Evanescent wave lithography. Towards the 3D nano-patterning of surfaces

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Abstract: Under total reflection, the evanescent wave generated permits the recording on photolithographic resins close to the interface. The control of the penetration depth by simple means enable the production of profiles and 3D surface structures in practically one step and to and extended field of view. In this contribution we present some first experimental results, the description of the technique and its expected capabilities to fabricate sub-wavelength structured surfaces (Λ~100nm) by means of interference or simply by projecting masks.

Currently, the author is working on a project financially supported by the Comuidad de Madrid entitled, "*Evanescent wave lithography. Generation of nano-structured surfaces*". The basic goal of this presentation is to describe the technique and the potential uses of the same.

It is well known that two coherent waves propagating in reverse directions, generate an interferential electromagnetic field with a periodicity of $\Lambda=\lambda/2n$ where n is the refractive index and λ the vacuum wavelength. Consider a refractive media of n = 1.775 and a λ of 355 nm, then we will have a grating of Λ~100 nm and a minimum detail of around 50 nm. Choosing the appropriate optics configuration, the interference structure can be transferred to the evanescent wave, which has a limited penetration depth. This clearly points out to the possibility of fabricating sub-wavelength patterned profiles, though conventional lithographic and optical materials and sources. Therefore, we do not need to resort to sophisticated vacuum etching techniques or VUV-EUV lithography to fabricate sub-wavelength systems in the order of 100 nm details. The potential is then very relevant and our interest is to validate this technique. There are previous results that support indirectly its viability. Sainov [1]-[2] uses the evanescent wave to generate a holographic grating of Λ=156.7 nm with a laser of emitting at 514.5 nm. Although our proposal keeps some similarities with the work of Sainov, it does not seem that the evanescent wave has been used before for nano-profile fabrication.

The techniques for nano-patterning the surfaces under design are based on ion-etching, electron-beam, etc… [3]; or based in other scanning technologies, like atomic force microscopy or scanning tunneling microscopy, which permit nano-patterning point by point with a nanometric probe by means of different physical mechanisms, for example, the anodization of differential oxidation of the surface. However, they are costly techniques in terms of time and inappropriate for extended areas. The evanescent wave promises a simple and rapid fabrication of several devices of large areas. Recently, A. Nesci y H. Tao *et al* [4]-[5] have measured the structure of the interferential evanescent wave encountered in the set-up of Fig.1. A similar set-up has been used by the author to register lithographically the interference of two laser beams and we obtained the satisfactory results of Fig.2, confirming the capability of the evanescent field to sculpt 3D profiles on the surface of a resin.

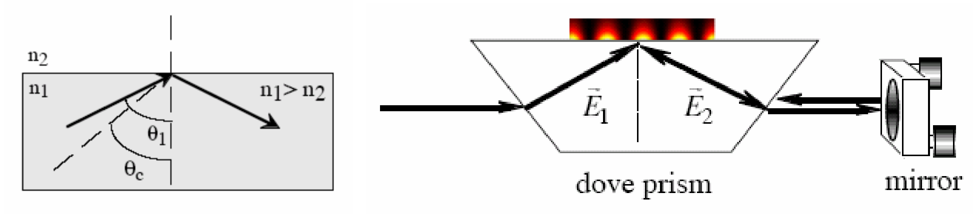

Fig. 1 Left: As is well known, to obtain a surface evanescent wave it is necessary that $n_1>n_2$ (refractive indices) and $\theta_1 > \theta_c$ (incidence angle above critical angle). Right: Field amplitude structure of the interference of two evanescent waves under a possible set-up.

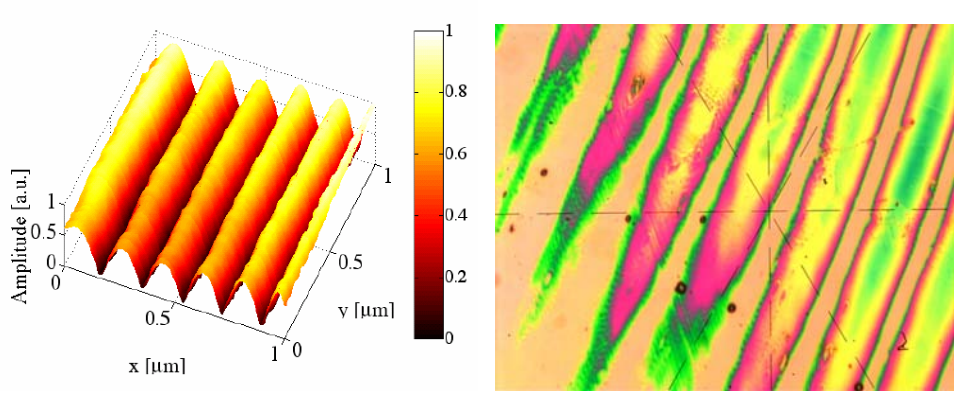

Fig. 2 Evanescent wave lithography. Left: Measured evanescent field near a surface under the interference set-up of Fig. 1 with a SNOM apparatus. Right: first experimental results obtained by the author showing the recording of an evanescent wave interference (like the one in the left) in a photolithographic resin. The image is obtained with a conventional optical microscope and every colour corresponds to an interference fringe, i.e. a certain thickness or penetration depth. The colour-depth map demonstrates the ability of the evanescent recording to generate 3D profiles on surfaces in one single step. Conventional lithography would need several steps to achieve an approximated binary profile and more limited in lateral resolution.

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[2] S Sainov, "*Nanoscale surface-wave holographic recording*", J. Phys.: Condens. Matter 11 (1999) 9857–9860

[3] Philippe Lalanne, Mike Hutley, *"The optical properties of artificial media structures at subwavelength scale"*, http://gea.df.uba.ar/curso2002/lect3.pdf

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[5] Antonello Nesci, *"Measuring amplitude and phase in optical fields withf sub-wavelength features"*, Tesis doctoral, noviembre de 2001, Universidad de Neuchâtel, Instituto de microtecnología