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电液动力微泵微电极的不同制作工艺的比较

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摘要：基于 MEMS 加工技术的电液动力微泵在微流体冷却系统和解决高热流器件的冷却问题中占有重要地位。电液动力微泵的核心部分是通过 MEMS 加工工艺制作的由成对的发射极和集电极组成的微电极。在电极对间的强电场作用下，电介质流体中的离子、极子以及微粒同电场相互作用来驱动流体流动。本文系统地讨论了微电极在设计和制作中需要关注的问题：电极材料的选择方针，多种形状的电极设计和两种电极加工工艺—电镀法和剥离法的对比。实验结果表明：贵金属有更好的抗电化腐蚀能力；同普通平行电极结构相比，带有尖锐结构的电极更能提高微泵的性能；相比电镀法，剥离法能更好地提高电极的制作质量。

关　键　词：电液动力效应；微机电系统；微泵；微电极

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Comparison of different processes in making EHD micropump electrode

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Abstract: The fabrication and design of micro-electrodes(the key component of Electrohydrodynamic (EHD) micropump) using MEMS technology are studied in this paper. The main part of the EHD micropump is a planar electrode array composed of electrode pairs made of the emitter and the collector. The electrohydrodynamic (EHD) pump uses the interaction between an electric field and electric charges, dipoles or particles embedded in a dielectric fluid to drive the fluid. The major key-controlling variables including the selection of electrode materials, diversification of electrode geometrical design, comparison of different fabrication processes, electroplating and kit-off process are analyzed systematically. The experimental results show that noble metals have good performance of resistance for corrosion electrochemical processes, and the electrode with sharp geometry can improve the performance of micropump. It also shows that kit-off process is better than electroplating process in electrode quality.

Key words: electrohydrodynamic (EHD); MEMS; micropump; micro electrode

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1 Introduction

With the development of advanced microfabrication techniques, MEMS have shown promising potentials in many real applications. Currently there is a significant effort towards developing microfluidic systems for integrated microelectronic cooling devices. Electrohydrodynamic (EHD) pump has advantages of the absence of moving parts, simply design, little dissipate power, the minimum of maintenance and low weights. For this reason, many theoretical and experimental investigations concerning the EHD pump are widely pursued in the early 1960s. The development of MEMS techniques is able to fabricate the EHD pump with much smaller dimensions and much lower voltages. The design and functionality of the micropump play an integral role in microfluidic systems and microelectronics cooling technologies[1-4]. In the microfabricated systems, the EHP pump without moving parts have drown more attention, and thir advantages make EHD pumps attractive for application involving microcooling devices.

An electrohydrodynamic (EHD) micropump is designed with an array of planar comb finger electrodes. The electrodes are fabricated on different substrates[5-6]. The major driving force of EHD micro-pump is the movement of ions across an imposed electric field, which is established between the two planar comb finger micro-electrodes. EHD pumps use electric field to pull along ions because of Coulomb forces, which in turn drag the bulk fluid by momentum transfer due to fluid viscosity. In this paper, we propose some key controlling variables of electrodes and their influences on the EHD pumping performance. In addition, we compare two different fabrication processes: electroplating and kit-off process.

2 Design and fabrication of electrodes

Electrodes are the key components for EHD micropumps and micro total analysis systems, the interaction between electric fields and flow fields can induce the flow motion by an electric body force[7], and Fig. 1 shows the mechanism of a EHD pumping. Fig. 2 also shows the schematic diagram of electrodes including emitter and collector electrodes. The design and fabrication of electrodes are involved in the optimization of the micropump design. The selection of materials, geometrical design and fabrication techniques of electrodes are the three main keys for micro-electrodes.

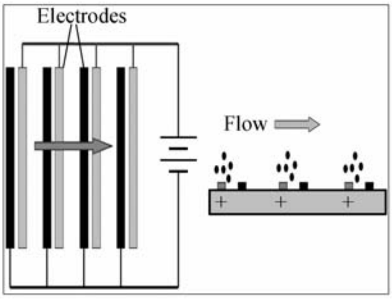

Fig. 1 Mechanism of ion EHD pumping

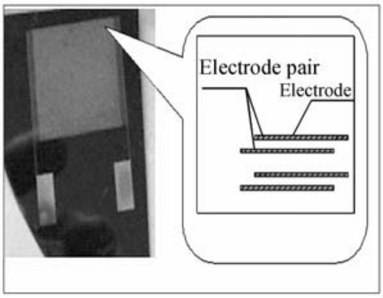

Fig. 2 Schematic diagram of electrodes

The selection of materials is decided by the EHD pump phenomena, fabrication technologies and micropump applications. In general, the right materials should be semiconductor insulators and have low electrical receptivity for minimal power consumption and Joule heating. Noble metals, such as Gold and Platinum, have good potential resistant performance for corrosion electrochemical processes, but it also turns out to be too challenging for fabrication (metal deposition and patterning). we should also think over the ability of the metal to inject charges, since the electric body force is proportional to the charge (see Tab. 1)[8]. In this experiment, titanium/copper are chosen for metal electrodes, titanium is needed to adhere copper to substrate.

Tab. 1　Work functions of several metals

Metal	Pt	Au	Cu	Cr	Nb	Al
electrode potential(V)	1.18	1.69	0.52	N/A	N/A	−1.66
work function (eV)	5.65	5.1	4.7	4.5	4.3	4.28

The main driving force of EHD micropump is based on electrical field between the two electrodes. Micropump electrodes are designed to improve both the pump performance charge injection and the electric body force depending on the maximum electric field, which is determined by electrode geometry once the materials are fixed. Two ways are carried out to increase the electric field: reducing the distance between emitter and collector electrodes and using sawtooth electrode to create sharp-angle protrusion on the electrodes. In this experiment, four electrodes with different electrode gaps and electrode geometries are designed and tested (as shown in Fig. 3～Fig. 4), and the results show that the sharp geometry could improve the performance of the micropump[9].

Generally, two different fabrication workflows are used in fabricating the micropump electrodes[10-11]: electroplating using a positive mask and kit-off using a negative mask. The major steps of the two workflows are shown schematically in Fig. 5 and Fig. 6.

Electroplating process is well suited to fab-

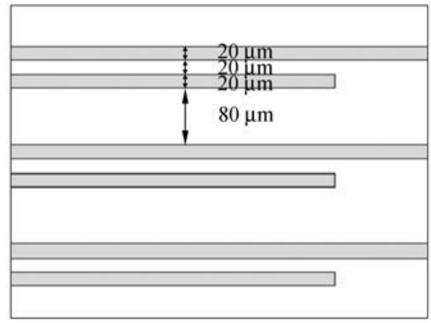

Fig. 3　Fabrication process of plating

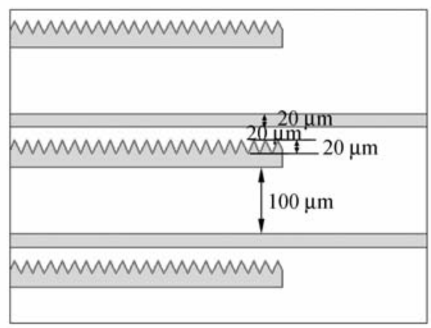

Fig. 4　Fabrication process of kit-off

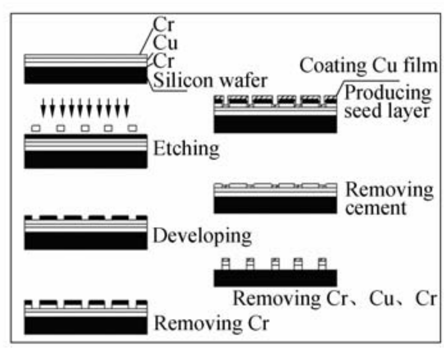

Fig. 5　Fabrication process of plating

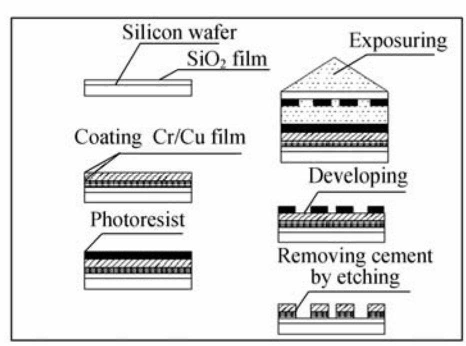

Fig. 6　Fabrication process of kit-off

ricate films of metals such as copper, gold. The films can be fabricated in any thickness from 1 μm to 100 μm and with good stress characters. The electroplating process requires a thin metal layer as a seed, which limits substance choice. The electroplating process uses a positive mask to form electrode, for electroplating could form a compact substance. However we have to face electrode collapse and metal form desquamation, especially for saw-tooth electrodes. Different from the electroplating process, kit-off process uses a negative mask. Making process is easy to control and electrode frame definition is better than electroplating process. But kit-off process has to face eroding process problems[12-14].

In this experiment, Ti/Cu are selected to make two kinds of geometries (planar/flat and saw-tooth) using two different fabrication processes: electroplating and kit-off process. It shows that electroplating is better in electrode quality but hard to control for high thickness metal films.

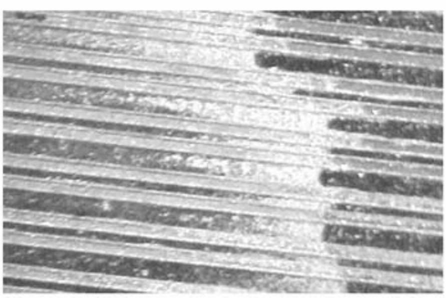

Fig. 7 Schematic diagram of failed electrodes

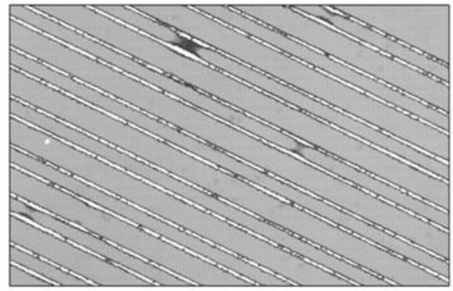

Fig. 8 Schematic diagram of failed electrodes

3 Conclusions

In this paper, the design and fabrication of electrodes, the key components of electrohydrodynamic micropumps are discussed. The three key focuses of electrodes are studied, and different materials are analyzed by using the selection of electrode materials. Different geometry electrodes and their influences on EHD pumping are studied. Two fabrication processes are used in fabricating electrodes. These results are very promising for further development of EHD micropumps and micro total analysis systems.

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