Synthesis of Spatially Controlled Responsive Hydrogels via ATRP based PCμCP

Hariharasudhan D. Chirra, J. Zach Hilt
University of Kentucky, Lexington, KY 40506

Statement of Purpose: Spatially functionalized 'smart' micro- and nanohydrogels with specific structure and orientation have tremendous potential in the biomedical field [e.g., diagnostic sensing and therapeutic drug delivery]. Herein, atom transfer radical polymerization (ATRP) based polymerization controlled by microcontact printing (PCμCP), was applied as a platform, to synthesize tunable temperature responsive hydrogels [poly(N-isopropyl acrylamide)-co-poly(ethylene glycol)n dimethacrylate, PNIPAAm-co-PEGnDMA hydrogels]. Spatially controlled XY patterning via μCP, Z controlled ATRP growth, and temperature responsive analysis was completed.

Methods: μCP of a hydrophobic thiol was performed over a gold surface using a replica-mold prepared PDMS stamp. Hydrophilic initiator thiol was then assembled to the non microcontact printed zones. ATRP was then carried out under N_2 atmosphere at 25°C (figure 1). Various crosslinkers of increasing molecular weight and crosslinking density were used for varying reaction times. Characterization was done using FTIR, SEM, AFM and optical microscopy. Responsive studies were carried out using liquid cell AFM imaging and QCM-D.

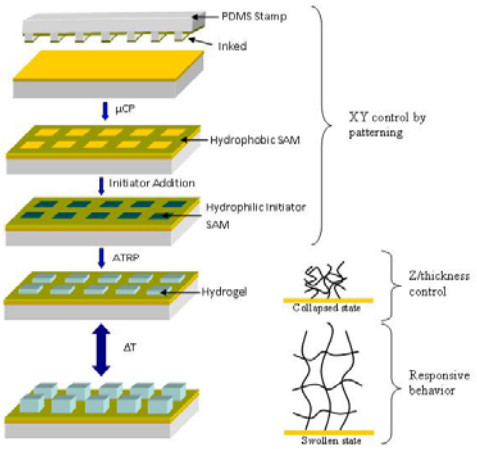

Figure 1. Scheme of ATRP based PCμCP and responsive behavior

Results/Discussion: SEM, and optical microscopy analysis revealed that the patterns were confined only to the initiator square regions as controlled by μCP. Chemical characterization using FTIR confirmed the presence of both NIPAAm monomer and PEGnDMA crosslinker in the hydrogels.

The hydrogel growth for the various crosslinkers and crosslinking density employed was verified with AFM imaging. From figure 2, it can be observed that, in addition to precise spatial XY control, a controlled Z growth was achieved. An increase in molecular weight of the crosslinker employed, resulted in an increase in the growth of the hydrogel for the same reaction time. This can be effectively used for fine tuning the Z spatial growth of these patterns, for fabricating a wide range of hydrogel films for biosensing applications.

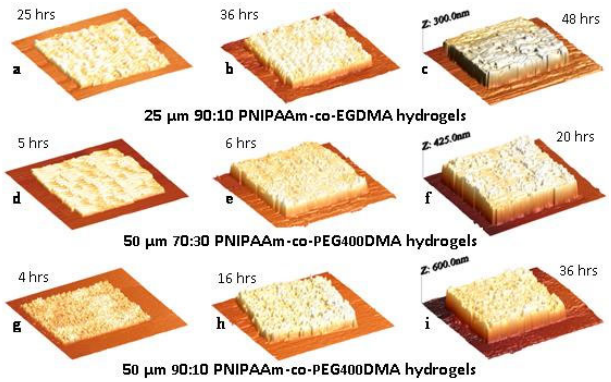

Figure 2. Normalized AFM images of patterned hydrogels showing spatial XY patterns and Z controlled hydrogel growth

When exposed to temperature stimuli in the swollen state, a thickness change was observed for the various hydrogel systems (figure 3). Preliminary QCM-D analysis showed that the crosslinking density and type of crosslinker used had a tunable effect on the response behavior of the hydrogels.

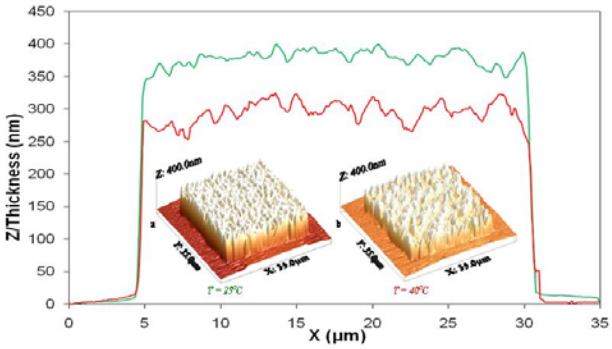

Figure 3. Thickness profile depicting responsive behavior of 25μm 90:10 PNIPAAm-co-PEG400DMA hydrogel at 40°C (green), and 25°C (red), and the respective normalized 3-D AFM images (inlays a & b)

Conclusions: We have successfully demonstrated a route for forming spatially controlled patterned hydrogel surfaces using μCP and ATRP. While μCP was effective for precise XY patterning, ATRP proved to be an accurate tool for obtaining very thin hydrogel films. Results show that these hydrogels respond to environmental stimuli (temperature). We have also shown that the molecular weight of the crosslinker and crosslinking density has a tunable effect on their response behavior. Combinatorial AFM and QCM-D analysis is currently employed to study the responsive controlled drug release using these systems. ATRP based PCμCP will be applied to integrate 'smart' hydrogel systems into various micro- and nanodevices for potential biosensing and therapeutic drug delivery applications.