Formation of aligned wrinkling patterns by selective adhesion

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Wrinkling is an extensively encountered phenomenon in nature. Consider for example the wrinkles of the human skin, the hierarchical folding patterns forming the mountains or the cells crawling on a soft substrate. In all these cases, wrinkles form when a compressive force acts on a rigid skin that rests on a softer foundation. This phenomenon was fully understood and transposed to artificial systems only recently. Systems made up of thin stiff skins attached to a thick elastic (e.g., polydimethylsiloxane) or a thin viscoelastic (e.g., polystyrene) foundation supported on a thick substrate were hugely investigated. Different ways were reported in the literature to forming the skins. They were either formed by making denser the topmost part of the foundation by some physical treatment (plasma, ultraviolet/ozone treatment) or by depositing a thin layer of metal. In these systems, bi and trilayers, wrinkles with random orientation could be produced on applying a thermal treatment on the samples. These wrinkles are in both cases attribute to the uniform compressive stress that arises from the considerable mismatch between the thermal expansion coefficients of the different soft and rigid layers.

A control of these wrinkling morphologies could be extremely useful in a large number of applications in contrasting domains such as diffraction gratings, mechanical strain sensors, microfluidic devices, cell culture surfaces … Several strategies were proposed to orient the wrinkles. Except for the trivial use of a specific topography with grooves that could orient the waves, all the strategies reported in the literature are based on the anisotropic stress induced by the patterning of the topmost skin of the multilayer.

In this communication, we will describe an original method to control these wrinkles. Instead of patterning the skins as previously reported in the literature, we use chemically patterned substrates prepared by microcontact printing with highly contrasted adhesion properties. A change of surface free energy (from bare gold to methyl terminated surface) induces drastic modification of the wrinkles. A low energy (adhesion) substrate suppresses almost completely the wrinkling process. This is the first evidence about the major role of substrate/foundation interface on wrinkling. In addition, we bring new insights about the mechanism responsible of wrinkling formation, a controversial issue in the recent literature.

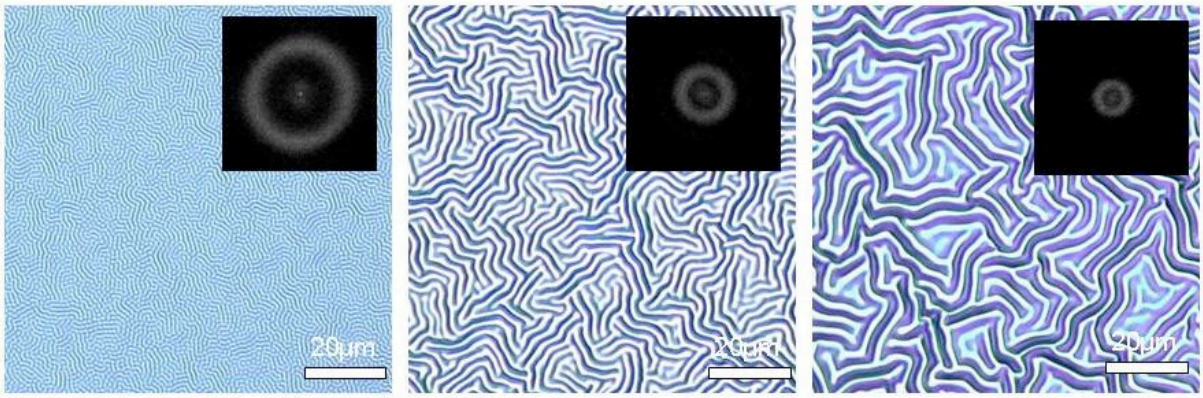

Fig.1: Wrinkling on homogeneous substrates

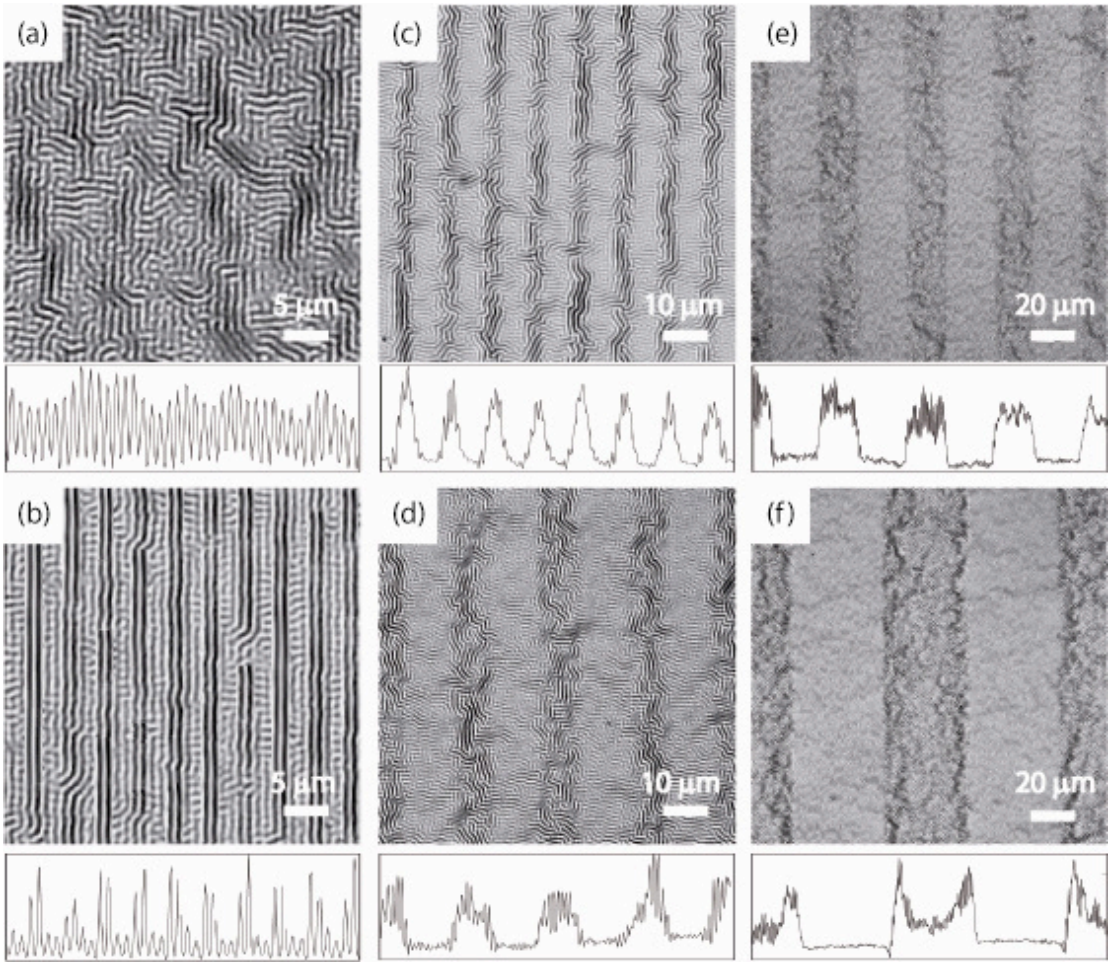

Fig. 2 : Wrinkling on heterogeneous substrates