Femtosecond laser micromachining in azopolymer films

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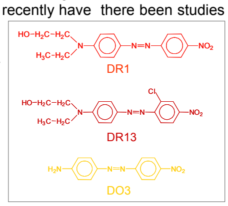
Introduction

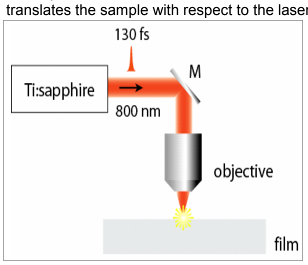
Femtosecond laser micromachining has receivied much attention due to its precise ablation capability and its application to a broad range of materials, including metals, glasses and polymers. Although polymeric materials are being developed to meet the properties required for a variety of applications, only recently have there been studies on femtosecond laser micromachining in polymers.



In this work, we investigated femtosecond laser micromachining in poly(methyl methacrylate) (PMMA) doped with the azoaromatic compounds Disperse Red 1 (DR1), Disperse Red 13 (DR13) and Disperse Orange 3 (DO3). These compounds are particularly interesting due to their linear and nonlinear optical properties.

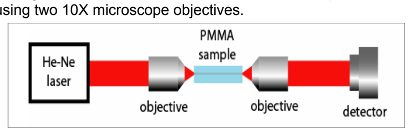
Experimental Technique

We used a Ti:sapphire laser oscillator (130 fs, 800 nm, 76 MHz) for the micromachining experiments. The laser beam was focused into the sample by a 0.65-NA objective. The sample is placed on a computer-controlled *x-y-z* stage, which translates the sample with respect to the laser beam, allowing structures to be written.



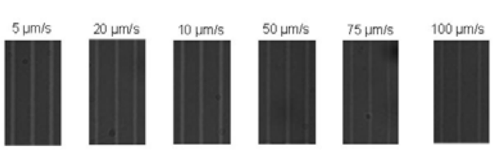
Optical microscopy and UV-Vis spectroscopy were used to study the influence of pulse energy and sample translation speed on the features of the polymer microstructures fabricated in thin films.

The waveguiding was verified by placing the micromachined sample on a three-axis stage for alignment, such that a HeNe laser can be coupled into and out of the waveguide using two 10X microscope objectives.



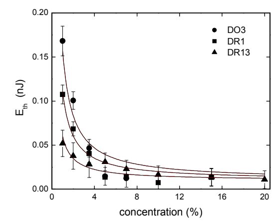
Micromachining films

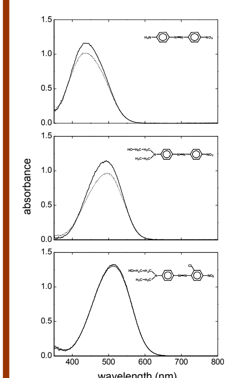
We micromachined samples of PMMA doped with varying concentrations (ranging from 1% to 15%) of DR1, DR13 or DO3. For comparison, a pure PMMA composition was also studied. The figure below shows an optical microscope image of microstructures produced in DR1-PMMA (3.5%) for several translation speeds and energy of 0.19 nJ. Similar structures were obtained for DR13 and DO3.



Micromachining mechanism

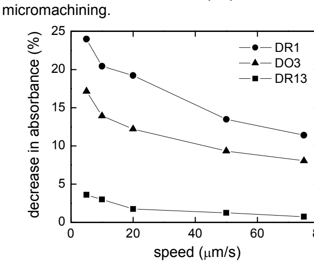
The threshold energy decreases as the chromophore concentration increases. For a fixed concentration, the threshold energy is proportional to the inverse of the two-photon absorption cross-section, revealing the micromachining is related to the chromophore two-photon absorption. The solid line represents the fits obtained with $E=A/N\sigma_2$, where σ_2 is the two-photon absorption cross-section, N the chromophore concentration and A a constant. The damage threshold energy for pure PMMA was measured to be 0.54 nJ.





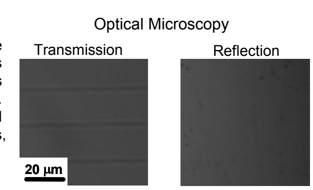
The photobleaching induced by the femtosecond laser pulses was monitored by the change in absorption spectrum of chromophore-doped PMMA sample.

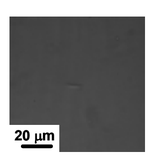
We also measured the absorption change at 455 nm (DR1 and D03) and at 535 nm (DR13) for several sample translation speeds. These results can be used to choose the proper conditions for micromachining.



Waveguides

The nonlinear absorption of the azoaromatic chromophores localizes the excitation to the focal volume, as seen in the optical microscopy images. The energy deposited in the material produces permanent structural changes, which result in refractive index changes.





The ability to modify the refractive index provides an opportunity to directly write optical waveguides inside of a material. We have demonstrated that by writing waveguides inside a sample, as shown in the cross-sectional image.

Acknowledgements: This research is supported by NSF, ARO, FAPESP and CAPES (Brazil).

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