Immobilization of layered double hydroxides in the fluidic system for nanoextraction of specific DNA molecules
Jem-Kun Chen, Chia-Hao Chan, and Feng-Chih Chang

Citation: Applied Physics Letters 92, 053108 (2008); doi: 10.1063/1.2840175
View online: http://dx.doi.org/10.1063/1.2840175
View Table of Contents: http://scitation.aip.org/content/aip/journal/apl/92/5?ver=pdfcov
Published by the AIP Publishing

Articles you may be interested in
Evanescent field: A potential light-tool for theranostics application

Detection of specific DNA using a microfluidic device featuring tethered poly(N-isopropylacrylamide) on a silicon substrate
Appl. Phys. Lett. 97, 063701 (2010); 10.1063/1.3476356

Effect of the atmospheric pressure nonequilibrium plasmas on the conformational changes of plasmid DNA
Appl. Phys. Lett. 95, 083702 (2009); 10.1063/1.3212739

Effect of pH on the structure of lipoplexes

Single molecule analysis of bacterial polymerase chain reaction products in submicrometer fluidic channels
Biomicrofluidics 1, 034105 (2007); 10.1063/1.2789565
Immobilization of layered double hydroxides in the fluidic system for nanoextraction of specific DNA molecules

Jem-Kun Chen

Department of Polymer Engineering, National Taiwan University of Science and Technology, 43, Sec. 4, Keelung Rd., Taipei 106, Taiwan, People’s Republic of China

Chia-Hao Chan and Feng-Chih Chang

Institute of Applied Chemistry, National Chiao-Tung University, Hsinchu 30043, Taiwan, People’s Republic of China

(Received 31 August 2007; accepted 15 January 2008; published online 8 February 2008)

The purpose of this study was to immobilize inorganic layered double hydroxides (LDHs) on the poly(methylmethacrylate) substrate as the media to extract the specific DNA molecules through fluidic system to enhance the efficiency of extract specific DNA molecules from extremely low concentration in sample solution. LDH immobilized through solvent swelling and plasma treatment on the polymer surface captured the specific DNA molecules lysed from Escherichia coli (E. coli) cells as the target DNA molecules with $2 \times 10^{-4}$ g/l of concentration in sample solution mixed biomacromolecules lysed from human blood. The encapsulated DNA molecules released through dissolving of LDHs by slight acid ($pH=4$–$5$) solution then amplified by polymerase chain reaction (PCR) process through the primers for E. coli cells. The DNA molecules amplified by PCR process were characterized by gel electrophoresis to recognize the existence of E. coli cells. The results show that immobilized LDHs could be regarded as the specific DNA detector for rapid disease diagnosis through fluidic system. © 2008 American Institute of Physics. [DOI: 10.1063/1.2840175]
substrate by air micropump for controlling the fluidic velocity and direction. The DNA molecules suspended in the solution mixed biomolecules were captured rapidly by LDHs from the fluidic system through anion exchange with interlayer anion for 5 min. Then, the unexpected biomacromolecules were removed from the channels of PMMA to approach the nanoextraction by fluidic system. The LDHs would then be removed slowly in the solution with slight acidic $pH=4–5$, then, the encapsulated DNA molecules were released in the fluidic solution. The system was preceded with the fluidic flow in the channel inside the PMMA substrate.

The morphology of PMMA the surface treatment by THF swelling was investigated by atomic force microscope, as shown in Fig. 2. The amorphous surface of PMMA substrate without surface treatment showed the smooth structure with 1.686 nm of the roughness, as shown in Fig. 2(a). THF permeated into the amorphous surface to arise the end of PMMA chains as the pillarlike structure. The THF was removed from the surface. (B) Oxygen plasma treatment was used to chemically modify the surface with arisen end of polymer chains to enhance the adhesion between PMMA surface and LDHs as the THF was removed from the surface. (C) LDHs dispersed in the surfactant solution were spun on the surface treated by oxygen plasma for immobilization by entanglement from the ends of polymer chains. (D) The sample solution mixed target DNA molecules and biomacromolecules lysed from the human blood were injected into the channels for extraction through a simple ion-exchange reaction to form bio-LDH nanohybrids on the PMMA surface in fluidic system. (E) The slight acid solution ($pH=4–5$) was injected into the channels to dissolve LDHs for releasing the encapsulated DNA molecules after the biomacromolecules were removed from the channels by fluidic system.

Figure 3 showed the microfluidic chip system with the channels of 1 mm feature size on PMMA substrate with LDHs. The sample solution mixed target DNA molecules and biomacromolecules lysed from the human blood were injected into the channels for extraction through a simple ion-exchange reaction to form bio-LDH nanohybrids on the PMMA surface in fluidic system. (E) The slight acid solution ($pH=4–5$) was injected into the channels to dissolve LDHs for releasing the encapsulated DNA molecules.
straight channels to enhance the extracted efficiency due to the extreme low concentration. The morphology of the immobilized LDHs on the channels was shown in Fig. 4 with various concentrations of the LDHs in the mixed surfactant solution, which the LDHs were dispersed on the straight channel surface. The 5, 10, 15, and 20 wt % of concentration solution, which the LDHs were dispersed on the straight various concentrations of the LDHs in the mixed surfactant electrophoresis process. Lanes 5, 10, 15, and 20 wt % of concentration for LDHs coated on the PMMA substrate aggregated in the range of 1–50 μm feature size.

The encapsulated DNA molecules lysed from human blood cells and E. coli cells as the target were obtained from the channel in the solution for amplification by polymerase chain reaction (PCR) process to enhance the quality of target DNA molecule for identification. The forward and reverse primer sequences to the target DNA molecule of E. coli cells for amplification through PCR process were 5’-GAGGATTAGATACCGTGTA-3’ and 5’-TTCCCCTACGGTTACCTTGTT-3’. The DNA molecules shorter than 620 base pair obtained from PCR process were the primer or incomplete reacted DNA molecules for PCR process, as shown in the end of the lanes in Fig. 5.

In conclusion, the key feature of this approach is the use of polymer entanglement enhanced by the solvent swelling and plasma treatment to immobilize LDHs on the PMMA surface but buried LDHs in the PMMA. The efficiency of encapsulation of DNA molecules is reduced as the LDHs buried in PMMA substrate due to polymer entanglement surrounding. The results obtained from agarose gel electrophoresis suggest that the immobilized LDHs on the surface could regard as the rapid detector for specific DNA molecule in the human blood by one droplet human blood to approach the LOC system.

FIG. 4. (Color online) Optical microscope images of the channels immobilized LDHs with (a) 5.0, (b) 10.0, (c) 15.0, and (d) 20.0 wt % of concentration in the surfactant solution on PMMA surface.

FIG. 5. Agarose gel electrophoresis diagram of the specific DNA molecules released from LDHs, then amplified by PCR process. Lanes (1) and (2) were positive control. Lanes (3), (4), (5), and (6) were 5.0, 10.0, 15.0, and 20.0 wt % LDHs in surfactant solution for spin coating, respectively.

specific DNA molecules captured from LDHs. Enlarged aggregation of the LDHs (Fig. 4) impeded the exchange of interlayer anions with DNA molecules for 20 wt % of LDHs, caused the similar brightness between lanes (5) and (6). The DNA molecules shorter than 620 base pair obtained from PCR process were the primer or incomplete reacted DNA molecules for PCR process, as shown in the end of the lanes in Fig. 5.

In conclusion, the key feature of this approach is the use of polymer entanglement enhanced by the solvent swelling and plasma treatment to immobilize LDHs on the PMMA surface but buried LDHs in the PMMA. The efficiency of encapsulation of DNA molecules is reduced as the LDHs buried in PMMA substrate due to polymer entanglement surrounding. The results obtained from agarose gel electrophoresis suggest that the immobilized LDHs on the surface could regard as the rapid detector for specific DNA molecule in the human blood by one droplet human blood to approach the LOC system.