Femtosecond laser micromachining in the conjugated polymer MEH-PPV

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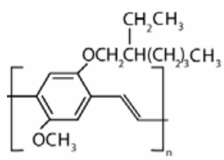
Introduction

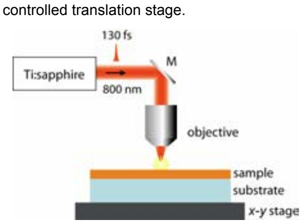
In this work, we investigate femtosecond laser micromachining in poly[2-methoxy-5-(2'-ethylhexy- loxy)-*p*-phenylene vinylene] (MEH-PPV). MEH-PPV is a conjugated polymer with photo- and electro-luminescent properties desirable for fabricating optoelectronic devices such as organic light-emitting diodes, chemical sensors, semiconductors and flexible displays.

We studied the influence of pulse energy and translation speed on MEH-PPV micromachining using optical and atomic force microscopy. We determined the energy threshold for polymer removal, and distinguished polymer removal from surface modification or photobleaching.



Experimental Technique

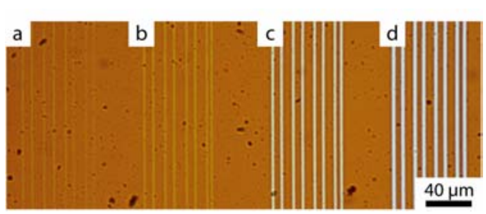
The MEH-PPV films were micromachined using 130-fs, 800-nm laser pulses from an oscillator at a 76-MHz repetition rate. The pulses were focused through 0.65-NA microscope objective onto the sample surface, which was translated at a constant speed with respect to the laser beam. The speed was maintained by a computer controlled translation stage.



The micromachined samples were analyzed by atomic force microscopy, transmission optical microscopy, and fluorescence microscopy. To evaluate the optical properties of the samples, we measured their UV and visible absorbance with a spectrophotometer.

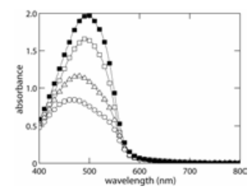
Micromachining films

Optical microscope images of microstructures produced in MEH-PPV at a translation speed of 20 µm/s and pulse energies of (a) 0.07 nJ, (b) 0.14 nJ, (c) 0.34 nJ and (d) 0.68 nJ. The transmission of visible light by the micromachined lines clearly increases with the pulse energy. At an energy of 0.07 nJ (a), the smallest pulse energy employed, little contrast is obtained, whereas at higher pulse energies (0.68 nJ – d) a much higher contrast is observed.

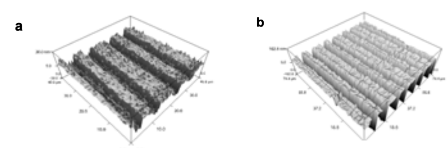


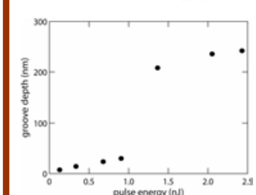
Micromachining features

We measured the absorbance of samples fabricated at various pulse energies with a translation speed of 20 µm/s (right). The open symbols shows the absorption spectra of such samples, while the solid squares show the absorption of a sample that has not been irradiated. The absorption band decreases with the pulse energy used for the micromachining, indicating photobleaching of the sample during the micro-machining.



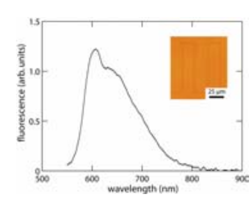
To determine the effect of the laser pulse energy on the depth and morphology of the micromachining, we micromachined a set of lines for pulse energies ranging from 0.07 nJ up to 2.4 nJ. The figure below shows two representative atomic force micrographs of grooves machined at pulse energies of 0.3 (a) and 2.0 nJ (b).





As seen in the figure in the left, there are two distinct regimes for the depths of the grooves as a function of pulse energy. For energies up to 1 nJ, the groove depths varies from 7 to 30 nm, indicating only slight material removal from the surface. For energies higher than 1.4 nJ, however, the groove depth becomes comparable to the 240-nm films thickness.

We carried out fluorescence microscopy measurements of the micromachined MEH-PPV films. As shown in the figure (right), the MEH-PPV film (not exposed to the fs laser) exhibits fluorescence at approximately 600 nm when excited at 540 nm. The inset corresponds to the fluorescence microscopy image for the sample micromachined at an energy of 0.07 nJ. As can be seen, the micromachined lines present the characteristic fluorescent emission of MEH-PPV, although with smaller intensity in comparison to the not irradiated region.



We demonstrated here that although photobleaching occurs during the micro-machining process, for the energy regime up to 1.2 nJ, the optical properties of the polymer remain unchanged. Our results provide the optimum parameters for fs-laser micromachining of MEH-PPV for applications in polymeric-based photonic devices.

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

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