Fabrication of biochip based on CD/DVD manufacturing technology

LI Pei, XU Bin, LI Lihua, YAN Mingming, PAN Longfa
Optical Memory National Engineering Research Center (OMNERC), Department of Precision Instrument and Mechanology, Tsinghua University, Beijing, P.R.China, 100084

ABSTRACT :

Biochip is a kind of nano/microfluidic chip based on biology system. All advanced microfluidic are moving into small micro-meter and nano-meter scale and need a low cost and high production manufacturing method. The history and situation of biochips as well as the situation of optical storage industry, including the difficulties which producers face to, are surveyed. The advantages and disadvantages for the fabricating method of biochip based on CD/DVD production line are put forward. Once the low cost technology is developed, it will be able to speed up biotech research as well as revival of optical storage industry and make use of the unemployed optical instruments.

KEYWORDS: biochip, microfluidic, optical storage, CD/DVD manufacturing line

1. INTRODUCTION

Biochip manufacturing technique based on CD/DVD manufacturing line is assumed to have the largest market in the near future years because of its high utilization rate of the CD/DVD manufacturing line and high productivity at low cost. All advanced microfluidic based on biology system developments moves into small micrometer and nanometer scale. Microfluidic manufacturing technology is critical to their success. But no mature low cost manufacturing technology is developed.

The current situation of optical storage industry is introduced in this paper. Then, biochip and situation of its study are introduced. The possibility of improving the CD/DVD production line to fabricate biochips is discussed. At the same time, technical difficulties are analyzed. In conclusion, it's feasible to fabricate nanometer scale microfluidic chips based on CD/DVD manufacturing line. This method is suitable for volume manufacturing and is beneficial to both optical data storage and biotech industries.

2. SITUATION OF OPTICAL STORAGE INDUSTRY AND BIOCHIP STUDY

2.1 Situation of optical storage industry

China is the biggest country of both origin and consumption in the world optical storage industry. The data from CDs21 Solutions (a organization who works on promoting the wider use of CD-R/RW) shows that annual output of CD-R in the world is more than 10 billion in 2003 and China had made 70% production including mainland and Taiwan area [1] . But all optical disc manufacturers in China have to pay much patent royalty just because Chinese never hold the core technology of CD and DVD. The total cost in patent fee is almost equal to the sum of DVD production cost. This unfair charge mode brings massive impairment to optical player and disc manufacturing companies in China. Many instruments in optical disc/player companies have been unemployed capital because the companies cannot support the pressure.

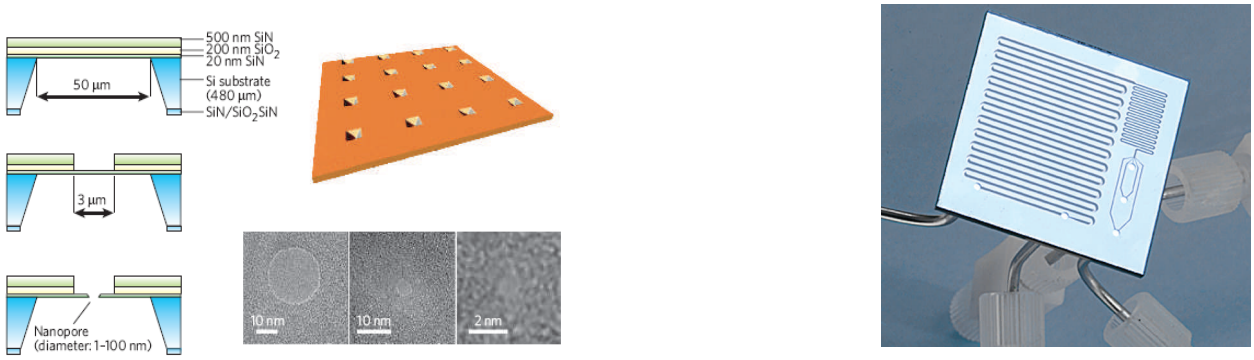
It's very important to find a new way to develop Chinese optical storage industry not only in researching a new storage format but also a new area where the existing industry conditions can be made use of. Biochip is emerging research field in recent years. Many organizations and experts have worked on it. Adapting CD/DVD manufacturing technology into this field is feasible and beneficial to both Optical data storage and Biotech industries. Once the low cost technology is developed, China will be able to speed up its biotech research as well as revival of optical storage industry.

2.2 Biochip and its research

Biochip is a kind of nano/microfluidic chip based on biology system as the name implies. In Biology area biochip is known as a chip which is used in the static hybridization and don't have any nano/microchannels in because of some history reasons. But in manufacturing industry, it's appropriate to define it as a nano/microfluidic chip with nano/microchannels and we can call it nano/microfluidics or lab-on-a-chip also. It's agreed that Biology is the most important application area of nano/microfluidics. Biochips can roughly divided into cell chips, protein chips and DNA

Photonics and Optoelectronics Meetings (POEM) 2009: Optical Storage and New Storage Technologies, edited by Masud Mansuripur, Changsheng Xie, Xiangshui Miao, Proc. of SPIE Vol. 7517, 751709 · © 2009 SPIE · CCC code: 0277-786X/09/$18 · doi: 10.1117/12.841272

chips. Be different with semiconductor chips, biochip is a biological laboratory constructed on a several square centimeters chip. It contains all the sections of sample preparation, interaction, separation, detection, cell culture, sorting, lysis and etc. on a small chip (Figure 1). Nano/microchannels on it form network and control fluids to flow all the system so that the chip can work like a natural biologic laboratory.



a. Nanopores used for DNA translocation studies. Left: cross-sectional schematic of an engineered nanopore in silicon nitride showing three phases of the pore fabrication. Top right : AFM image of an array of engineered pores formed on a chip. Bottom right: transmission electron micrograph of three different pores [2].

b. a piece of biochip: used to perform Chemical reactions [3] .

Fig. 1. Example of biochips

The concept of microfluidic chips originated in the early 1990s, by A. Manz. He did some researches on capillary electrophoresis on a chip [4] and defined the concept of "u-TAS". In the 1990s, microfluidic chip more regarded merely a chemical analysis platform, so often were interchangeable with "u-TAS" which is proved not all the microfluidic chips but only a category. Whitesides et al. in Harvard University used lithography, the technology commonly used in microelectronics industry, in the field of biology and developed a better method-soft lithography [5]. After the article about microfluidic published in Science [6], it's clearly appreciated that microfluidic chip will be far beyond the "u-TAS" to become an important scientific and technological platform. A special column about "Lab-on-a-chip" has been published in Nature in July 2006. D. Janasek[7], D. Psaltis[8], H. Craighead[9], A. J. deMello[10] et al. expatiated on the history, state and applied prospect of lab-on-chip from different perspectives. Lab-on-a-chip attracts more attention in the field of science and industry.

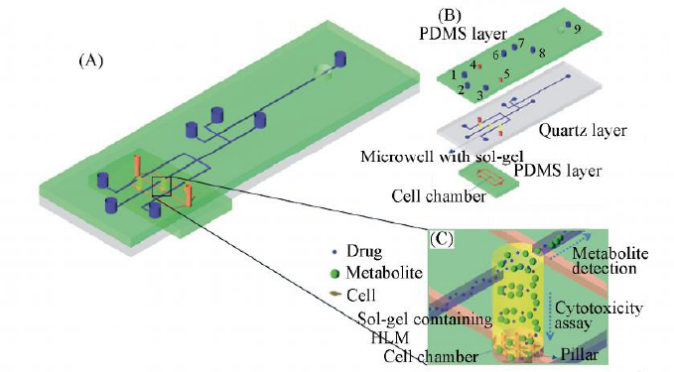


Fig. 2. Schematic of a three layer microfluidic device for characterization of drug metabolites and cytotoxiccity assay simultaneously (A) Layout of the chip (B) design of the chip (C) a magnified schematic of one sol-gel bioreaction on the microfluidic device[14].

In physics, biochip is a kind of system that controls the movement of tiny volume fluid in nano/microchannels or nano/micro-components with only dozens of nanometer to several hundred microns scales. The raw materials making biochip are mainly silicon chips, PMMA, PDMS, PC and hydrogel, etc. The traditional processing methods of biochip (e.g. PDMS molding, micro-milling, glass etching, etc.) have its limitations, including expensive production cost, lower productivity, and not suitable for volume manufacturing and mass production. There is not mature low cost microfluidic

processing technology currently. Only a few companies and research units can achieve the plastic injection molding for biochips. Microsystems Laboratory in Ecole Polytechnique Fédérale de Lausanne (EPFL)[11,12], Solid-State Electronics Lab of University of Michigan[13], etc. have achieved the processing of microfluidic chips, but only in laboratory, and their processing method cost too much for biological needs. In China, some research institutes including Dalian University of Technology can process 40*40mm size microfluidic chip moulds and small amount of artificially copies [14]. But the finished products have poor precision, low efficiency of procession, and can't process larger size (Figure 2). Cheng Jing et al. in Tsinghua University can make electrophoresis chip[15] and DNA chip[16], protein chip[17] and other types of chips now, but it needs a long time to manufacture a piece of biochip and still cannot achieve mass-production.

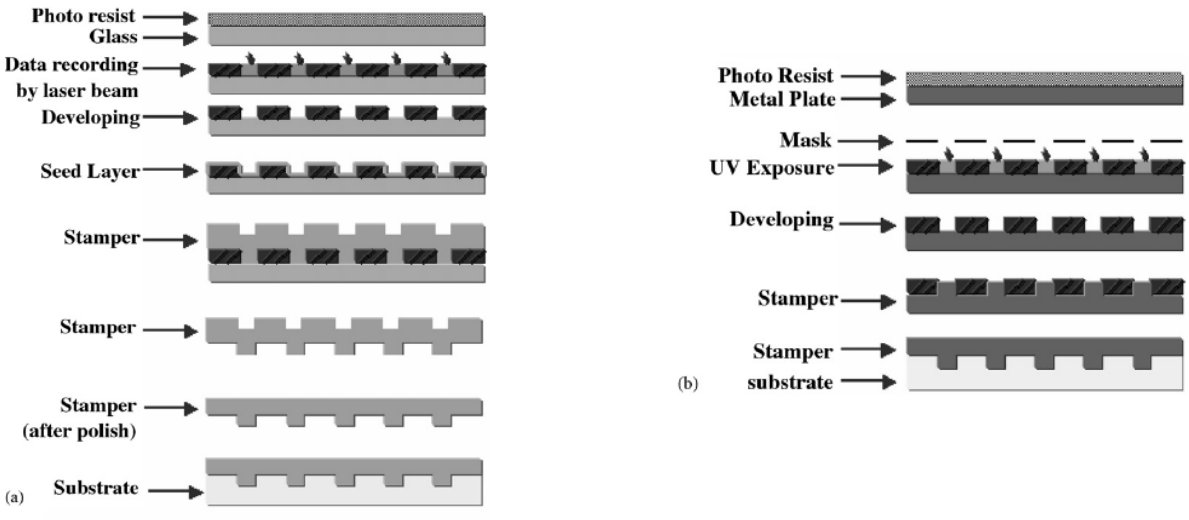
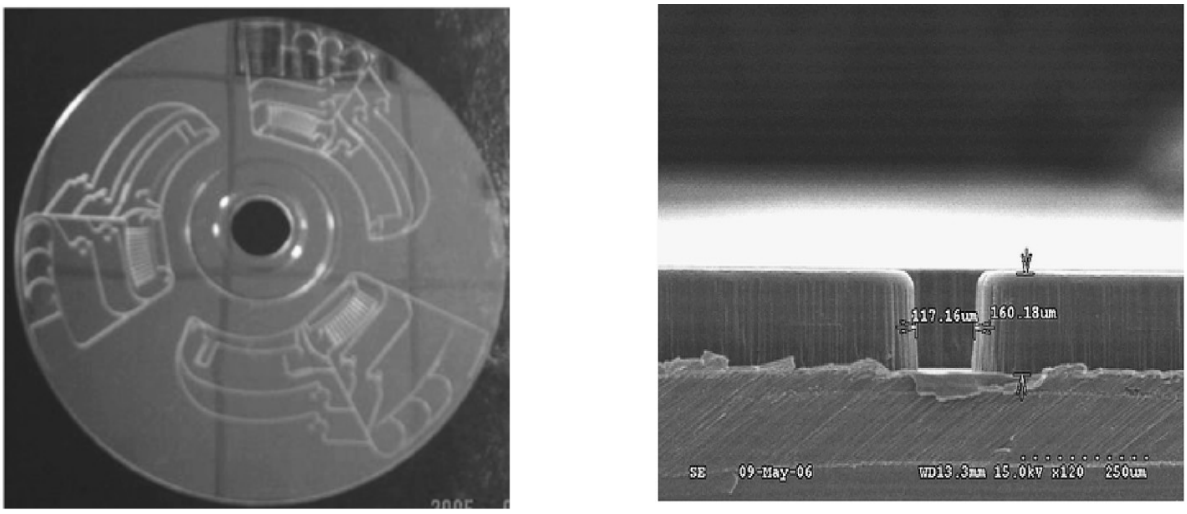


Fig. 3. Process of (a) the optical disc substrates and (b) the microfluidic substrates [20].

Take note of that all advanced microfluidic are moving into small micro-meter and nano-meter scale and have higher requirements on surface morphology, scientists want to design and fabricate it based on CD/DVD process instrumentation. M.J. Madou adapted CD/DVD manufacturing technology into the fabrication of biomedical devices to meet the need for low cost, biocompatibility, flexible process and the capability to be mass produced [18,19]. Chun-Han Wu et al. in National Chiao Tung University in Taibei, have designed and fabricated the polymer microfluidic substrates using the optical disc process. They used a new optical disc process to prevent damage on the mirror plate of the mold (Figure 3). The cycle time of the injection molding can be reduced several ten-folds compared to the conventional methods by means of a new cooling system. The molding system is comprised of a mold insert (stamper) holder and vacuum system to join the mold insert with the mold [20]. Fig. 4 shows the plastic substrate and its micro-channel. The surface and channel both had high precision.



(a) (b)

Fig. 4. (a) Drawings and photo images of microfluidic plastic substrate (b) SEM photos of structure features of a microchannel of plastic substrate[20].

3. FABRICATION OF BIOCHIP BASING ON CD/DVD MANUFACTURING TECHNOLOGY

The fabrication of biochip basing on CD/DVD manufacturing technology means making use of some optical disc bulk copy equipment and improving the CD/DVD production line and making progress in process procedure and technologies. A certain number of biochips are fabricated on an optical master disc by photo lithographic processing. Then son biochips are reproduced by molding as the same as optical disc production process and cut into pieces. Biochip with nano/micro-meter scale can be manufactured by this method and low cost and high efficiency of procession goal can be reached.

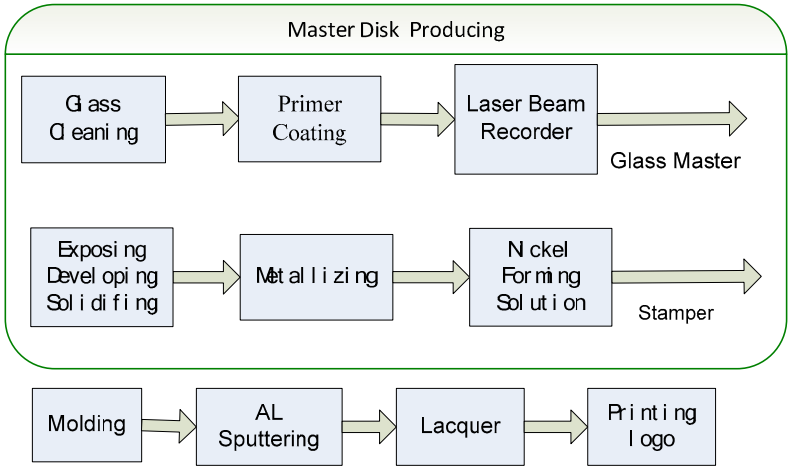


Fig. 5. The Production Processes of CD/DVD master disk.

Figure 5 shows the Production Processes of CD/DVD master disk. The CD/DVD master disk manufacturing technology is maturity and much experience about actual production line has been mastered. At the same time, the special lithography UV-LIGA [21] has been used in the biochip manufacturing. It can be improved that the source of light and other conditions on existing CD/DVD production line for the manufacture of biochip.

The manufacturing processes are dependent on the materials of biochip basal plate. Molding and coping are particularly suitable for high molecular polymer because of low cost and short production cycle. The preceding procedure in production is very similar to integrated circuit (IC) and optical disc manufacture. The subsequent procedure is decided by the particular materials. Figure 6 shows a workable production schematic design for biochip imitating CD/DVD (including master biochip recording and son biochip production reproducing).

The preceding procedure of master biochip is lithography-Glass positive or negative photoresist coating, exposure and developing. If the material of biochips is polymer, the basement should be metalized first in order to be a galvanograph. The metal stamper can be got after the nickel forming solution. Then son biochips could be got by molding or in-situ polymerization or hot-press approach.

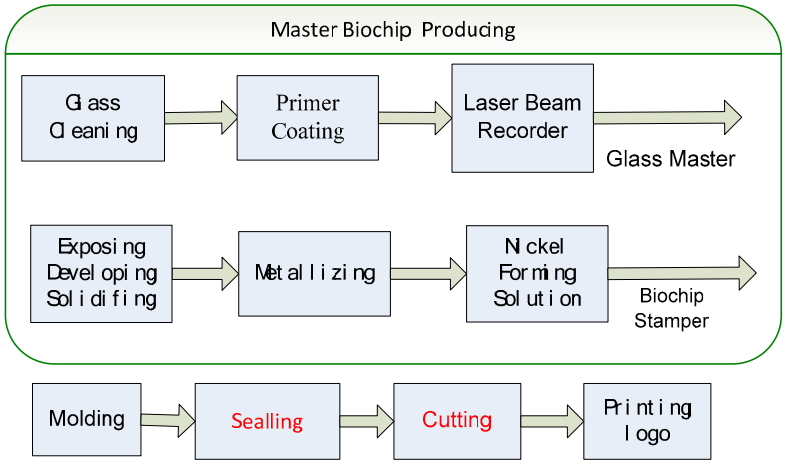


Fig. 6. A workable production schematic design for biochip imitating CD/DVD

There are still many technical problems to be solved. Microfluidic chips have different characters with optical discs. First, biological chip have high requirement for the channel morphology even to nanometer level. Through this method of producing biological chip, we need to link the two surfaces together, so how to seal is a difficult question. Secondly, biochip requires biological reagent for experiments, so we should process access and exit holes for biologic materials, the positions and sealing of holes is another technical problem needed to be solved. In addition, the surface of biochip is more complex than CD/DVD, it has many forms. It's difficult to control the power of lasers .At the same time, under the situation of high depth to width ratio, we can't ensure the accuracy of photolithography. At a time because of height-width ratio of biochip array, it's more difficult when lifting pattern, and the method of mold release and the design of point becomes difficult.

There are many strict requirements in surface roughness, flatness, etc of biochips. In order to ensure the products meet the requirements, measuring systems are required to guarantee quality and production rate. Therefore, there is still a long way to research and develop the suitable production technology on CD/DVD line to bring about biological chips mass production.

4. CONCLUSION

All advanced microfluidic basing biology system developments are moving into small micro-meter and nano-meter scale. Microfluidic manufacturing technique is critical to their success. Current microfluidic manufacturing technique is limited and not suitable for volume manufacturing. Adapting CD/DVD manufacturing technology into this field is feasible and beneficial to both industries although there are still technical problems to solve. Once the low cost technology is developed, we will be able to speed up our biotech research as well as optical storage industry.

REFERENCES

[1] Zhong X., "the annual output of CD-R exceeded 10 billion", China Media Tech, 14(2004).

[2] Diego K., Wu M., Smeets R., Zandbergen H., Dekker C., and Lemay S., "Fabrication and Characterization of Nanopore-Based Electrodes with Radii down to 2 nm" , Nano Letters, November 21, (2005).

[3] Hogan J., "a little goes a long way", Nature, 442(27), July, (2006).

[4] Manz A., HarrisonlD., Elisabeth M., James C., Aran P., Hans L. and Michael H., "Planar chips technology for miniaturization and integration of separation techniques into monitoring systems : Capillary electrophoresis on a chip", Journal of Chromatography, Feb. 28, 253-258, (1992).

[5] McDonald J., David C., Janelle R., Daniel T., Wu H., Olivier J., and George M., "Fabrication of microfluidic systems in poly(dimethylsiloxane)", Electrophoresis , 27-40, Jan, (2000).

[6] Thorsen T., Maerkl S., and Quake S., "Microfluidic large-scale integration", Science,580(2002).

[7] Janasek D., Franzke J., and Manz A., "Scaling and the design of miniaturized chemical-analysis systems" , Nature, 442(27), 374-380, July, (2006).

[8] Psaltis D., Quake S. and Yang C., "Developing optofluidic technology through the fusion of microfluidics and optics", 442(27), 381-386, 27 July, (2006).

[9] Craighead H., "Future lab-on-a-chip technologies for interrogating individual molecules" 442(27), 387-393, July, (2006).

[10] A. Demello, "Control and detection of chemical reactions in microfluidic systems", 442(27), 394-402, 27 July, (2006).

[11] Reto B., Lintel H., and Philippe R., "Effect of the surface charge on ion transport through nanoslits", Physics of Fluids, 17, 100604,(2005).

[12] Reto B., Lintel H., and Philippe R., "pH-Controlled Diffusion of Proteins with Different pI Values Across a Nanochannel on a Chip", Nano Letters, 543-547, 6 (3), (2006).

[13] Guo L., Cheng X., and Chou Ch., "Fabrication of Size-Controllable Nanofluidic Channels by Nanoimprinting and Its Application for DNA Stretching", Nano Letters, 4 (1),69–73, (2004).

[14] Lin B., and Qin J., "Microfluidics Based Analytical Chemistry Laboratory on a Chip", Chemical Journal of Chinese University, NO.3, 433-445, (2009).

[15] Xiong Q., Xin W., Gu G., Sun A., Guo X., Cheng J., and Xiang Y., "A high performance capillary electrophoretic system used for manifold bioanalysis", Journal of analytical science, 22(6), Dec.(2006).

[16] Tao Sh., and Cheng J., "SARS the production of coronavirus gene chip and preliminary clinical samples validation", J Tsinghua University (Sci & Tech), 43(1), No. 5,(2003).

[17] Xie W., Wang D., Du H., and Cheng J., "Protein microarray detection of antigen - antibody interaction", Prog. Biochem. Biophys, 29(2), 311-315, (2002).

[18] Madou M., Lee L., Koelling K., Dauner S., Koh C., Juang Y., Lu Y., Lu L., "Design and fabrication of CD-like microfluidic platforms for diagnostics: polymer-based microfabrication", Biomed. Microdev, 3 (4), 339–351, (2001).

[19] Madou M., Lee L., Dauner S., Lai S., Shih C., "Design and fabrication of CD-like microfluidic platforms for diagnostics: microfluidic functions", Biomed. Microdev., 3(3), 245–254, (2001).

[20] Wu,Ch., Chenb Ch., Fanb K., Hsua W., Lin Y., "Design and fabrication of polymer microfluidic substrates using the optical disc process", Sensors and Actuators ,A 139, 310–317,(2007).

[21] Lv Ch., Du R., Yin X., "Studies on the Microfabrication technology for production of microfluidic chips based on SU-8 negative photoresis.", Doctoral Dissertation, Zhejiang University, May(2007).