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(G*) Nanoscale polymer blister formation using single femtosecond pulses

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Blister formation occurs when a laser pulse is focussed through a transparent substrate onto a coated polymer thin film. A pocket of expanding vapor is formed beneath the film, which pushes the film upward locally. This process has been used for Laser-Induced Forward Transfer (LIFT) of materials. Most studies of blister formation and blister-based LIFT use linear absorption of nanosecond or picosecond lasers to obtain large target areas (˜100s of μm^2). We are the first to achieve nanoscale blisters, through nonlinear absorption of femtosecond pulses.

We spin-coated polyimide films achieving a thickness of 1.3 µm. We used a Ti:Sapphire laser producing pulses of 45-fs duration at a central wavelength of 800 nm. We mounted samples onto a 3D motion stage, and focused single pulses of various energies through the glass substrate onto the polymer-glass interface. Since polyimide is transparent to 800 nm light, we used tightly-focused (NA ≥ 0.4) femtosecond pulses to induce nonlinear absorption. We characterized samples after blister fabrication using atomic force microscopy (AFM). At intensities above 10^{13} W/cm^2, interactions of the pulse with both the film and substrate must be considered. We model these interactions and find that the resulting blister volume is proportional to the energy deposited in the film.

The use of 0.95 NA focusing led to a minimum structure diameter of 700 nm, smaller than the wavelength of the laser pulse. In the future, we propose the use of thinner films and shorter wavelengths to reach further into the nanoscale. This technique can be used for direct micro- and nano-fabrication, and potentially to LIFT sensitive materials on the nanoscale. It is a possible alternative to lithography, laser milling, and laser-based additive machining that also leaves the surface composition unchanged, since the laser energy is deposited beneath the film.

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