Stability of Self-Assembled Monolayer Surfactant Coating in Thermal Nanoimprint

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High-resolution and low-cost fabrication techniques are essential for nanotechnology to overcome the commercialization barrier to benefit our society. Since its inception in 1995, nanoimprint has attracted huge attention in academic and industrial research by providing such fabrication capability due to its inherent characteristics such as sub-10 nm resolution, high throughput and low cost. It has become the ideal technology to fabricate dense sub-micron structures over large areas with low cost, which are important to many applications such as high-density storage disks and diffractive optical devices. The decade-long development in nanoimprint equipment has reached a point where large-scale manufacturing of high-density nanostructures are possible. However, there are a few remaining issues that need to be studied before the advent of commercial application of nanoimprint. One of the important issues is the long-term stability of the mold surfactant coating. It is important to understand the details of the surfactant wear during nanoimprint in order to limit defect density to a tolerable threshold in a high-volume manufacturing process. The surfactant wear information also helps to optimize the time interval for surfactant recoating to keep the fabrication throughput as high as possible.

The first thing in addressing surfactant wear in nanoimprint is to understand the mechanism through which surfactant coating degrades. The stability of PTFE-like coatings on nickel template and their interaction with polymer resists during hot embossing have been reported [1]. This work focuses on the stability of self-assembled monolayers (SAM) on different mold materials and their interaction with polymer resists during nanoimprint. The SAMs on a mold surface and their thermal behavior are probed by surface-analysis techniques such as contact-angle measurement and X-ray photoelectron spectroscopy (XPS). Figure 1 shows the continuous decrease of water contact angle of a 1H,1H,2H,2H-perfluorodecyltrichlorosilane (FDTS) -coated substrate annealed at 350^{o}C and an octadodecyltrichlorosilane (OTS) -coated substrate annealed at 300^{o}C. Figure 2 shows the XPS spectra of an FDTS-coated substrate before and after thermal treatment. It clearly shows the reduction of the fluorine and carbon peaks with concomitant enhancement of oxygen peaks after annealing. The detailed mode of degradation can be ascertained by examining the changes in the fine structures of the carbon spectra. In this work, the degradation rate and mechanism are studied for a variety of SAMs on a variety of mold materials. The collected data reveal two different modes of degradation: whole molecule desorption and gradual chain scission. The effect of the polymer resist on surfactant degradation is also studied under typical nanoimprint conditions. The results of those studies indicate that different SAM coatings exhibit large difference in thermal stability. The surfactant wear information obtained from these studies allows us to select SAM coatings of highest durability for large-scale production.

1. Jaszewski, R.W., H. Schift, B. Schnyder, A. Schneuwly, and P. Groning, *Applied Surface Science*, 1999. **143**(1-4): p. 301.

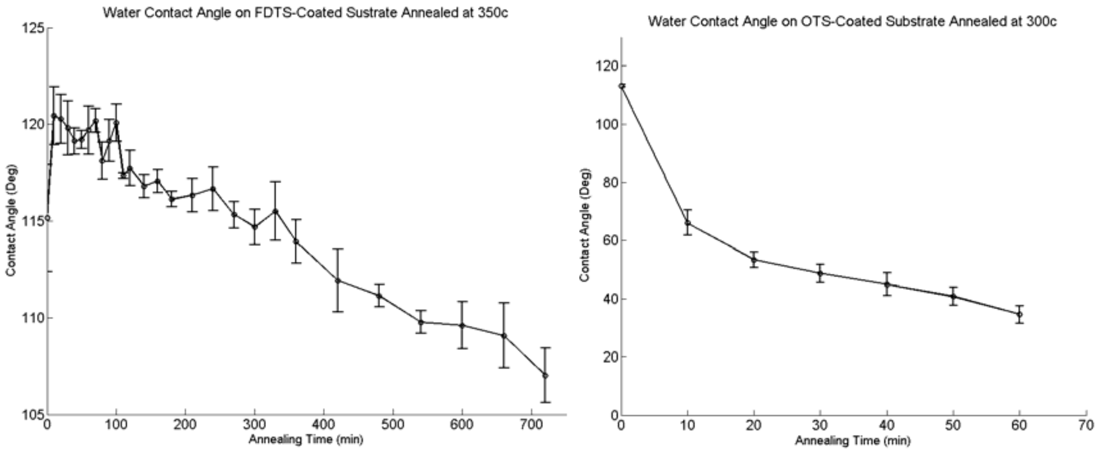

Figure 1. Contact-angle measurements of an FDTS-coated substrate annealed at 350°C (left) and an OTS-coated substrate annealed at 300°C (right).

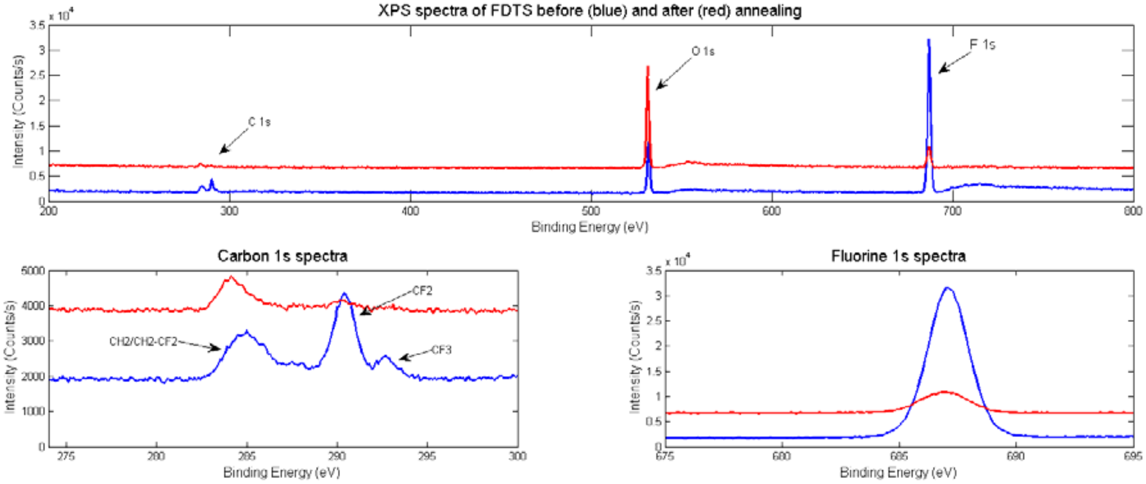

Figure 2. X-ray photoelectron spectra of FDTS before and after annealing at 350°C for 2 hours (top). Bottom left and bottom right are the expanded view of the carbon 1s and fluorine 1s spectra, respectively. FDTS spectrum of the sample after annealing is shifted upward to better visualize the spectrum change.