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Direct femtosecond laser irradiation of polymeric substrates for high resolution ink-jet printing of conductive lines

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Abstract

In this work, polyethylene terephthalate (PET) and polyimide (PI) films of 125 μm, two polymers commonly used for ink-jet printing, have been processed with a Ti:Sapphire laser system which generates 130 fs pulses at a central wavelength of 800 nm, with a 1 kHz repetition rate. A study of the formation of surface micro/nanostructures was performed by scanning the selected areas at a constant speed for different laser parameters. These structures have notably increased the surface water and Ag ink wettability. The fabricated polymer surfaces were subsequently used as substrates for ink-jet printing of Ag conductive lines for improving and controlling the ink jet flow in a highly efficient way, giving rise to Ag lines with a resolution five times better than the one for non-treated polymers.

Keywords: ultrafast laser; polymer; ink-jet printing.

1. Introduction

Surface modification and wettability control of materials have attracted an increased interest in recent years because of their importance and applicability in fundamental research and practical applications such as self-cleaning surfaces [Vorobyev et al., 2015], improved corrosion resistance [Su et al., 2015] or antibiofouling [Marmur, 2006]. Ink-jet printing technology is also demanding polymers with controlled wettability in order to solve its main challenges: high resolution and precision printing [Yeo et al., 2014]. In this field, direct femtosecond laser processing can provide an adequate approach for selective polymer modification.

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2. Experimental

Two types of polymers commonly used for ink-jet printing were selected: polyethylene terephthalate (PET) and polyimide (PI) films of 125 μm. Films were ultrasonically cleaned prior to laser irradiation.

Samples were machined in open air atmosphere with a Ti: Sapphire laser system which generates 130 fs pulses at a central wavelength of 800 nm, with a 1 kHz repetition rate. The 8 mm-diameter laser beam was focused on the samples using a 10x microscope objective with a NA of 0.16. A study of the formation of surface micro/nanostructures was performed by linearly scanning the selected area at a constant speed for different parameters according to Table 1. Field-emission scanning electron microscopy (FE-SEM) was used to analyze polymer surface topography as a function of the laser processing parameters. Static apparent contact angles (APCA) measurements were obtained using the sessile drop method with the Low-Bond Axisymmetric Drop Shape Analysis (LBADSA) plugin for ImageJ

Table 1. Laser processing parameters.

Parameter	Range
Pulse Energy (μJ)	0.5 - 3.0
Scan Speed (mm/s)	1.0 – 3.0
Polarization	Horizontal
Line Separation (μm)	10.0 – 25.0

3. Results and Discussion

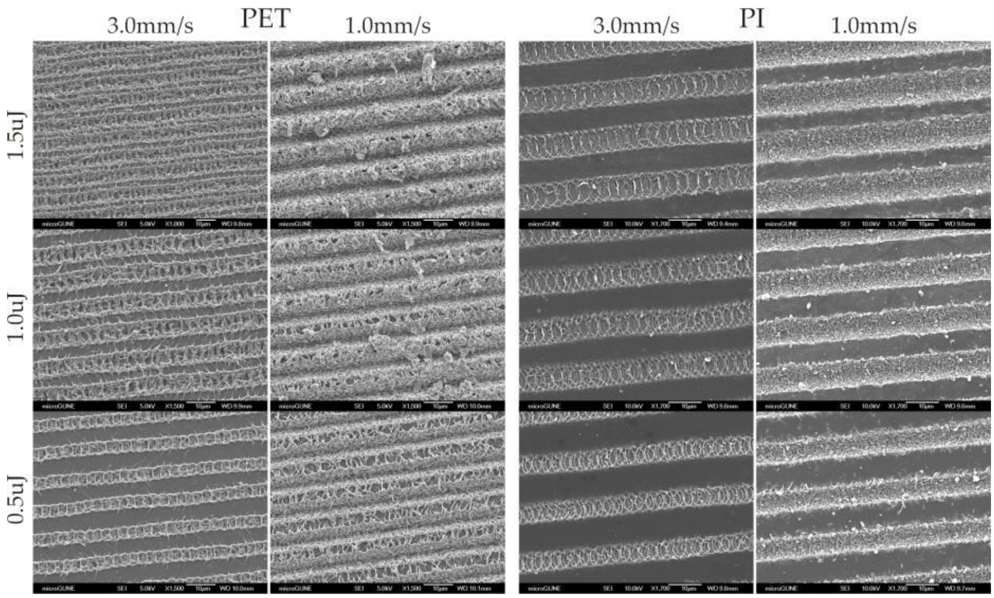

Fig. 1. FE-SEM micrographs of the resulting micro and nanostructures in PET and PI for different irradiation conditions

All the tested conditions gave rise to micro and nanostructures over the scanned area. As can be observed in Fig. 1, where the most representative FE-SEM micrographs are presented, both PET and PI are modified in the same ranges of pulse energy and scan speed. The resulting nanostructures over lines with a width in the order of several microns constitute hierarchical structures highly promising for wettability control.

The APCA of pristine PET and PI are 70^0 and 74^0, respectively. The APCA of irradiated PET, which are presented in Table 2, revealed higher values of the APCA for those structures with the higher line width to line separation ratio (close to 1/2).

Table 2. APCA values for PET samples irradiated with certain laser parameters.

		Line separation 25 µm		Line separation 15 µm	
		3 mm/s	1 mm/s	3 mm/s	1 mm/s
Ep	0.5 µJ	65	83	87	84
	1.0 µJ	74	85	95	82

An additional sample was irradiated with the process parameters that resulted in the higher APCA (1 µJ, 3 mm/s, 15 µm separation) in a matrix configuration instead of a set of lines. The resulting APCA was increased from 95 to 106, as can observed in Fig. 2

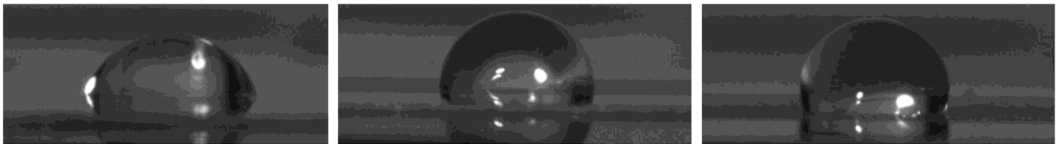

Fig. 2. APCA measurements of (left) pristine PET, (center) lines processed with 1 µJ, 3 mm/s, 15 µm separation and (right) matrix processed with 1 µJ, 3 mm/s, 15 µm separation.

4. Conclusions

Selective modification of PET and PI by direct femtosecond laser irradiation has been successfully achieved for a range of parameters. APCA of PET has been increased in more than 30 degrees from its pristine value, resulting in hydrophobic behavior. These irradiated polymers increase ink-jet printing resolution and precision.

References

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