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Soft thermal nanoimprint of PMMA doped with upconverter nanoparticles

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ABSTRACT

Upconversion of low-energy photons into higher energy photons is a non-linear effect that can be strongly enhanced by increasing the intensity of impinging light. Such an enhanced intensity can also be achieved by near-field optical effects in photonic structures. In this paper, we investigate photonic structures in the form of linear gratings with varying periods realized in poly-methyl-methacrylate (PMMA) layers using soft stamps in a thermal nanoimprint process. Master structures were fabricated using e-beam lithography and reactive ion etching in silicon. These master structures were replicated into bi-layer polydimethylsiloxane (PDMS) stamps. PMMA layers with embedded β-$NaYF_4$: 25% Er^{3+} upconverter nanoparticles were applied to glass substrates using spin coating. The PDMS stamps were used to imprint the PMMA layer with very accurate pattern fidelity. The upconversion luminescence around 980 nm was enhanced more than three times by the photonic structure under 1523 nm laser excitation with 0.43±0.02 W/cm² irradiance, in comparison to a reference sample containing the same amount of upconverter material.

Keywords: Upconversion, nanoimprint lithography, hot embossing, PDMS, soft lithography, photonic structures, solar cells.

1. INTRODUCTION

Upconversion – the emission of one high-energy photon after the absorption of two or more low-energy photons – is relevant for many applications including bioimaging and theranostics [1–4], security [5] and photovoltaics [6–9]. In photovoltaics, upconversion offers the potential for significant efficiency gains by converting photons with energies below the absorption threshold into photons with sufficient energy for utilization, pushing the maximum achievable efficiency for a silicon solar cell from 30% to 40.2% [7]. For silicon photovoltaics, especially trivalent erbium (Er^{3+}) features conveniently spaced energy levels that allow for upconversion of photons with wavelengths