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Soft-Confinement Pattern-Induced Nanoparticle Segregation in Thin Films (SCPINS)

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ABSTRACT:

The modification of nanoparticles with polymer ligands has emerged as a versatile approach to control the interactions and organization of nanoparticles in polymer nanocomposite materials. Besides their technological significance, polymer-grafted nanoparticle (PGNP) dispersions have attracted interest as model systems to understand the role of entropy as a driving force for microstructure formation. For instance, densely and sparsely grafted nanoparticles show distinct dispersion and assembly behaviors within polymer matrices due to the entropy variation associated with conformational changes in brush and matrix chains. Here we demonstrate how this entropy change can be harnessed to drive well dispersed pmma-grafted gold nanoparticles in PMMA homopolymer matrix into spatially organized domain structures on submicrometer scale within topographically patterned thin films.[1] This selective segregation of PGNPs is induced by the conformational entropy penalty arising from local perturbations of grafted and matrix chains under confinement. The efficiency of this particle segregation process within patterned mesa−trench films can be tuned by changing the relative entropic confinement effects on grafted and matrix chains. More recently, we show that spatially controlled organization of self-assembled nanoparticle-brush-clusters (NPBCs) can be generated via topographical soft-pattern confinement. This blend system is composed of polystyrene-grafted titanium dioxide nanoparticles (PS-g-TiO¬2) embedded in polystyrene (PS) thin film (~90nm) matrices. The highly selective segregation of the NPBCs in mesa regions of the patterned polymer thin films is induced by minimization of the total free energy of the grafted chains. The extent of particle clusters segregation into patterned mesas is quantified by the partition coefficient K, which reflects the particle density ratio among patterned mesa and trench regions. Finally, we show the effect of enthalpic interactions on the patterned segregation is inherently 2D by introducing a chemically dissimilar polymer matrix from the nanoparticle brush polymer.[2] The versatility of topographic patterning, combined with the compatibility with a wide range of nanoparticle and polymeric materials, renders SCPINS (soft-confinement pattern-induced nanoparticle segregation) an attractive method for fabricating nanostructured hybrid films with potential applications in nanomaterial-based technologies.

BIOGRAPHY:

Alamgir Karim obtained his Ph.D. in Physics from Northwestern University in Illinois in 1992. He did a post-doc in Chemical Engineering at University of Minnesota till 1993, before joining the National Institute of Standards and Technology (NIST) in Gaithersburg, Maryland. He was Group Leader of Polymer Blends, Combinatorial Methods and Nanomaterials Group at NIST. Since 2009, he is Goodyear Chair Professor of Polymer Engineering, and Co-Director, Akron Functional Materials Center at University of Akron. He has held administrative positions of Associate Dean of Research and Institute Director. His areas of interest and research include polymer thin films, surfaces and interfaces. Polymer systems of interest include nanoparticle polymer systems, patterning polymer films, polymer blends phase separation, polymer thin film nanocomposites, elastomers based systems, block copolymers thin film ordering, as well as polymer thin films and processing methods for functional applications. He has published over 200 papers with an h-index of 60 and edited several books in these areas of polymer research, and organized several international conferences on these topics. He is a Fellow of the American Physical Society (APS) as well as Fellow of American Association for the Advancement of Science (AAAS) and recipient of Keck Foundation Award. He is presently Dow Chair Professor, and Director of Materials Science and Engineering Program and Director of Polymer and Soft Matter Center at University of Houston.