changes with the vortex density and energy density. In this paper, heating plates with different cavities are designed and the changes are analyzed. The high-frequency square wave current \((I_0)\) is applied to the simulation solution process with a coil of 1A and a power supply frequency \((f)\) of 70 kHz. The heating time starts from 0 s and ends at 1 s.

4.1. Single row hole heating plate

![Single-row hole heating plate model](image1)

![Double-row hole heating plate model](image2)

Figure 4. Single-row hole heating plate model    Figure 5. Double-row hole heating plate model

![Temperature distribution cloud map](image3)

Figure 6. Temperature distribution cloud map
The simulation model of a single row of holes is shown in Figure 4. At the central axis of the metal heating plate, a row of cavities with an array is designed, and the cavity radius and cavity spacing (the distance between the centers of adjacent cavities) Analyze the energy density, eddy current density, and temperature distribution of the heating plate.

Figure 6–Figure 8 are simulation cloud diagrams of metal heating plates with the same hole diameter and the same hole distance. They are energy density distribution cloud diagram, eddy current distribution cloud diagram, and temperature distribution cloud diagram. Take the section shown in Figure 4, and respectively intercept the heating plate energy distribution curve and eddy current distribution curve, as shown in Figure 9–Figure 10. When the cavity radius remains unchanged and the hole distance remains unchanged, the energy around the heating plate cavity, The eddy current is obviously higher than the position where there is no cavity. Because the heating plate is too small, the temperature of the heating plate is faster and the temperature is not obvious.
4.2. Double row hole heating plate

The double-row hole simulation model is shown in Figure 5. A row of cavities with an array is designed above and below the central axis of the metal heating plate. The difference between the cavity radius $R$ and the cavity distance $d$ is changed and analyzed. Energy density, eddy current density, heating plate temperature distribution.

Figure 9. Energy profile distribution curve

Figure 10. Vortex cross section distribution curve
Analyze the cross section of the double-row hole heating plate, as shown in Fig. 11. From Fig. 12 and Fig. 13, it is known that the double-row hole array has little effect on the distribution of eddy current density, and has a great influence on energy density. Select the center point of the double row of holes in the vertical direction as the research object, as shown in Fig. 11, which are position 1, position 2, position 3, and position 4. As shown in Fig. 14, when the distance d is constant, as the aperture increases, the energy density will gradually increase, but as the aperture increases, the horizontal distance of the cavity will gradually decrease, which will cause the energy density of position 2 to be higher than that of position 1. It can be seen from Fig. 15 that when the aperture is constant, as the distance increases, the energy density changes less and less. When the distance is constant, the cavity has a very small effect on the energy density.
Figure 13. Energy density distribution curve of double row holes

Figure 14. Energy density distribution of double-row holes at a distance of 0.02mm

Figure 15. Energy density distribution of double row aperture 0.05mm
5. conclusion
This paper discusses the simulation of micro heaters through ANSYS software. Two heating plate models are designed, namely a single-row hole model and a double-row hole model. The simulation analysis shows that as the diameter of the cavity increases, as the distance between adjacent cavities decreases, the energy density and eddy current density around the cavities will increase, which can cause higher temperatures around the cavities to facilitate the generation of bubbles, and make the bubble micropump have a better effect. The holes can make the eddy current more concentrated, and the double-row holes have more cavities, which will increase the surrounding resistance and have higher energy. When the cavity radius is 0.05mm and the distance is 0.02mm, the distribution of energy density and eddy current is more obvious, which is convenient to control the growth of bubbles.

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