Efficient organic distributed feedback lasers fabricated by thermal nanoimprint

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Solid-state lasers based on semiconducting polymers have become an active field of research in the past few years [1]. Polystyrene (PS) films doped with perylenediimide (PDI) derivatives have shown a great potential in this regard due to its highly photostable optically-pumped amplified spontaneous emission (ASE) at low threshold [2]. On the other hand, the use of distributed feedback (DFB) structures as resonant cavities, significantly enhance the lasing properties of organic materials, providing single-mode emission and lower pumping thresholds [1]. In order to get such a structured medium, nanoimprint lithography (NIL) is one of the most promising techniques for grating fabrication, even for future industrial applications, because its high throughput, low cost and high fidelity pattern transfer.

In this work we first present the fabrication by NIL and dry etching of second-order DFB gratings in SiO_2 (periodicity of 368 nm and equal line and space, fig. 1) on which PS films doped with 0.5 wt% of a PDI derivative were spin-coated afterwards [3]. 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 (340, 220 and 105 nm) were obtained by varying the etching time. Furthermore, we also imprinted DFB gratings directly on the active material using the same master stamp. After spin-coating a 880 nm-thick 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 kind of devices becomes more cost-effective.

Both types of lasers showed highly photostable laser emission at around 572 nm, when pumped at 533 nm with a pulsed Nd:YAG laser. As shown in Fig. 2, thresholds were drastically reduced with respect to the ASE threshold of a sample without grating. Moreover, the performance of the devices with gratings directly embossed on the doped PS film was superior, in terms of threshold, than that of devices with gratings imprinted on SiO_2 .

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References:

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Figures:

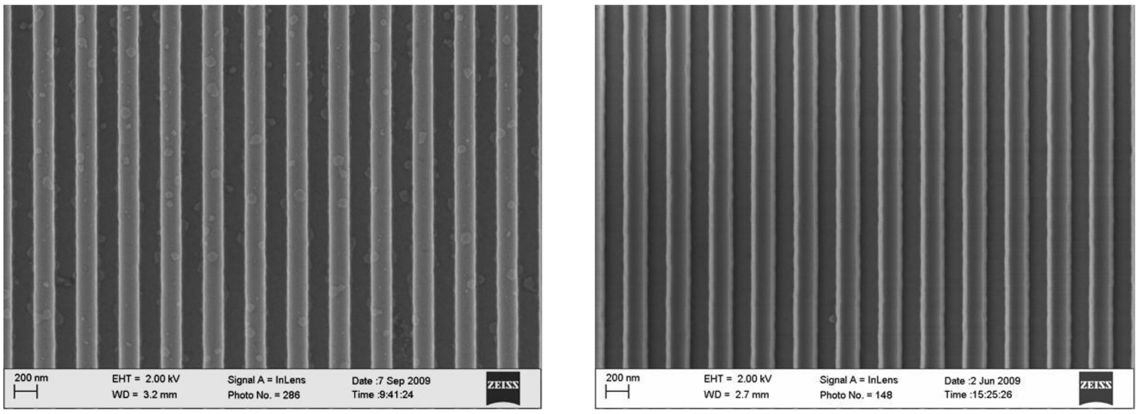

Figure 1. FE-SEM micrograph (Inlens detector) showing a representative area of the DFB grating in the stamp (left) and transferred in SiO_2 after NIL (right).

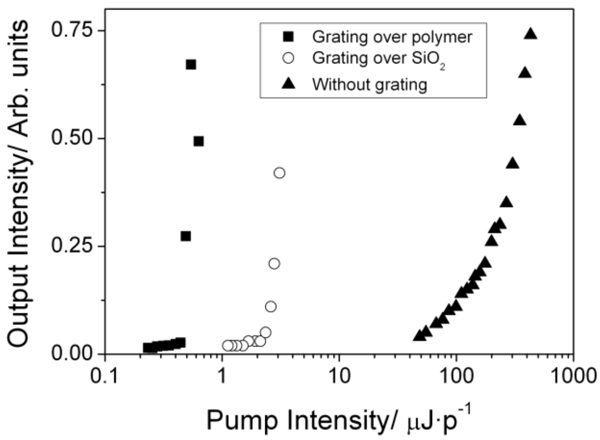

Figure 2. Output intensity versus pump intensity for DFB devices with gratings on the polymer and on SiO_2. For comparison purposes, data for a film deposited on SiO_2 without grating are included.