Ideal Glasses and New Materials

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Glasses are generally regarded as highly disordered and the idea of “controlling” molecular packing in glasses is reasonably met with skepticism. However, as glasses are non-equilibrium materials, a vast array of amorphous structures are possible in principle. Physical vapor deposition (PVD) allows a surprising amount of control over molecular packing in glasses and can be used to test the limits of amorphous packing in two ways. PVD can prepare glasses that approach the limits of the most dense and lowest energy amorphous packings that are possible. In some cases, PVD glasses have the properties expected for supercooled liquids that have been equilibrated for thousands of years. The activation barriers for rearrangements in these materials are very high, giving rise to high thermal and chemical stability. These materials also have unprecedented mechanical properties and secondary relaxation processes are strongly suppressed. In addition, PVD allows control over anisotropic packing in glasses. For rod-shaped molecules, for example, glasses can be prepared in which the molecules have a substantial tendency to stand-up or lie-down relative to the substrate. As these materials have applications in organic electronics, an important question is: How much anisotropic order can be added to a glass without destroying key technological advantages such as macroscopic homogeneity? The high density and anisotropic packing of PVD glasses can be explained by a mechanism that depends upon surface mobility and is “anti-epitaxial” as structure is templated by the top surface rather than by the underlying substrate.