Design and Application of Optical Polymers

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Abstract

Organic materials are becoming increasingly popular in the fabrication of optical devices. While traditional materials such as semiconducting materials, glass, and crystals can be obtained with very well characterized properties, organic materials have attractive properties that are desirable for applications in cross-disciplinary fields. Polymer materials provide a large degree of customizability, both in their chemical and mechanical properties. Many polymers are also biocompatible and are desired for the growing interdisciplinary research into biomedical devices and microfluidics. Here within, optical principles and polymer materials are combined to produce novel structural materials with applications in printing, microfluidic flow, and biological characterization.

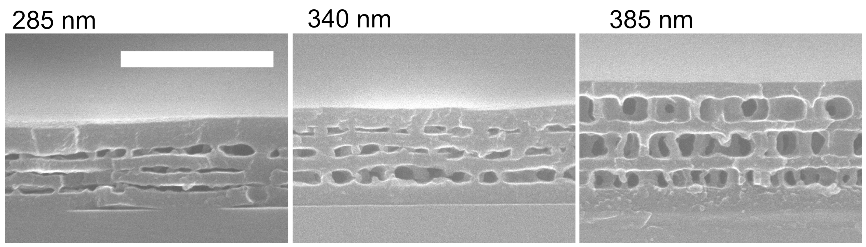

Figure 1: SEM cross section of 16 kDa polystyrene porous films. The films were crosslinked with different wavelengths of light as indicated. Scale bar is 1 µm.

The first part of this thesis investigates a phenomenon for producing porous polymer thin films using the standing wave interference of light and explores the mechanisms behind the process. Interference within polymer films selectively crosslinks the films according interference pattern. The films are then exposed to a weak solvent resulting in plasticization and internal cracking of the non-crosslinked regions. The final structure produced is a polymer film with photonic crystal behavior and periodic porous layers determined by the standing wave interval, Fig. 1. It is shown that this method in general and can be applied different types of polymer such as: polystyrene, polycarbonate, and poly(methyl methacrylate). The porous layers are formed by solvent induced crazing guided by the standing wave interference.

Two applications of this process are explored. The first is inkless color printing. Custom stencils can be used to make images of different color on different types of substrate. High resolution printing was achieved using Micro-LED to print images at with micron level resolution, Fig. 2. Control of feature size was used to influence the final color of the films.

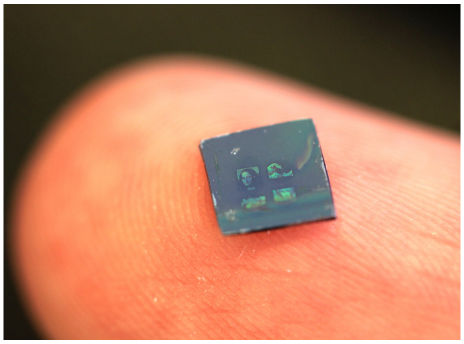

Figure 2: Micron level illumination was applied to polymer films to make high resolution structural color images.

The process was also applied to the design of microfluidic channels. By using different wavelengths, the pore size within the porous layers can be varied. This provides an alternative way of producing microfluidic devices where the channels can be designed via stencils. The effect of the crosslinking wavelength on the capillary flow properties of the film was examined and it was shown that the flow rate is related to the periodic structure.

The second part of the thesis describes a method for producing optically responsive polymer substrates that can monitor the beating of heart cells via deformation of the substrate, Fig. 3. The optically responsive substrates provide a new method of drug screening which can assist with higher throughput screening of novel pharmaceuticals.

The polymer of choice in the study was polydimethylsiloxane (PDMS), a silicon polymer well known for its processibility. Diffraction gratings were fabricated from PDMS using a diffraction grating mold. The soft gratings were coated with platinum to allow adhesion of cells. Heart cells from rats were seeded on the substrate. The beating of the heart cells was observed via the change in reflected light from the substrate due to deformation of the surface. Proof of concept of the substrate was provided by observing the change in beating rate of heart cells after a drug was applied to the system.

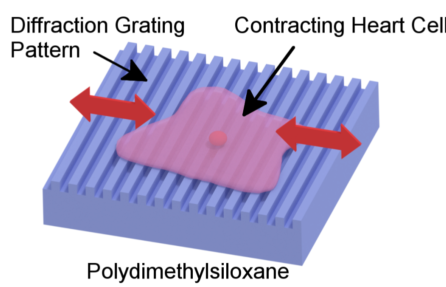

Figure 3: Soft PDMS diffraction grating substrate responds to beating cells