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Modeling the mechanical deformation of PTFE flexible stamps for nanoimprint lithography on double-curved surfaces

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The work presented in this abstract is a part of a larger project called NANOPLAST. The aim of this project is to produce injection molding tool inserts with nano-structured functional surfaces. With such surfaces, features like antireflective-, hydrophobic- and color-effects (see FIG. 1) will be possible to injection mold directly onto the surface of plastic parts. The nano-structures are transferred to the steel inserts by Nanoimprint Lithography (NIL). As the tool inserts are non-planar 3-D structures, so-called flexible stamps are used for the NIL manufacturing process. Unfortunately, the nano- structures can only be created on the flexible stamps in a flat 2-D shape. The flexible stamps are in this case made of a Teflon (PTFE) foil, which has been manufactured by hot embossing from a original silicon master stamp, containing the nano-structures that are going to be replicated. The flexible PTFE stamp is then by a special NIL machine (developed by NIL Technology) pressed into the resist on the curved surface of the mold insert. As the PTFE foil is stretched when pressed into the curved tool insert, the 3-D deformation of the flexible stamps is essential to take into account, when designing the nano-structures in 2-D. Prediction of these deformations are performed using finite element simulations, which in many aspects are non-linear: the materials constitutive behavior is temperature dependent viscoelasto-viscoplastic[1], large strains and deformations have to be taken into account, and contact between the PTFE foil and the steel tool insert adds another non-linearity to the system of equations. The simulations are verified through a Design of Experiments (DoE), where thermal-NIL on curved tool inserts formed as concave, are performed varying temperature, imprinting pressure and stamp thickness, in order to study the effect of these parameters on the shape of the imprinting PTFE flexible stamp.

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[1] M. R. Sonne, J. H. Hattel , Microelectronic Engineering, 2013 , volume 106 , pp. 1-8

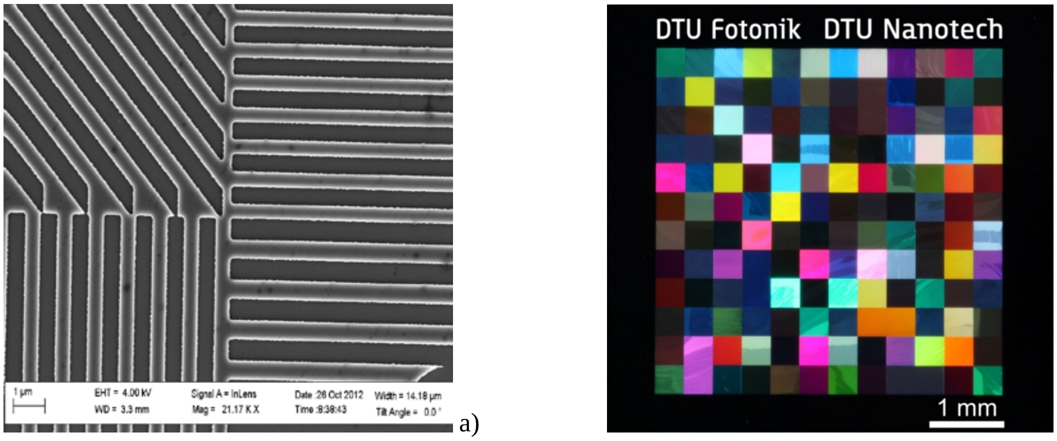

FIG. 1: By combining diffraction gratings with different periods and orientations a glitter-effect can be created. a) Close-up SEM image of the intersection between four different areas with different periods and orientations. b) Photo of glitter sample in black PMMA.

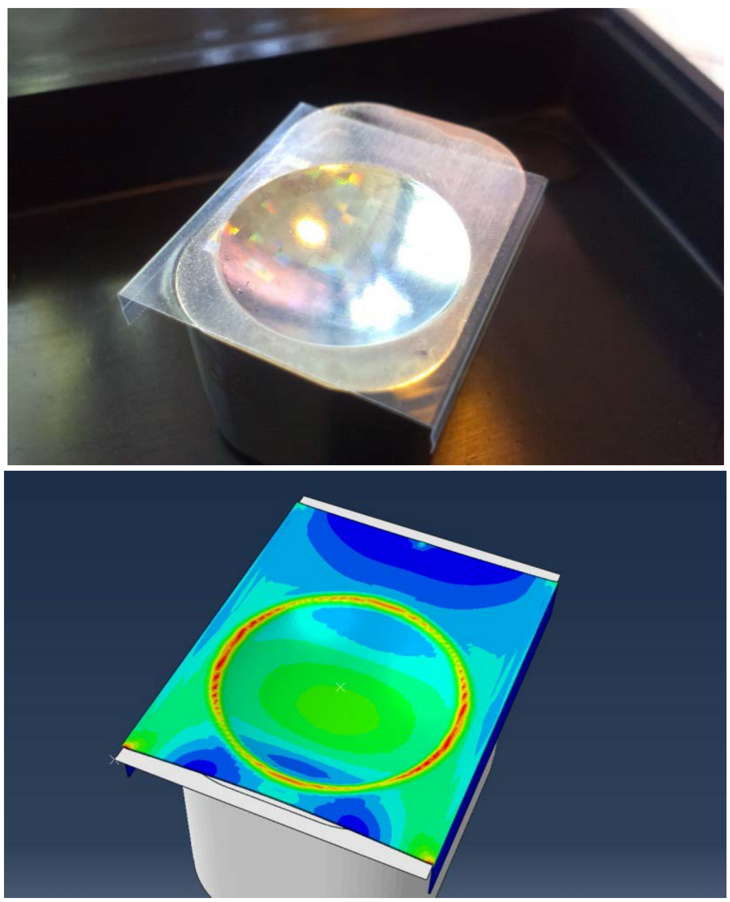

FIG. 2: NIL on the double-curved tool insert for injection moulding. In this case, the mould consists of a hemisphere with a radius of 15 mm and a height of 3 mm. a) The used PTFE flexible stamp with the glitter-effect pattern, on top of the steel tool insert after nanoimprint. b) Numerical model of the same setup, where it is possible to study the stretch and deformation of the flexible stamp, in combination with the actual imprinting pressure underneath the flexible stamp.