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Controlled Formation of Surface Wrinkles and Folds on Poly (dimethylsiloxane) Substrates Using Plasma Modification Techniques

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Surface engineering plays a significant role in fabricating highly functionalized materials applicable to industrial and biomedical fields. Surface wrinkles and folds formed by ion beam or plasma treatment are buckling-induced patterns and controlled formation of those patterns has recently gained considerable attention as a way of creating well-defined surface topographies for a wide range of applications. Surface wrinkles and folds can be observed when a stiff thin layer attached to a compliant substrate undergoes compression and plasma treatment is one of the techniques that can form stiff thin layers on compliant polymeric substrates, such as poly (dimethylsiloxane) (PDMS).

Here, we report two effective methods using plasma modification techniques for controlling the formation of surface wrinkles and folds on flat or patterned PDMS substrates. First, we show a method of creating wrinkled diamond-like carbon (DLC) film on grooved PDMS substrates. Grooved PDMS substrates fabricated by a molding method using a grooved master prepared by photolithography and a dry etching process were treated with argon plasma and subsequently coated with DLC film, which resulted in the formation of wrinkled DLC film aligning perpendicular to the steps of the pre-patterned ridges. The wavelength and the amplitude of the wrinkled DLC film exhibited variation in the submicron- to micron-scale range according to the duration of argon plasma pre-treatment. Second, we present a method for controlled formation of folds on flat PDMS substrates treated with oxygen plasma under large compressive strains. Flat PDMS substrates were strained uniaxially and then treated with oxygen plasma, resulting in the formation of surface wrinkles at smaller strain levels, which evolved into surface folds at larger strain levels. Our results demonstrate that we can control the formation and evolution of surface folds simply by controlling the pre-strain applied to the substrates and/or the duration of oxygen plasma treatment.

Keywords: plasma treatment, polymers, surface patterns, wrinkles, folds