Development and characterization of phase-separated PS/PMMA nanostructured substrates for cellular adhesion

Siena Wong, Dr. Fabio Variola (Faculty supervisor)
Mechanical Engineering, University of Ottawa

uOttawa

Surface Nanoengineering Lab

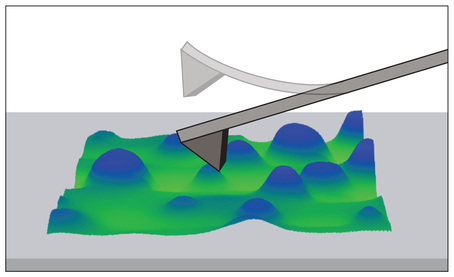
Introduction

In the biomaterials field, it is now well known that the nanoscale features of surfaces influence cellular behaviour. Cells respond to physicochemical properties of surfaces, such as the nanotopography and stiffness. In particular, when a material's surface properties closely resemble those of the cell's extracellular matrix (ECM), cellular events such as cell adhesion and growth are enhanced.

Polystyrene (PS) and polymethyl methacrylate (PMMA) blends are one group of materials which undergo simple self-assembly due to their immiscibility. Starting with these two polymers, a range of surfaces can be engineered by tuning the blend ratio and annealing conditions. This offers a simple yet efficient pathway to engineer the ideal substrate.

Methodology

Thin films were formed by spin casting blends of PS and PMMA from 2% w/v toluene solutions onto glass slides where phase separation occurred spontaneously. Annealing was performed in a vacuum oven at 160 °C followed by quenching in DW at room temperature. Surface characterization was performed using atomic force microscopy (AFM) with a WITec Alpha 300 integrated microscope equipped with a cantilever of spring constant 0.2 N/m. Contact mode was used to determine the topography while digital pulsed force mode (DPFM), an intermittent contact mode, was used to measure stiffness.



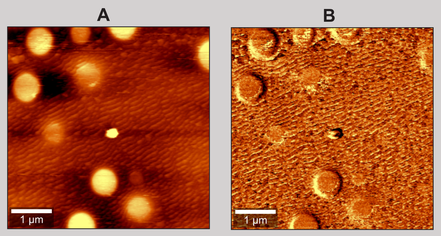
AFM involves using a micrometer-scale tip to scan over the surface of the material to map its topography and probe its physical response to applied force (e.g. surface stiffness). In this project, the drawback of Contact AFM is that it cannot differentiate between two variations in surface chemistry or physical characteristics.

Results

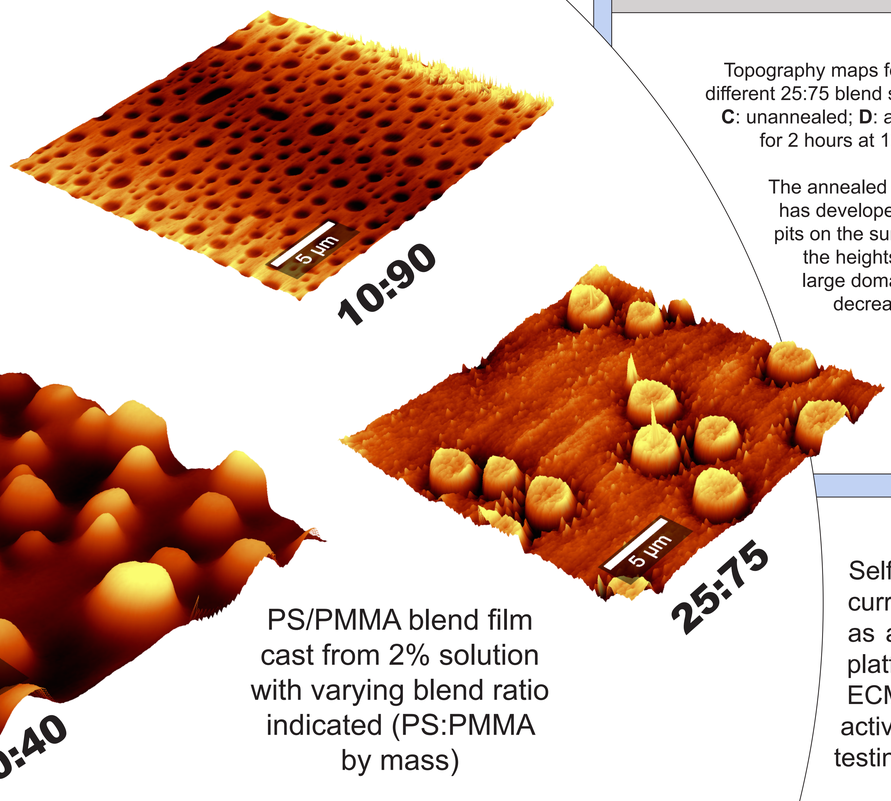
Porous and granular morphologies were obtained in a range of sizes from the micrometer to nanometer-scale by only varying the blend ratio between PS and PMMA.

The characterization method used does not indicate which polymer formed the domain and which the matrix, however topographic variations indicate phase separation between PS and PMMA which corresponds to results previously obtained.

The stiffness resulted to be similar for both polymers. Literature suggests that different degrees of polar interactions still exist between the 2 phases which can be investigated for its impact on cellular activity.



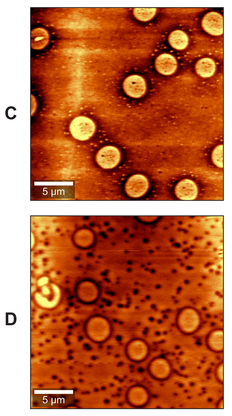
DPFM colour maps for a 50:50 blend sample. **A:** Topography map; **B**: Stiffness map; the nearly uniform colour for B indicates similar stiffness throughout, even where two different phases are encountered when compared to A.

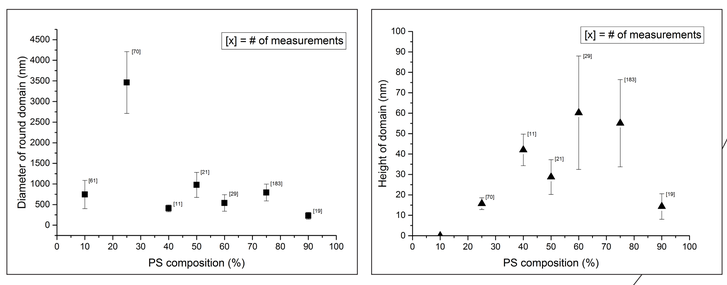


PS/PMMA blend film cast from 2% solution with varying blend ratio indicated (PS:PMMA by mass)

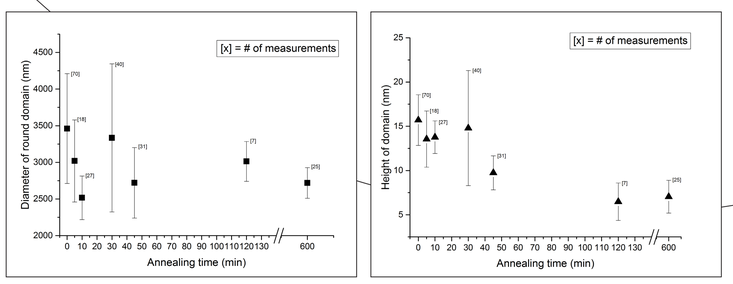
Topography maps for two different 25:75 blend samples. **C**: unannealed; **D**: annealed for 2 hours at 160°C.

The annealed sample has developed more pits on the surface and the heights of the large domains are decreased.





Graphs of measured diameter and height values as blend ratio changes for unannealed surfaces. Heights were measured above the baseline height thus the height of the pitted morphology of the 10:90 blend was nil. Similarly, pure PS and pure PMMA blends did not show any phase-separated domains due to their uniform compositon



Graphs of measured diameter and height values as annealing time was increased for PS/PMMA 25:75 blends annealed at 160°C. As anneal time was increased, a flattening of the domains was observed. The large variation in height at the 30 min suggests that the bulk of the transition starts to occur at this timepoint. According to literature it is also expected that the 2 polymers will demix over time.

Conclusion

Self-assembling polymers are currently being investigated as a method to generate 3-D platforms which can mimic the ECM and support *in-vitro* cell activity for applications in drug testing and tissue engineering.

Self-assembling 2-phase materials allow the creation of micro- and nano-scale features that can be tuned by controlling treatment parameters. A wide range of domain sizes were obtained in relation to changing blend composition. Development of the surface also occurs with thermal annealing. The accessibility and low cost of the base materials, PS and PMMA, make this a feasible approach to surface engineering. As well, the ease of fabrication of a range of different topographies are the main advantages to investigating these surfaces as potential cell substrates.

References

Ton-That, C.; Shard, A.G.; Teare, D.O.H.; Bradley, R.H. XPS and AFM surface studies of solvent-cast PS/PMMA blends. Polymer, 2001, 42, 1121-1129.

Walheim, S.; Boltau, M.; Mlynek, J.; Krausch, G.; Steiner, U. Structure Formation via Polymer Demixing in Spin-Cast Films. Macromolecules,1997, 30, 4995-5003.

Acknowledgements

Thanks to Dr. Variola, Alex Steeves for the technical assistance with AFM, and the rest of the SNL team.

Contact

Siena Wong: swong122@uottawa.ca

Dr. Variola's Surface Nanoengineering Lab (SNL): http://www.variolasnl.com