Magnetic nanopatterning of YIG films via direct laser writing for magnonics

(in-depth report)

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The goal of magnonics is to exploit spin waves (SWs) for data transmission and processing applications, aiming for the next generation of low-energy consumption devices. In the last years magnetic materials with periodically modified properties, known as magnonic crystals (MCs), have been investigated to achieve control over the spin wave phenomena [1]. Yttrium Iron Garnet (YIG) is the most promising material within the field of magnonics, mainly for having the lowest Gilbert damping ever recorded, which allows for the coherent propagation of SWs up to millimetres, a fundamental quality necessary for computing tasks based on spin wave interference [2]. The use of YIG for the realization of devices based on SWs propagation is difficult with the current standard lithographic processes, due to unwanted effects like edge roughness, planarization and degradation of magnetic properties. For this reason, new nanofabrication techniques are needed to make use of the unrivalled properties of YIG. In this work, we employed direct laser writing (DLW) to pattern a single crystal 1-µm thick YIG, obtaining effective grayscale tuning of its magnetic properties, following a new phase-nanoengineering approach [3]. Patterns of different geometries and sizes have been realized, and by varying the writing parameters we were able to tune the local magnetic, optical and structural properties of the film. The change in the static magnetic properties has been investigated through Magnetic Force Microscopy (MFM), revealing an altered magnetic structure in the irradiated patterns, with the stripe domains of the pristine material reducing in periodicity and displaying a stronger magnetic contrast (Fig. 1a). The patterns also revealed a higher coercivity with respect to the pristine film in MFM experiments performed with an external applied field. The irradiated areas also presented mild structural modifications, as revealed by Raman spectroscopy experiments. In Fig. 1b it is possible to see a left-side broadening of Raman peaks of the patterned film respect to the peaks of the pristine one. These effects are compatible with the creation of oxygen vacancies in the patterned regions [4]. Ultimately, micro-Brillouin Light Scattering (µ-BLS) experiments have been performed, revealing the effect on the spatial localization of spin waves, propagating in an array of nanodots (Fig. 1c). These results prove how phase nanoengineering holds promise for the design and implementation of novel magnonic devices based on the crafting of the magnetic and structural properties of YIG films.

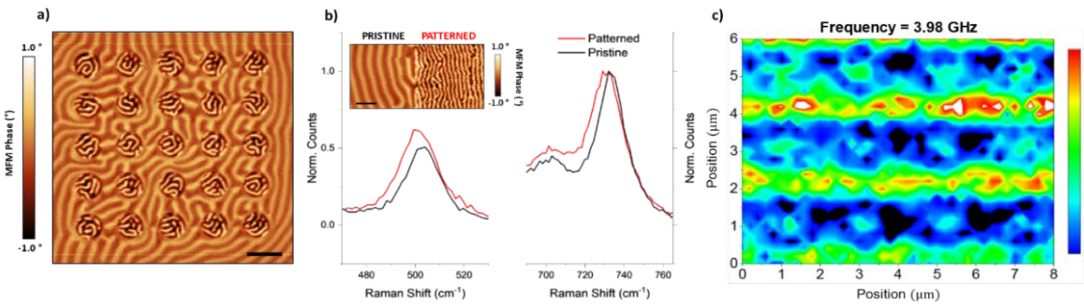

Fig. 1: Phase nanoengineering of YIG film. a) MFM image of a 3 µm dot array, the patterned regions show a reduced periodicity of the stripe domains with respect to the pristine film. Scale bar is 5 µm. b) Raman spectra of the patterned film shows a left side broadening compared to the one of the pristine film. In the top-left corner the MFM image of the pristine and patterned regions. Scale bar is 3 µm. c) µ-BLS measurement of a magnonic crystal made by an array of patterned nanodots revealing the spatial localization of the spin-wave intensity at the frequency of 3.98 GHz.

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