Influence of particle geometry on the elastic properties of layer-by-layer assembled composite thin films

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ABSTRACT

Composite thin films were created using linearly grown layer-by-layer (LbL) assembled structures. Films were created by pairing long-chained polymers with nanoparticles of three different geometries: rod-like, thin plate, and spherical. The volume fraction of the LbL films was varied by using multiple layers of two different polymers or by varying the polymer concentration of the precursor solution. The mechanical properties of these films were measured using Brillouin light scattering. Although the addition of higher stiffness particle typically increases the modulus of the composite film, the effects on in-plane vs. out-of-plane modulus depend heavily on the geometries and volume fraction of the nanoparticles. For rod-like nanoparticles, the in-plane modulus increases linearly and the out-of-plane modulus increases sublinearly with increasing particle amount. In one case, the out-of-plane modulus even drops off at high particle loading. For thin-plate particles, the in-plane and out-of-plane moduli both increase linearly up to 10% particle loading and then level to a plateau. For spherical nanoparticles, the out-of-plane moduli are higher than that of in-plane moduli. The modulus increases linearly with volume fraction of particles for smaller size particles, but remain constant for the large particle size. The modulus is also inversely proportional to the particle size. The data is interpreted in terms of LbL structure, nanoparticle arrangement, adhesion between layers, layer thickness, and layer interpenetration.