Nanohardness and Elastic Modulus Depth Profiles of Solvent Soaked Polycarbonate

Polymers are prized for their flexibility, high strength to weight ratio, and ability to form complex geometries. These traits have made them indispensable for products we use every day. However, these desirable properties present in the raw materials do not always make it to the final product. Polymer properties are affected by processing methods, like injection molding or compounding, and by environmental effects such as UV light radiation or solvent exposure. Thorough testing and investigation are necessary to ensure that polymers can withstand demanding usage such as high or frequent load bearing or unpredictable environmental exposure.

Polymers like polycarbonate can swell or absorb surrounding fluid when immersed in a fluid for a prolonged period of time. Depending on the amount of swelling, the mechanical properties of the polymer can change dramatically. To quantify the effect of fluid absorption has on polycarbonate, three sample pieces of polycarbonate were soaked in different solvents while a fourth piece was kept dry as a control. The samples then underwent nanoindentation depth profiling testing using Ebatco's G200 Nanoindenter. An image of the G200's main components is shown in Figure 1.

Figure 1. G200 Nanoindenter inside its environmental enclosure.

The G200 Nanoindenter is capable of performing quasi-static nanoindentation as well as a dynamic nanoindentation using a technique called Continuous Stiffness Measurement (CSM). In quasi-static nanoindentation, contact stiffness at the maximum depth is calculated and mechanical properties such as Young's Modulus and nanohardness can be determined using the well-established Oliver & Pharr Method. In dynamic nanoindentation tests, the CSM technique allows for continuous measurements of contact stiffness as the displacement increases, which allows for mechanical property depth profiling testing at much faster speeds than the quasi-static nanoindentation approach.

In this study, the effects of exposure to different solvents on the mechanical properties of polycarbonate were investigated using the CSM technique. One sample was tested as-received, while three other samples were tested after having been soaked for 96 hours in water, denatured alcohol, and acetone respectively. To obtain the Young's Modulus from nanoindentation data, a Poisson ratio of 0.37 was assumed for all polycarbonate samples. Figure 2 shows the nanohardness and Young's Modulus depth profiles.

It can be seen that the nanohardness and Young's Modulus values of the solvent-soaked samples were significantly lower than that of the control sample. Softening and reduction of the mechanical strength in polymers is a known effect of solvent absorption. Absorbed solvent molecules push the polymer chains apart and weaken the bonding between them. Further, the hardness and modulus exhibit lower values at the surfaces of the samples and reach plateaus around depths of 2 µm displacement. This indicates the surface of the samples absorbed significantly more solvent than the inner portions. The plateaued values of the mechanical properties suggest differences in the levels of interaction between solvent and polycarbonate molecules. Acetone was found to have the strongest interaction with polycarbonate, followed by alcohol and water.

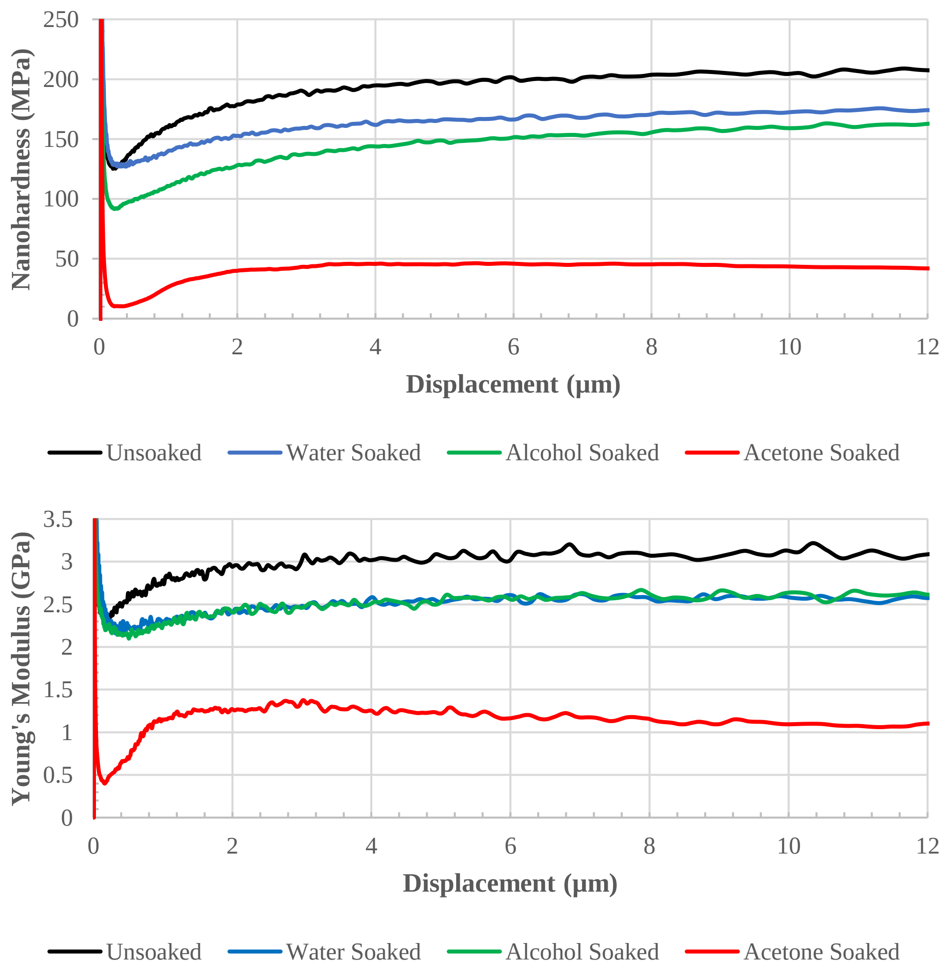

Figure 2. Nanohardness (top) and Young's Modulus (bottom) of unsoaked and solvent soaked polycarbonate samples as a function of indentation displacement into the specimen.