High accuracy UV-NIL step and repeat master stamp fabrication for wafer-level camera application

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The massive introduction of digital cameras in cell phones and smart phones has led the industry to produce increasingly higher quantities of lenses for camera objectives. Wafer-Level Cameras (WLC) enable the design and manufacture of miniaturized optics at wafer scale up to 300 mm. The camera modules can be produced cost effectively, with reduced form factor, by applying micro-moulding processes. The production technology is scalable from a single-element for VGA lenses up to multi-element mega pixel modules, where the lens wafers are precision aligned, bonded together and diced to form multi-element lens stacks. The technical challenges in fabricating wafer level cameras are several. They include: manufacturing the master stamp; replicating the lens on the wafer level; combining these full wafer micro-moulded lens wafers with other essential parts like apertures or filters; and, finally, aligning and assembling these modules in a manner that yields an integrated optical component. High-end mega pixel wafer-level camera modules require tighter alignment and profile tolerances for the entire process - from the mastering to the final stacking and dicing.
Conventional master stamp fabrication processes like diamond or micro milling [1][2], UV proximity printing [3], resist reflow [4][5] or gray scale lithography [6] do not address all critical parameters like lens axes tilt control, lens to lens lateral positioning and profile accuracy. Step and repeat UV-nanoimprint lithography (UV-NIL) mastering meets all requirements for low end camera modules like VGA's and also high-end multi-element mega pixel cameras. Considering for example a low-end VGA camera module consisting of one lens element with two refractive optical elements on front and back side, there is the need for two lens master stamps with the desired optical design. These master stamps have to match each other accurately in lateral distance and positioning. Taking in account that conventionally available wafer scale master stamp fabrication techniques like diamond, or micro milling can achieve ± 1.5 µm absolute lateral position accuracy with lens to lens profile accuracies down to < 100 nm, the lens apex de-centering can end up at 3 µm without considering the miss alignment in the wafer scale replication process. Thus, for high end mega pixel modules, where up to four lens elements have to be stacked together, this lateral placement accuracy is inadequate to achieve the requested optical properties of the camera module. Other mastering techniques with good lateral placement accuracies like resist reflow have their deficiencies in regards to lens profile accuracy. A master stamp lens to lens profile irregularity leads to yield loss because of focal length differences, unwanted light path deviations, as well as intensity changes which all result in image quality deterioration. In this abstract we report on the fabrication of high accuracy master stamps by UV-NIL [7]. Step and repeat moulding of polymers performed on a commercial system (EVG770) (Figure 1) is a state of the art process for master manufacturing. Starting out from a single lens pin, this technique (Figure 2) replicates one lens at a pre defined position at a time and then moves to a new area until the entire master substrate is imprinted (Figure 3). The lateral distance in x and y direction between each lens is defined by the optical module. A low-end VGA master stamp with a lens diameter of 1.66 mm and an image sensor die size of 1.76 mm in diagonal requires maximum ~ 4500 lenses on one master stamp, whereas a high end mega pixel camera master stamp with a lens diameter of 4.25 mm and an image sensor die size of 4.55 mm consists of ~ 770 lenses per substrate with increased lateral placement and profile specifications. This work addresses unmatched step and repeat mastering needs for wafer-level camera applications like lateral lens to lens position accuracies of < ± 100 nm on arbitrary x and y distances for VGA's as well as high-end mega pixel modules, profile and surface roughness comparison and lens axes tilt control.

Figure 1: EVG 770 Gen II Step-and-repeat semi automated UV-NIL system

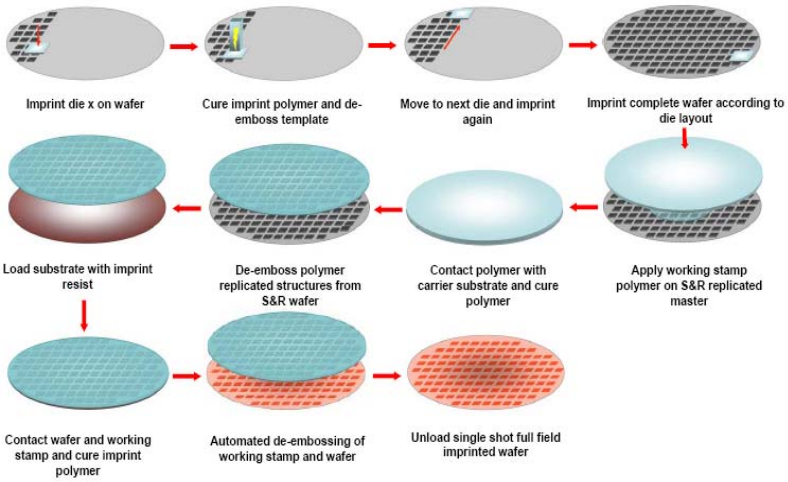

Figure 2: Step-and-repeat mastering and full wafer replication process

Figure 3: 200 mm master stamp with 400 replicated lenses

[1] Badrawy, S.: “Micro Milling – An Alternative Solution for Diamond Turning of Lens Arrays”. Proc. Optonet – Ultra Precision Workshop, Jena, Germany (2008)

[2] Scheiding, S. et al.: “Lens array manufacturing using a driven diamond tool on an ultra precision lathe”. Proc. 9th int. EUSPEN Conference, San Sebastian, Spain, Vol II, p. 423–426 (2009)

[3] T.-H. Lin C.-K. Chao Department of Mechanical Engineering, National Taiwan University of Science and Technology Taipei, Taiwan 106 Microsystem Technology (2007)

[4] Feidhlim T. O'Neill, John T. Sheridan “Photoresist reflow method of microlens production Part I: Background and experiments Optik” - International Journal for Light and Electron Optics, Volume 113, Issue 9, 2002, Pages 391-404

[5] Feidhlim T. O'Neill, John T. Sheridan Photoresist reflow method of microlens production Part II: Analytic models Optik - International Journal for Light and Electron Optics, Volume 113, Issue 9, 2002, Pages 405-420

[6] J.-J. Yang et al. / Optics Communications 270 (2007) 433–440

[7] S.Chou, et. al, Nanoimprint Lithography, J.Vac. Sci, Technol. B 14 (6), 1996