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Implementing nDSE (nano-scale Displacement Sensing and Estimation) - based Alignment Using Imprint Molds with Non-marking Alignment Features

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Compared with its sub-10 nm resolution, [1] the alignment capability available today for nanoimprint lithography (NIL) is very limited. It is highly desirable to bridge the gap between the high resolution and the low alignment accuracy of NIL with a highly precise but economical alignment solution that also helps to keep the overall cost of NIL tools low.

Over the years, Hewlett-Packard has developed a range of image-based displacement sensing and estimation (DSE) technologies for applications such as handheld scanners and optical media advance sensors.[2] In our recent publications, we have introduced the nDSE technology, which is an extension of DSE to the nano-scale. Using a set-up with a 50x objective lens and a piezo nano-positioning stage, we have demonstrated successfully that nDSE can track the displacement of a stepping wafer to within 1 nm (1σ).[3] These results indicate that nDSE could provide us with a suitable alignment solution for NIL, because of its sub-pixel-size, sub-wavelength sensitivity and its low-cost for using only conventional optical elements and image sensors.

In this paper, we present a displacement-measurement-based alignment (DMA) scheme for NIL. The concept is illustrated in FIG. 1. Imprint molds with non-transferable alignment features are the key elements for its implementation, because the alignment features from different imprint layers should not overlap in the microscope field of view so that they can be easily extracted for image processing. During imprinting, microscopic images of patterns on the mold and the substrate are obtained and analyzed by nDSE. Alignment is achieved by positioning the non-transferable alignment features of both the first and the second imprint mold at the same displacement relative to the wafer marks pre-patterned on the substrate.

To fabricate a mold with non-marking alignment features, both the alignment features and the transferable imprint features have to be generated in a single lithography step, which ensures that the imprint features are placed at a known location relative to the non-transferable alignment features with minimal placement errors. Through processing (FIG. 2), however, the alignment features are made significantly shallower than the imprint features. When such a mold is used for imprinting, the non-marking features are used for the alignment purpose but they do not transfer to the wafer after metalization and lift-off (FIG. 3).

Using imprint molds with non-marking alignment features and the nDSE algorithm as a test platform, series of experiments are being carried out to test this displacement-measurement-based alignment scheme. Our experiments have shown very promising preliminary results. This technology has the potential to provide us with a path towards the realization of a new generation of imprinting tools that can perform sub-10 nm resolution lithography with sub-100 nm alignment accuracy at a low cost.

[1] S. Y. Chou, P. R. Krauss, and P. J. Renstrom, *Science* **272**, 85 (1996).
[2] J. Gao, C. Picciotto, and W. Jackson, *Appl. Phys. A: Mater. Sci. Process.* **80**, 1265 (2005).
[3] C. Picciotto, J. Gao, E. Hoarau, and W. Wu, *Appl. Phys. A: Mater. Sci. Process.* **80**, 1287 (2005).

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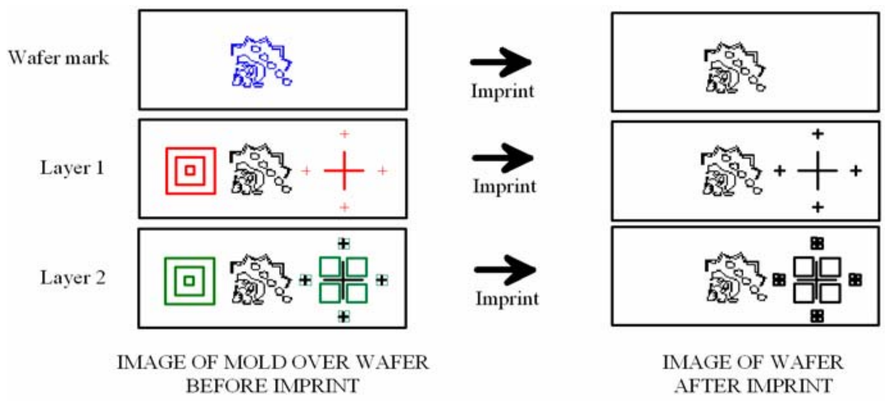

FIG. 1. Schematic of the nDSE-based DMA concept: molds with non-transferable alignment features are critical for its implementation. During the alignment phase of NIL, each new layer is first aligned to the pre-patterned wafer mark relative to the microscope field of view by nDSE. Nano-patterns (which are not discernable by optical microscopy) of the first and second imprinted layers are aligned indirectly by positioning the non-transferable alignment features of both the first and second imprint molds at the same displacement relative to the same "wafer mark" patterns on the substrate.

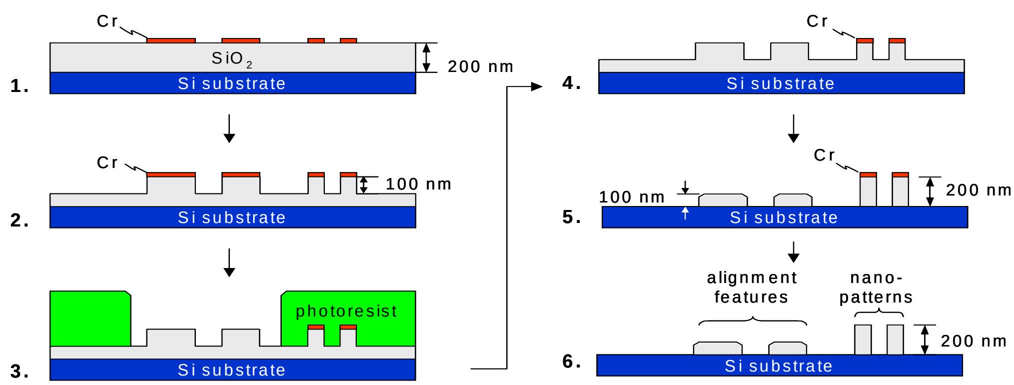

FIG. 2. Schematic of the processing steps for the fabrication of imprint molds with non-transferable alignment features. Both the alignment features and imprint features have to be generated in a single lithography step. Through processing, however, the alignment features are made significantly shallower than the imprint features.

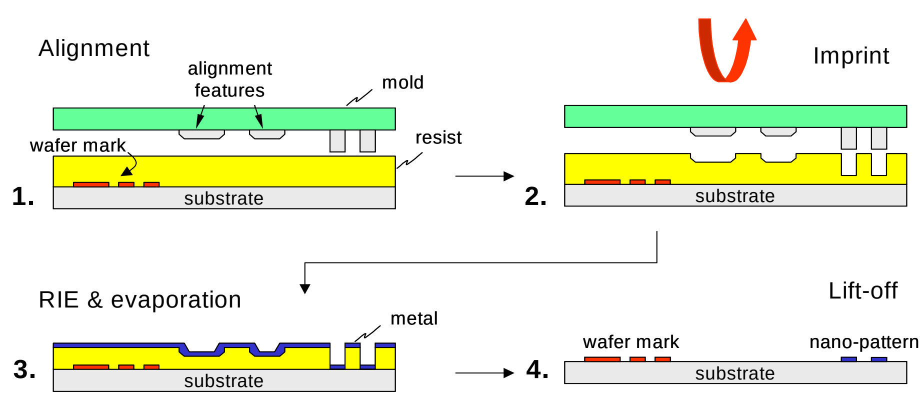

FIG. 3. Schematic showing the mold in action: the non-transferable features are used for the alignment step but these patterns do not transfer to the wafer after metalization and lift-off.