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Microfluidic Devices Integrated with Parmalloy Micropatterns for Manipulating Magnetic Beads

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1. Introduction

Magnetic beads modified with specific functional groups on their surfaces are currently used for feasible separation and purification of proteins and cells. Furthermore, functionalized magnetic beads are available as a convenient carrier of molecules. Namely one can handle small amount of molecules by handling bead-target molecule complex for microscopic study of cell-molecule interactions, for instance. However, behaviors of the massive magnetic beads in the magnetic field is rather complex and hence it is far from handling each magnetic beads in the sophisticated manner. This paper proposes a microfluidic device for handling small amount of magnetic beads by localized magnetic field and reports the fabrication of microfluidic chips integrated with micropatterned permalloy thin films. Dry etching process originally developed has been applied to the precise micropatterning of thin permalloy films.

2. Chip Fabrication

Figure 1 shows the schematic of the microfluidic chip with branched microchannels and permalloy micropatterns for the generation of localized magnetic field distribution. The process steps for the chip fabrication are depicted in Fig. 2. A thin permalloy (Ni: 78%, Fe: 22%) film of 500 nm thickness was sputter-deposited on a borosilicate glass substrate of 30 by 30 mm area, and was sequentially coated by a thin Cr film. Subsequently a Cr film was patterned by photolithography and wet chemical etching to play a role of the hard metal mask during the following dry etch process of the permalloy thin film. A permalloy film was etched in $CO/H_2/Ar$ mixture plasmas, which is an original process recipe recently developed by our group [1]. Figure 3 shows the chemical reactions involved in this reactive ion etching. High etch rate selectivity against the Cr mask was attained due to the consumption of carbon or carbon monoxide on permalloy surfaces via carbonyl production. The main role of H_2 is considered to be the removal of carbon films by chemical sputtering and the dilution of deposition precursors, while Ar ion bombardment enhances the desorption of etching products. As demonstrated in Fig. 4, fine line-and-space pattern etching of Ni thin films has been achieved under optimized conditions. At the final step a

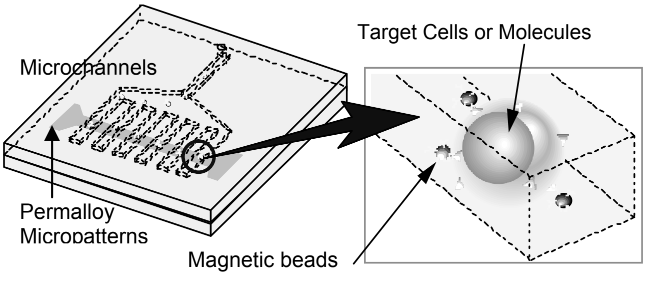

Fig. 1 A schematic diagram of microfluidic chip for the separation and purification of cells or biomolecules via the specific interaction with polymer coated magnetic beads trapped near fine permalloy patterns.

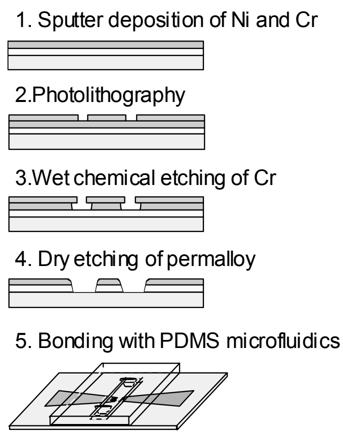

Fig. 2 Process sequence of the microflluidic chip integrated with permalloy micropatterns.

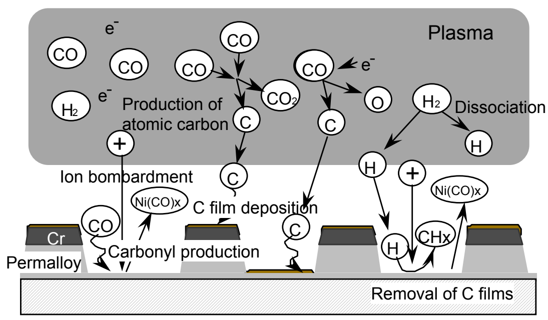

Fig. 3 Chemical reactions involved in dry etching process of permalloy thin films using $CO/H_2/Ar$ mixture plasmas.

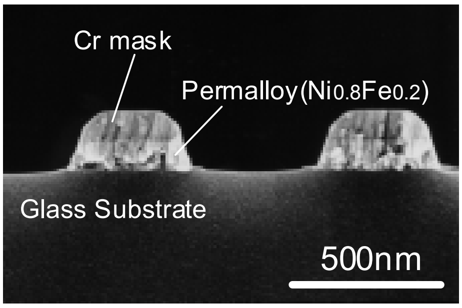

Fig. 4 A cross sectional scanning electron micrograph of the Ni thin film patterned using dry etching technology.

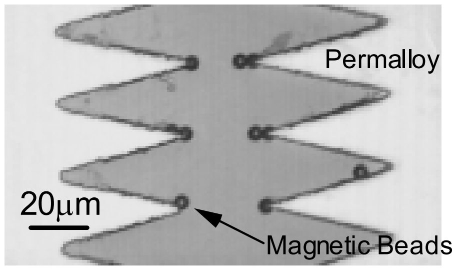

Fig. 6 A microscopic photo of magnetic beads trapped at the edge of permalloy micropatterns.

poly(dimethylsiloxane) PDMS microchannel sheet was bonded on the glass plate so as to locate the permalloy micropatterns in microchannels.

3. Results and Discussion

Performance of the prototype chip was examined on an inverted microscope as shown in Fig. 5. Magnetic beads of 4.5 μm in diameter (Dynabeads M-450) were suspended in the aqueous solution with the slight addition of surface active agent, and introduced into microchannels. Magnetic field was applied to permalloy micropatterns by flowing the electric current through the electromagnetic coils set on the pad portion of the patterned permally films. Behavior of magnetic beads near the permally micropatterns were observed and recorded using a CCD camera mounted on a microscope. When the electromagnet is active, magnetic beads drifting in the microchannels were found to be trapped mainly at the pointed part of permalloy micropatterns as shown in Fig. 6, and trapped beads could be released by applying additional magnetic field for degaussing.

(a)

(b)

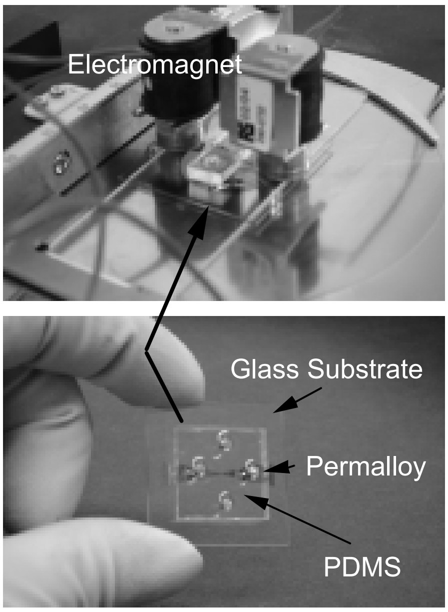

Fig. 5 (a) An experimental set-up for testing prototype chips. Small electromagnets were set on permalloy micropatterns. (b) A photo of the microfluidic chip with permalloy micropatterns.

4. Conclusions

In this paper a new type of biochips for the direct handling of biomolecules has been proposed by the combinative use of magnetic beads and the microfluidic chip integrated with micropatterns of permalloy thin films. For this purpose a new plasma etching process for the patterning of Ni based alloy thin films has been developed using $CO/H_2/Ar$ plasmas. Furthermore, preliminary results of the manipulation of magnetic beads on a microfluidic chip have been demonstrated using prototype chips.

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References

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