# 半導体デバイス製造用ナノインプリントリソグラフィの開発状況

# Nanoimprint Performance Improvements for Semiconductor Device Manufacturing

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Nanoimprint lithography (NIL) manufacturing equipment utilizes a patterning technology that involves the field-by-field deposition and exposure of a low viscosity resist deposited by jetting technology onto the substrate. The patterned mold is lowered into the fluid which then quickly flows into the relief patterns in the mold by capillary action. Following this filling step, the resist is crosslinked under UV radiation, and then the mold is removed, leaving a patterned resist on the substrate. The technology faithfully reproduces patterns with a higher resolution and greater uniformity compared to those produced by photolithography equipment. Additionally, as this technology does not require an array of wide-diameter lenses and the expensive light sources necessary for advanced photolithography equipment, NIL equipment achieves a simpler, more compact design, allowing for multiple units to be clustered together for increased productivity.

Previous studies have demonstrated NIL resolution better than 10nm, making the technology suitable for the printing of several generations of critical memory levels with a single mold. In addition, resist is applied only where necessary, thereby eliminating material waste. Given that there are no complicated optics in the imprint system, the reduction in the cost of the tool, when combined with simple single level processing and zero waste leads to a cost model that is very compelling for semiconductor memory applications. Any new lithographic technology to be introduced into manufacturing must deliver either a performance advantage or a cost advantage. Key technical attributes include alignment, overlay, defectivity and throughput. In this paper, we address overlay and throughput improvements.

Overlay has been addressed by applying methods that are unique to NIL. In 2021, MMO of 3.3 nm and SMO across the wafer was 2.4 nm using an FPA-1200 NZ2C were reported. These results were achieved by combining a magnification actuator system with a High Order Distortion Correction (HODC) system. Other process variables that are unique to NIL and that can be considered as process tunable variables include imprint force and tip/tilt of the imprint head relative to the wafer substrate during exposure. These variables can be used to modulate and control the overlay errors near the imprint field edges and provide good overlay control. An additional method to improve overlay is Refined Mold technology. The refined mold is manufactured based on the results of pre-test imprinting where the common error on the original mold is corrected. A cross matched machine overlay (XMMO) between ArFi and NIL by applying this technology has achieved less than 3 nm for the full fields.

For the purpose of further improvement of throughput and cost reduction, an alternative ambient gas for helium was investigated in the NIL process. Helium has been used in the NIL process because its high diffusivity has been regarded as the best solution to evacuate the gas between mold and wafer. The results of simulations and experiments proved that $CO_2$ was more efficient to evacuate the gas under the condition where the bottom layer of the resist stack includes a spin on carbon (SOC) film. Number of non-fill defect can be reduced and filling time can be shortened by using $CO_2$, thereby benefiting both throughput and cost of ownership.