Novel Approaches for Functional Patterns and Microfluidic Synthesis

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We introduce MIP system and molecular imprinting technique to create synthetic receptor or binding sites for bio/chemical detection technology. Those binding sites in MIP's system have specific molecular recognition functions for targeting specific chemical or bio-molecules. This study presents functional microfabrications using MIPs' system to develop useful bio- or chemical sensors/devices. We also demonstrate microfluidic synthesis to produce high affinity MIP's particles. A microfluidic reactor was designed and used to generate continuous MIP's particles in either micro- or nano-sizes.

Key words; Microfabrications, Nanofabrications, MIPs polymers, Molecular imprinting.

INTRODUCTION

Recent nanotechnology has brought us numerous innovations to improve device performances. Additionally, nanotechnology has potentials to create new technological emergences, which could overcome the conventional developments. For this reason, nanotechnology has taken our great attention.

For example, recent developments in this area include soft lithography, plastic electronics, nanofabrication, and microfluidic approaches, which we have been widely pursuing to explore and expand the scope of current limited nanotechnology.[1-9]

Nanofabrication has been widely used to integrate small patterns on a variety of substrates for developing novel devices using either organic or inorganic materials. Due to stringent demands on high fidelity lithography, challenges of developing new materials for nanotechnology applications currently lead this technology.

Since new materials can bring advances and improvements in nanotechnology, there are a lot of efforts for chemists and materials scientists to contribute to this area.

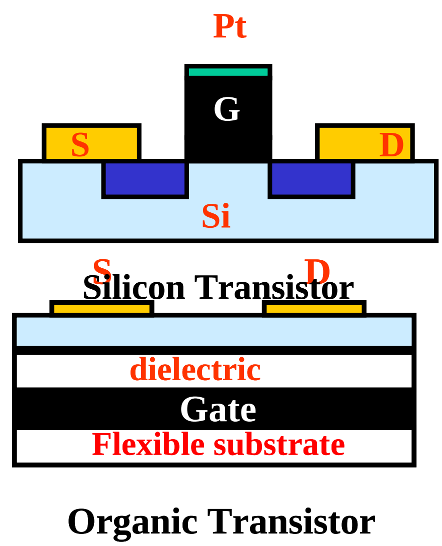

Figure 1. Organic transistor substitutes for conventional silicon transistor.

For this reason, chemists have been seeking for unconventional routes of synthesizing and fabricating novel materials. For example, chemists developed useful organic or polymer materials to substitute organic thin film transistors for conventional silicon transistors (Figure 1).

The developments of new materials for integrating smaller and more compact features have been studied to meet our growing demands in miniaturization. In this study, we were particularly interested in the generation of 'functional patterns' fabricated using functional polymers; because, most of conventional patterns in current nanotechnology use non-functional materials for pattern fabrications.

RESULTS AND DISCUSSIONS

In this work, we introduced novel chemical approaches on fabricating functional patterns and microfluidic synthesis of MIPs' system.

Molecularly imprinted polymers (MIPs) are highly cross-linked macroporous materials with specific molecular recognition functions (Figure 2). MIP's patterns fabricated on silicon wafers have potentials to develop chemical sensors or diagonostic bio-devices. MIP is a robust thermoset that tolerates high temperature and harsh environment. However, their commercial uses have been limited due to their poor sensitivity and selectivity. For this reason, we focused on increasing sensitivity and selectivity of recognition functions by manipulating MIP's synthetic conditions.

Since detection is elicited by modifying physicochemical properties of the interface, high affinity binding sites on molecules is a key contributor to achieve enhanced sensitivity.

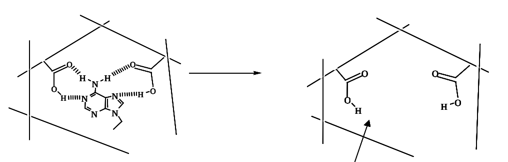

Figure 2. Creation of receptor sites with molecular recognition functions.

To demonstrate functional pattern fabrications, we provided a mold with micro-sized line features and photopatternable MIP's prepolymer. 'Microcapillary molding' technique was employed to generate MIP's patterns using the mold with 2 μm line-widths. Figure 3 shows MIP patterns fabricated on a silicon wafer. The result encourages us to use MIP's systems for photopatternable functional polymers.

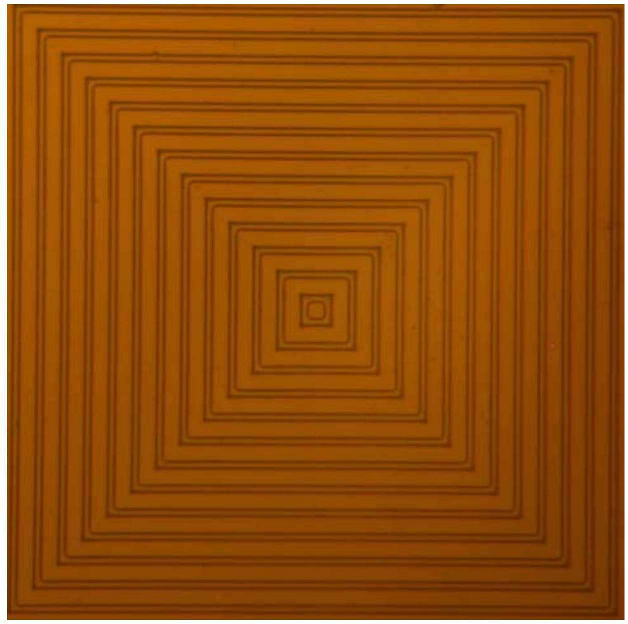

Figure 3. MIPs' pattern with 2 μm line-widths.

We also demonstrate the generation of micro-sized MIP's particles through microfluidic approach to prepare high affinity receptor sites that range in affinity and selectivity. The distribution of affinities significantly affects to the performances of molecular recognition capability; because, nonspecific binding would result in false positives or high background signals in chemical detection performances.

Figure 4. Microfluidic operations.

The use of microfluidic reactors for synthethic purposes offers a number of advantages over conventional bulk-scale synthesis. The innovation of MIP's particle synthesis arises from a microfluidic approach to produce MIP's particles with high affinity binding sites only. Those MIP's micro-sized particles with high affinity receptors only, will contribute to increase sensitivity of detection functions.

In this study, we demonstrate a microfluidic synthesis of MIP's particles. Figure 4 shows a microfluidic reactor and syringe pumps to inject activated photocurable MIP's solutions and thus generating micro-sized MIP's particles.

A new microfluidic reactor has been designed and used for the synthesis of MIP's microbeads. The microfluidic device has shown high performances on producing uniform MIPs' droplets.

Figure 5 shows the microfluidic reactor fabricated on PDMS stamp, which was used to produce MIPs' particles; as you can see, it has two inlets for reagent injections and two outlets to collect photocured MIP's particles. The channel width of the reactor was 30 μm.

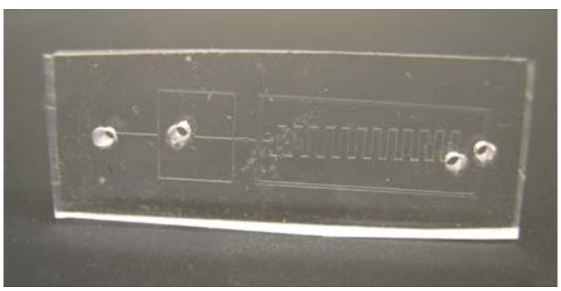

Figure 5. PSMD-based microfluidic reactor designed for MIP's particle synthesis.

The microfluidic reactor has T-junction, which generates MIP's droplets. Those MIP's droplets were then photocured through the PDMS stamp using an UV light at 365 nm. Subsequently, photocured MIP's particles were collected at the two outlets with different channel widths to separate MIP's microbeads; the wider channel has 200 μm and narrow one has 30 μm of channel widths.

The overall goal of microfluidic synthesis of MIP's particles is to produce microparticles with high affinity binding sites only using microfluidic device efficiently and economically by minute amounts of MIP's prepolymers.

Figure 6 shows resulted MIPs particles in different magnifications; the microfluidic device shows photocured MIP's particles in either micro-size (30 μm in diameter) and nano-size. Those micro- or nano-sized MIP's particles can be particles with higher affinity only.

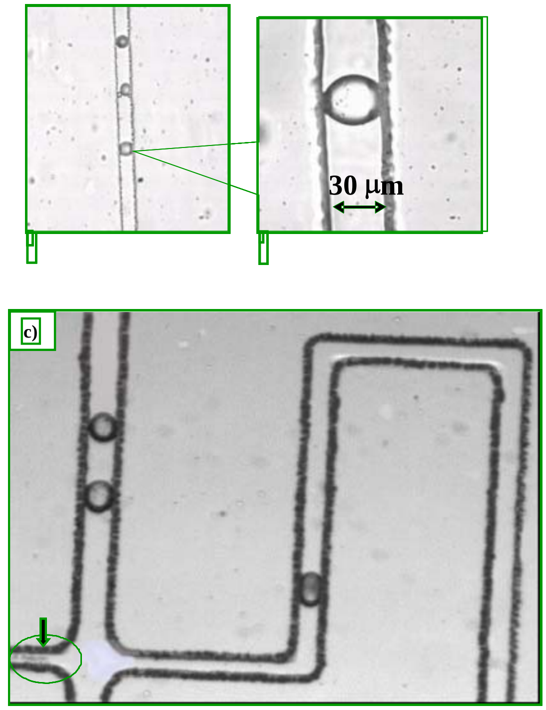

Figure 6. Photocured MIP's particles in the 30 μm channels. It also shows nano-sized MIPs' particles in a circle pointed with an arrow.

As demonstrated above, microfluidic approaches offer unconventional performances in synthesis, especially nanomaterial synthesis. Additionally, microfluidic synthesis also results improvements in mixing efficiency and better control concentrations of reagents compared to conventional synthetic routes.

Micro-scale synthesis can also provide more efficient equal concentration of reagents and fusion of mutiple reagents at micro-scale, which allow us to achieve efficient chemical reactions with micro-scale volumes.

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