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On the Formation of an Ordered Array of Holes in a Polymer Film: What can Dew Formation Teach Us?
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Systems driven far from equilibrium have a remarkable tendency to produce very ordered structures. Such ordered structures have been observed in many a situation where the material subjected to an external perturbing field responds to this perturbation by creating ordered periodic structures. We have used a system driven far from equilibrium to create structures that have subwavelength dimensions and can be made reproducibly. Ordered subwavelength structures are ubiquitous in nature. However, it is only recently that ordered macroporous materials with pore dimensions on the order of the wavelength of visible light have attracted much greater attention. This interest has been in large part due to their anticipated optical properties. We have demonstrated the use of a simple and robust method that uses evaporative cooling for the formation of ordered structures with dimensions that are controllable in a systematic way ranging from about $0.2\mu\text{m}$ to $20\mu\text{m}$. This method uses the formation, and subsequent crystallization of “breath figures,” to create the structures. When a cold solid or a liquid surface comes in contact with moist air, moisture condenses on the surface, forming water droplets that grow with time to form patterns on the surface. Such phenomena, referred to as “breath figures,” have been studied in detail, starting with the early works of Lord Rayleigh, Baker and Aitken, and more recently by Knobler and co-workers who demonstrated that it was possible to form a hexagonally ordered array of water droplets on a liquid surface as condensation proceeded. We have used “breath figures” to form three-dimensional, ordered macroporous arrays with controllable dimensions. We generated breath figures on dilute solutions of polystyrene and other conjugated polymers dissolved in volatile solvents. When solvent evaporation is complete, one is left with a two or a three dimensional array of holes. In this presentation we will discuss the mechanism of structure formation as well as point to some applications for these structured films.