Preparation of a Flexible Microfluidic Chip Device with MMT/PEG Hydrogel Nanocomposite Molds for Nanobio-chip Applications

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ABSTRACT

A thin and flexible microfluidic chip device using microstructured montmorillonite (MMT) reinforced polyethylene glycol (PEG) (MMT/PEG) nanocomposite molds has been presented to apply miniaturized nanobio-chips. Biocompatible PEG hydrogel with 1-2 wt.% of MMT was used to fabricate environmentally friendly microchip molds. In fabrication procedures, a simple UV curing process of PEG hydrogel with microstructure patterned photo-mask was used. By UV irradiation for 7 seconds at 26 mW/cm^2, the 1-2 wt.% MMT/PEG hydrogel micro-molds were obtained and characterized by optical microscope and thermogravimetric analysis. Then the hydrogel micro-mold was used to prepare a thin and flexible microfluidic chip of polydimethylsiloxane (PDMS). The present method is rapid and conventional to prepare a thin and flexible microfluidic chip device for nanobio-chip applications.

Keywords: microfluidic chip, nanocomposite, hydrogel

1 INTRODUCTION

Microfluidic chip based various miniaturized devices such as lab-on-a-chips, biochips, diagnostic strips, biosensors have been rapidly developed for medical and environmental applications. Recently, biocompatible fabrication methods of microstructure devices such as bioassay chips or cell based microchips. Thus biocompatible preparation procedures of nanobio-chip devices with biocompatible materials including polyethylene glycol (PEG) or polydimethyl siloxane (PDMS) have great interest for biotechnological applications.

PEG hydrogel microarray placed in a microfluidic chip, PEG microfluidic chip with nanostructures were developed. PDMS is a well-kown biocompatible materials to prepare various microfluidic chip devices. PDMS have several important advantages including optically trasparent, non-biotoxic, gas permeable.

Microstructure fabrication procedures are generally by photolithographic method using photorigist material with photo-mask. However the photolithographic preparation procedures require expensive instruments with clean-room environment. Thus, simple and rapid productive preparation methods of microstructures instead of the photolithographic method are important for commercialization of microchip devices including microarray or microfluidic chips.

2 EXPERIMENTAL DETAILS

Polyethylene glycole diacrylate (PEGDA) as a PEG hydrogel, 2-hydroxy-2-methylpropiophenone as a photo-initiator, and montmorillonite (MMT) were obtained from Sigma-Aldrich (USA). PDMS elastomer solution (Sylgard 184, Dow Corning) was used to prepare PDMS thin microfluidic chips.

Microstructures of MMT/PEG hydrogel nanocomposites with micro-patterns were fabricated by the following procedures. The UV curable PEG hydrogel solution, a mixture of 95 wt.% PEGDA and 5 wt.% 2-hydroxy-2-methylpropiophenone. Then 1 or 2 wt.% MMTs were included to the above PEG solution, respectively. To disperse MMTs in the solution, the mixture vial was placed in sonication bath for 30 minutes. Photo-masks with dot array or other microshaped patterns were prepared by laser cutting according to predesigned pattern shapes. A spot UV irradiation device, Innocure 5000 Lichzent, with optical fiber was used to irradiate UV light to photopolymerize PEG hydrogel solution. Simply assembled substrates with two side jigs were used in fabrication procedures. The two side plates were placed on a bottom glass plate and an upper glass plate was covered on the two side plates. Then the MMT/PEG hydrogel solution was introduced to the space between the bottom and upper glasse plates by capillary action. In fabrication procedures, slide glasses, 1 mm thickness, was used as the side plstes. To prepare a thin and plexible microfluidic chip devices, a polyster thin film, 100 μm thickness, was used as a bottom plate. Then the photo-mask was placed on the upper glass plate. UV light was irradiated through the optical fiber from the above of the photo-mask for 7 seconds 26 mW/cm^2 intensity. After photopolymerization of PEG hydrogel, the substrates were disassembled and the unreacted solution was removed by nitrogen gas blowing. Then the cured microstructures of

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MMT/PEG hydrogel nanocomposites were obtained. The microstructured nanocomposites were exposed under UV light for additional 3 min to prepare fully photopolymerized microstructures of MMT/PEG hydrogel. Then rigid microstructures of the nanocomposites were obtained. The microstructured MMT/PEG hydrogel nanocomposites were characterized by an optical microscope (ICAMSCOPE from Sometech, South Korea) and thermogravimetric analysis (Q50, TA Instruments Inc., USA) within a temperature range of 20 to 550 ℃ and with a heating rate of 10 ℃/min under a nitrogen atmosphere. The microstructured MMT/PEG molds were used to prepare a thin and flexible microfluidic chip. The PDMS solution was placed on the microstructured mold. To prepare a thin microfluidic chip, a doctor blade was used to remove excess PDMS solution on the microstructured mold. Then, the PDMS covered mold was placed an oven at 80 ℃ for 2 hours. The thin PDMS replica, 300-500 µm height, of a microfluidic chip was obtained after peeled-off from the microstructured mold. The PDMS replica was placed on a polyester film, 100 µm thickness, after plasma treatment. The prepared thin and flexible microfluidic chip was examined by sample injection and manipulation.

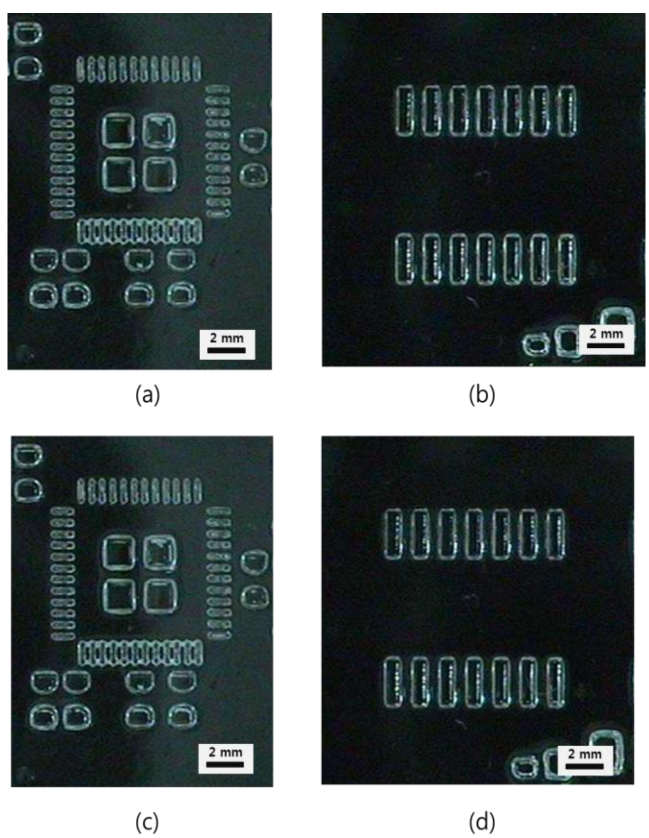

Figure 1: PEG hydrogel microstructures prepared by a simple and rapid UV curing process. (a) and (b) PEG hydrogel microstuctures, and (c) and (d) 2 wt.% MMT/PEG nanocomposite microstructures.

3 RESULTS AND DISCUSSION

Microstructures of PEG hydrogel and MMT/PEG nanocomposites was prepared as shown in Figure 1. Various micropatternes with bar or box shapes were well fabricated on a plate. Microstructures of 2 wt.% MMT/PEG hydrogel were well prepared as shwon in Figure 1c and 1d.

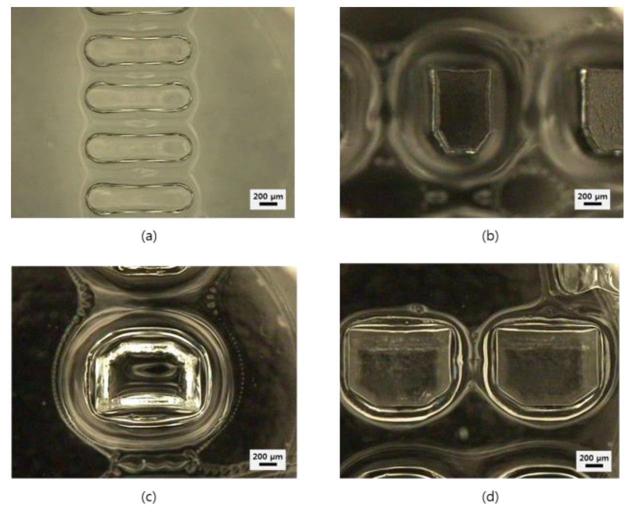

Figure 2: Microscopic characterization of micropattern shapes of PEG hydrogel on a substrate.

Microscopic structure shapes of PEG hydrogel are shown in Figure 2. The fabrication results shows that the present preparation method is available to prepare microstructe of hydrogel material for microarray or microfluidic chip devices (Figure 2).

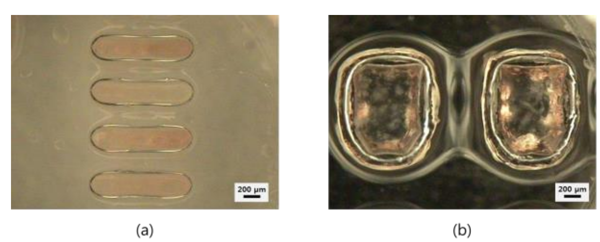

Figure 3: Microscopic characterization of micropattern shapes of 2 wt.% MMT/PEG nanocomposites on a substrate.

To reinforce PEG hydrogle microstructure materials, MMT nanomaterial was introduced to the hydrogel. Then 1 or 2 wt.% MMT was added to the hydrogel material. Although 2 wt.% MMT was included in the PEG hydrogel solution, photopolymerization of PEG hydrogel was well progressed as shown in Figure 3. The microscopic shapes of fabricated microstructures were proper as a micro-mold for nano-bio chip devices.

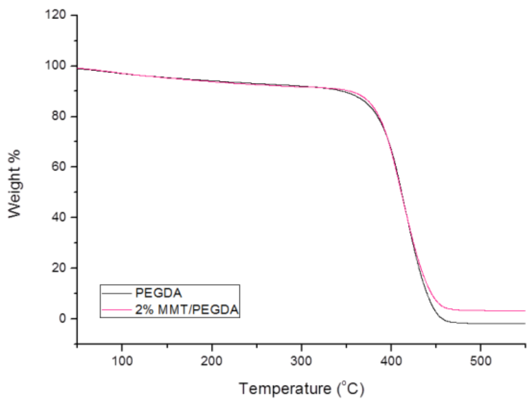

Figure 4: Thermogravimetric analysis of PEG hydrogel and 2 wt% MMT/PEG nanocomposites.

Nanomaterials such as MMTs in nanocomposites might change physical and thermal properties. Thus thermal property of 2 wt.% MMT/PEG nanocomposites was examined to compare the thermal property of PEG hydrogel material. The TGA thermodiagram of 2 wt.% MMT/PEG nanocomposites was similar to the curve of PEG hydrogel materials as shown in Figure 4. Thus, thermal property of MMT/PEG nanocomposites was maintained. The MMT/PEG nanocomposite material was some stable up to 350 ℃. The polymerized backbone chains of PEG material were rapidly decomposed at over 400 ℃. The results showed that MMT/PEG nanocomposites have good thermal property.

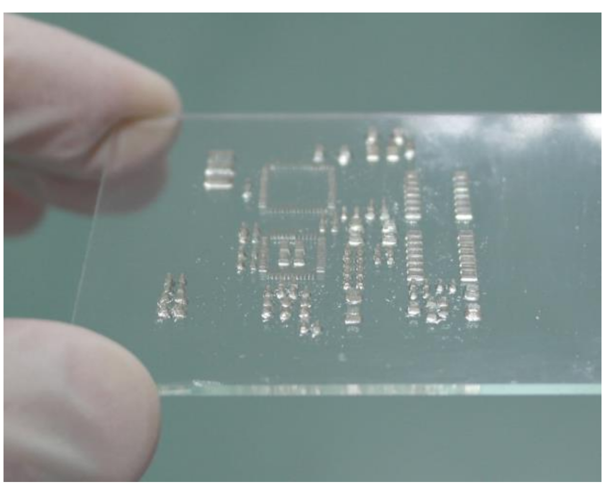

Figure 5: Microfabricated chip mold with 2 wt.% MMT/PEG nanocomposites.

To fabricate a thin PDMS microchip, the microfabricated chip mold with 2 wt.% MMT/PEG nanocomposites was prepaed and used as shown in Figure 5.

Then, PDMS replicas with microstructures were prepared and characterized as shown in Figure 6. In the preparation procedures, MMT/PEG nanocomposite micromold was used. Thus, the sizes and shapes of microstructures on PDMS replicas were very similar to those of MMT/PEG nanocomposites.

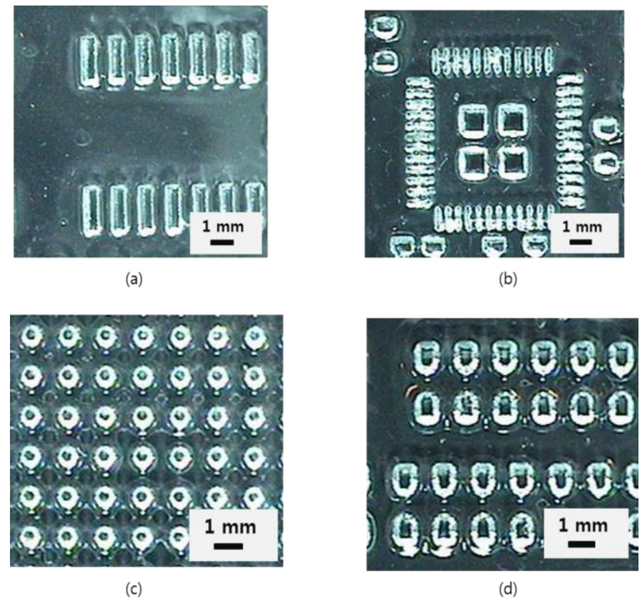

Figure 6: PDMS replica with various micropattern shapes prepared by softlithographic procedures using 2 wt.% MMT/PEG nanocomposites.

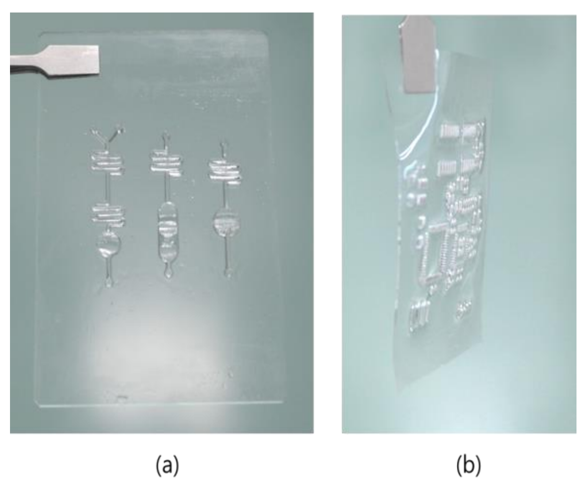

Figure 7: A thin and plexible PDMS microchips prepared using 2 wt.% MMT/PEG nanocomposite micromolds.

Thin and plexible PDMS microchips were prepared using the PDMS replicas as shown in Figure 7. The preparation procedures are simple and productive. Thus, the

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present method is availabe to fabricate various nano-bio chips for medical and nanobio applications.

4 CONCLUSIONS

Biocompatible PEG hydrogel based microstructures were prepared and characterized. Dot-arrays and various shaped PEG and MMT/PEG microstructures were well prepared by simple UV irradiation process. The present method provide a rapid and productive fabrication method for microfluidic chip and microarray chips. Then the MMT/PEG nanocomposite microstures were used as a micromold to fabricate PDMS thin microfluidic chips. With a thin film such as a polyster film, a thin and flexible microfluidic chip device was fabricated. The present fabrication procedures provide a rapid and simple microfluidic chip fabrication for nano-bio chip devices.

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