S2-P003

High aspect ratio wrinkled patterns on polymers by glancing angle deposition

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Instability of a thin film attached to a compliant substrate often leads to emergence of exquisite wrinkle patterns with length scales that depend on the system geometry and applied stresses. However, the patterns that are created using the current techniques in polymer surface engineering, generally have low aspect ratio of undulation amplitude to wavelength, thus, limiting their application. Here, we present a novel and effective method that enables us to create wrinkles with a desired wavelength and high aspect ratio of amplitude over wavelength as large as to 2.5:1. First, we create buckle patterns with high aspect ratio of amplitude to wavelength by deposition of an amorphous carbon film on a surface of a soft polymer poly(dimethylsiloxane) (PDMS). Amorphous carbon films are used as a protective layer in structural systems and biomedical components, due to their low friction coefficient, strong wear resistance against, and high elastic modulus and hardness. The deposited carbon layer is generally under high residual compressive stresses (～1 GPa), making it susceptible to buckle delamination on a hard substrate (e.g. silicon or glass) and to wrinkle on a flexible or soft substrate. Then, we employ glancing angle deposition (GLAD) for deposition of a high aspect ratio patterns with amorphous carbon coating on a PDMS surface.

Using this method, pattern amplitudes of several nm to submicron size can be achieved by varying the carbon deposition time, allowing us to harness patterned polymers substrates for variety of application. Specifically, we demonstrate a potential application of the high aspect wrinkles for changing the surface structures with low surface energy materials of amorphous carbon coatings, increasing the water wettability.

Keywords: Wrinkle, Ion Beam, GLAD