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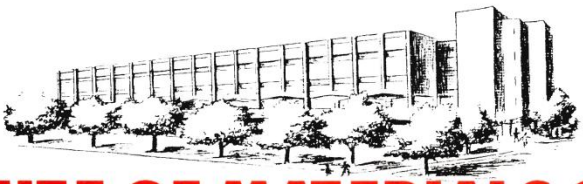

INSTITUTE OF MATERIALS SCIENCE

POLYMER PROGRAM SEMINAR

"Field Assisted "Z" Orientation of Functional Films Using a Continuous Roll to Roll Process"

Prof. Miko Cakmak
University of Akron

Friday, April 17, 2015
11:00 AM, IMS Room 20

Electric, Magnetic and Thermal gradient fields are three methods used in Field Assisted Self Assembly (FASA) of polymer blends, block copolymers, liquid crystals and polymer nanocomposites to produce films with preferential enhancement of properties in thickness direction. For potential applications in flexible electronics, membranes, supercapacitors, fuel cells, photovoltaic's where such enhancement is needed, a large scale manufacturing platform has been lacking.

At National Polymer Innovation Center we developed a novel roll to roll process to achieve "Z-direction" alignment of nanostructural units (phases, particles) [i] . This 70 ft. line was designed to cast desired thickness of liquid such as a monomer and/or polymer solution up to 6" wide on a flexible substrate. The substrate is then carried by pretensioned steel belt through an electric field application zone which consists of secondary roller electrode sitting on top of the steel belt with the solution cast film passing between the two electrodes. In this zone, DC, AC or a biased AC fields with sufficient potential difference applied to organize the phases or nanoparticles along nano "columns" oriented in "Z" thickness direction provided there is sufficient dielectric contrast between them. If orientation and self-assembly through magnetic field is desired a built in electromagnet is capable of applying magnetic fields up to 2.2 T is used. This line also contains a movable UV lamp which can be used to freeze the structure of required morphology using photocurable resin and could also be used to etch one phase of a polymer blend or block copolymer after electric field or magnetic field application zones.

The final tool that is built on this machine is the Thermal Alignment zone. It is designed to apply a "line of heat" oriented transverse to the line direction at 9 different zones. In each zone the material may be subjected to a temperature gradient in the machine direction through a successive heating and cooling units. It has been used to orient cylindrical phases of block copolymers in the thickness direction[ii]. This is potentially useful when these phases can be functionalized or etched away for selective membrane applications.

We will also discuss the characterization of these flexible functional films with custom designed metrology tools including real time measurement system that tracks all critical parameters during solidification of coatings/films. Kinetics of electric field alignment of particles and polymer chains is studied through integrated real time birefringence measurement, to determine various parameters effecting the orientation of particles[iii]/phases inside a polymeric film[iv].

In this presentation, we will summarize highlights of research carried out to produce unique functional film including those with high through thickness electrical conductivity with no conductivity in the plane while exhibiting high transparency, films with high ionic conductivity, and films enhanced dielectric permittivity for capacitor applications.

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[i] **"Field assisted self-assembly for preferential through thickness ("z-direction") alignment of particles and phases by electric, magnetic, and thermal fields using a novel roll-to-roll processing line"**, Cakmak, Miko; Batra, Saurabh; Yalcin, Baris, Polymer Engineering & Science 55, pp.34-36 (2015)

[ii] **Large-Scale Roll-to-Roll Fabrication of Vertically Oriented Block Copolymer Thin Films"** Singh, Gurpreet; Batra, Saurabh; Zhang, Ren; Yuan, Hongyi; Yager, Kevin G.; Cakmak, Miko; Berry, Brian; Karim, Alamgir ACS Nano (2013), 7(6), 5291-5299

[iii] **"Directed Electric Field Z-Alignment Kinetics of Anisotropic Nanoparticles for Enhanced Ionic Conductivity**" S. Batra, E. Unsal and M. Cakmak Advanced . Funct. Mater. 2014, 24, 7698–7708

[iv] **"Real-time measurement system for tracking birefringence, weight, thickness, and surface temperature during drying of solution cast coatings and film**" Unsal, E.; Drum, J.; Yucel, O.; Nugay, I. I.; Yalcin, B.; Cakmak, M. *The Review of scientific instruments* **2012**, *83*, 025114

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