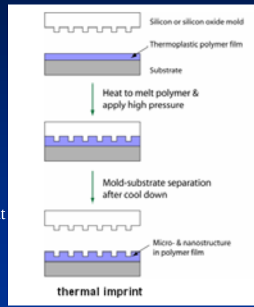
Polymer Semiconductor Patterning by Nanoimprint Lithography

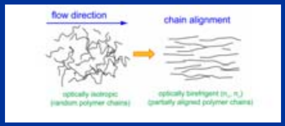
Background & Abstract

Polymer semiconductor patterning by nanoimprint lithography. Polymer semiconductors are novel materials that have a wide range of applications in organic light-emitting device, organic thin-film transistor and organic solar cells. For device application, we need to pattern polymer semiconductors into various shapes. Traditional photolithography is not compatible with polymer semiconductors. Therefore instead we will pattern them using nanoimprinting. Nanoimprinting is the mechanical process of creating nanometer scale patterns on any given polymer. This process is low-cost, high throughput, yields high resolution and is a non-destructive method of patterning functional polymers such as P3HT. After preheat treating and patterning, we will use analytical tools, such as absorption spectroscopy and photoluminescence spectroscopy to analyze the material properties of the patterned polymer semiconductor.

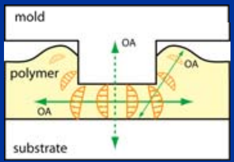


How Nanoimprint Leads to Polymer Chain Orientation:

- During nanoimprint, polymer melt is forced to flow to fill up mold cavities
- During melt flow, polymer chains will be stretched and aligned
- Polymer chain alignment is frozen into polymer microstructures at the cool down stage of the nanoimprint



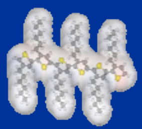
Schematic of polymer chain alignment induced by polymer melt flow



Polymer melt flow pattern in nanoimprint

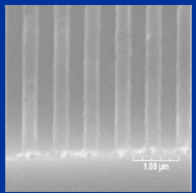
P3HT Introduction:

- Poly (3-hexylthiophene) (P3HT) is a semiconducting polymer.
- P3HT is the material of choice for organic thin-film transistors and organic solar cells.



Poly-3-hexylthiophene (P3HT)

P3HT molecular structure



Scanning electron microscope image of P3HT grating patterned by nanoimprint

Material Processing:

1[st] Phase: Spin Coat a layer of liquid Poly-3-Hexylthiophene onto a glass substrate.

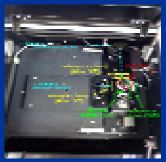
2[nd] Phase: Pretreatment of samples at a respective temperature

3[rd] Phase: Placed in imprinter with a nanoimprinted mold for an alotted time period

4[th] Phase: Cooled and separated from the mold.

Material Characterization:

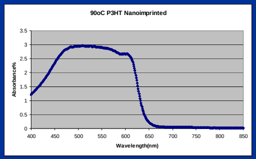
Absorption spectrum: Acquired by UV-Vis-NIR-Spectrophotometer through an absorbance scan.

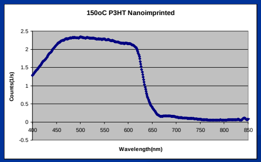


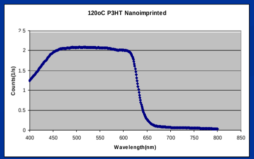
Photoluminescence spectrum: Acquired by Spectrofluorometer through an emission scan.

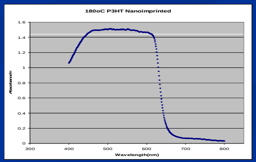
Both absorbance and photoluminescence spectra are obtained for P3HT gratings nanoimprinted at 90°C, 120°C, 150°C and 180°C.

Absorption Spectra:

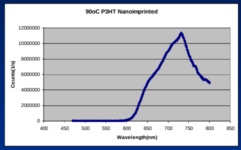


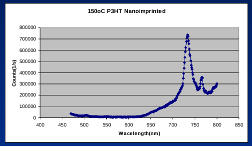


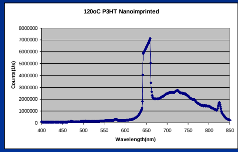


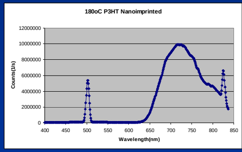


Photoluminescence Spectra:









Analysis:

- UV-vis-NIR absorbance spectrum does not show much change in P3HT samples nanoimprinted at different temperatures
- The photoluminescence spectra varies significantly for P3HT samples nanoimprinted at different temperatures, indicating nanoimprint temperature has impact on polymer chain orientation
- Detailed analysis of the emission spectra variation will be analyzed to identify the inter-chain interaction modes for P3HT structures patterned at different temperature

Conclusion:

- P3HT grating is successfully patterned by nanoimprint
- Polymer chain can be reoriented and aligned after nanoimprint
- Polymer chain reorientation modifies its optical properties, as demonstrated by the photoluminescence spectra
- Temperature at which nanoimprint is performed has clear impact on the optical properties of the P3HT microstructures
- Nanoimprint is a powerful technique to manipulate polymer chain orientation to fine-tune material properties

Future Work:

- Characterize the physical properties of polymer microstructures with chain-ordering
- Control the degree of chain extension and alignment by mold pattern design
- Long-term evolution of the chain morphology in thin film'
- Application in polymer electronics such as OTFT, OLED and OPV

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