Highly photostable organic distributed feedback lasers fabricated by thermal nanoimprint

I. Alonso[1], V. Trabadelo[1]*, A. Juarros[1], A. Retolaza[1], S. Merino[1], V. Navarro-Fuster[2], M.G. Ramírez[2], P.G. Boj[2], I. Vragovic[2], J.M. Villalvilla[2], J.A. Quintana[2], M.A. Díaz-García[2]

[1]Micro/Nano Engineering Unit, CIC microGUNE, Avda. Otaola 20, 20600 Eibar, Spain
[2]Instituto Universitario de Materiales de Alicante, Universidad de Alicante, 03080 Alicante, Spain
*Present address: EMPA-Swiss Federal Laboratories for Materials Science and Technology, Advanced Materials Processing, CH-3602 Thun, Switzerland.
ialonsovillanueva@tekniker.es

Nanoimprint lithography (NIL) is a promising technique for the fabrication of surface pattern features down to 20 nm, even for future industrial applications, because of its high throughput, low cost and high fidelity pattern transfer. We have used this technique to make distributed feedback (DFB) resonant cavities for solid-state lasers based on semiconducting polymers, an active field of research in the past few years [1].

In this work we present the last results obtained with two kind of devices. First, DFB gratings in SiO_2 (periodicity of 368 nm and equal line and space) on which polystyrene (PS) films doped with 0.5 wt% of a perylenediimide (PDI) derivative were spin-coated afterwards. Using a master grating fabricated by e-beam lithography and plasma etching, the grating was first imprinted onto an mrI-8030E resist layer spin-coated on a thermally oxidized silicon wafer. The embossing was carried out at 180 ºC and the applied force (20000 N) was held for 900 s. The residual layer was removed using an O_2 plasma and the grating was transferred to the SiO_2 by CHF_3/Ar plasma etching. Several grating depths were obtained by varying the etching time.

On the other hand, we also imprinted DFB gratings directly on the active material using the same master stamp. After spin-coating a PS film doped with 0.5 wt% of PDI on a SiO_2 wafer, it was embossed at 155 ºC applying 15000 N for 900 s. This way the dry-etching step can be avoided, so the fabrication process for this second kind of devices becomes more cost-effective.

For the optical characterization of the samples, they were pumped with a circular spot (1.3 mm diameter) provided by a pulsed Nd:YAG laser (10 ns, 10 Hz) operating at 532 nm. The emitted light was collected normal to the surface with a fiber spectrometer. For DFB gratings in SiO_2, the laser showed laser emission at between 569 nm and 572 nm, depending on the grating depth. In the case of imprinted DFB gratings, the emitted wavelength is at around 578 nm. Thresholds were drastically reduced compared with the amplified spontaneous emission of a sample without grating [2]. Moreover, the thresholds of the devices with gratings directly embossed on the doped PS film were even lower than for devices with gratings in SiO_2. Furthermore, this combination of low threshold devices and material properties has shown to be very photostable. The half-life, defined as the number of excitation pulses at which the emission intensity decays at half of its maximum value, is longer than 300000 pump pulses (i.e., more than 8 h at 10 Hz), at a pump intensity twice the threshold (see figure below).

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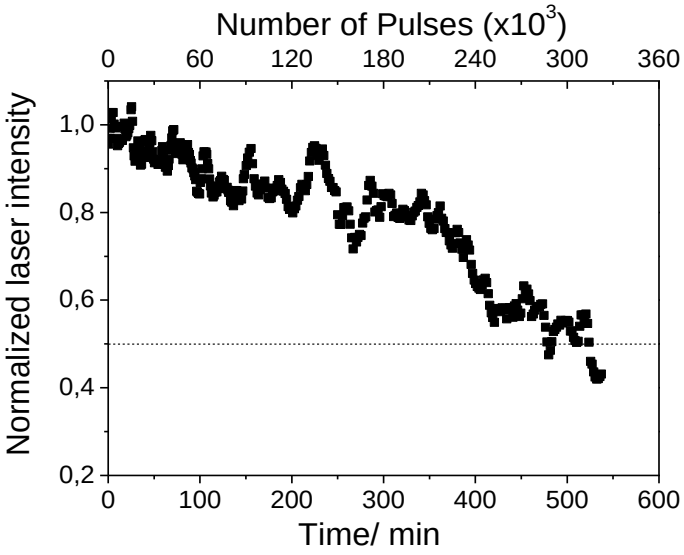
Figures



Normalized laser intensity vs irradiation time (bottomaxis) and vs the number of pump pulses (10 ns, 10 Hz; top axis for a DFB device based on a 0.5 wt % PDI- doped PS film and grating depth of 105 nm at 4 μJ/pulse (twice the threshold)