Modelling and experimental investigation on liquid confinement in immersion lithography

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Abstract

Immersion lithography has extended the resolution of optical lithography into 45nm and below by replacing the air that currently fills the gap between the substrate and the final optical element with liquid of higher refraction index. Confining a slice of liquid beneath the lens area is the essential problem for real production tools. For higher industrial throughput, higher wafer scanning velocities and accelerations are required. A direct result from higher wafer motion speed is the immersion liquid deposition, also called as liquid leaking, which appears when a substrate is withdrawn from a liquid receding contact line. In an immersion lithography tool, the stains from evaporated liquid deposition may be transmitted to the printed pattern as defects. Published research has shown that the film-pulling velocity is strongly affected by the behavior of the receding three-phase contact line decided by immersion liquid properties and substrate surface. As in our previous work, a liquid injection and collection model with analytic solutions is presented, allowing the critical velocity to be predicted for a given gap height between wafer and lens using only a measurement of the injection speed and knowledge of the fluid properties.

In the current work, a liquid pulling and striding model with higher accuracy is presented and compared with experimental results. Taking more factors into account including the capillary phenomenon and soaking-dewetting ability of solid surface, this model shows higher accuracy especially for the gap less than 0.7mm between wafer and lens. Experimentally, various solid surfaces ranging from hydrophilic to hydrophobic and glycerine-water mixtures of varying viscosities are tested, to determine the effect on critical velocity, showing a mean average error with 10%. For evaluating alternative immersion photo resist materials and immersion fluid, this model provides a useful tool to avoid liquid deposition.

Keywords: immersion lithography, noncontact sealing, critical velocity model, surface tension

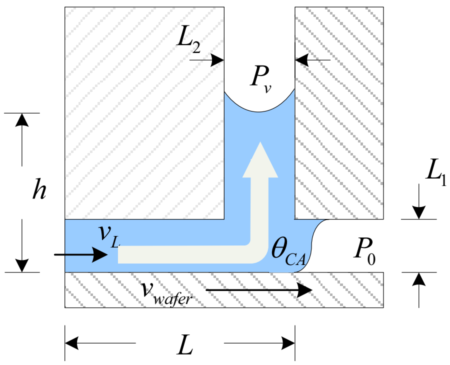

Figure 1. Schematic of the important parameters that affect noncontact sealing boundaries.

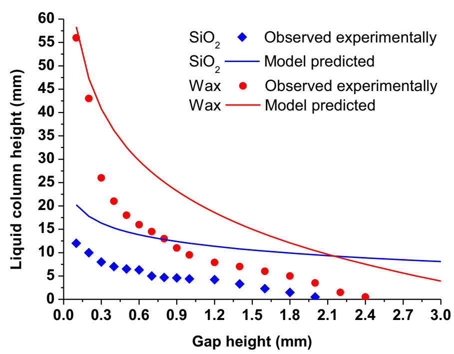

Figure 2. Liquid volume height supported by surface tension supporting vs. gap height within flow field between substrate and lens.

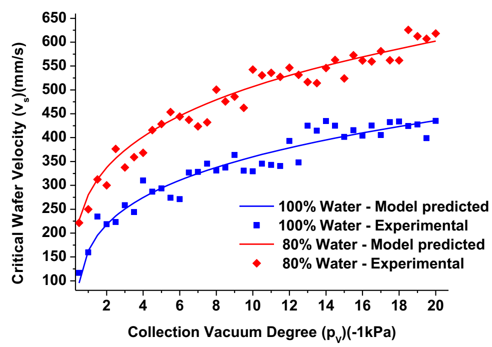

Figure 3. Critical velocity vs. liquid viscosity for experimental data and calculation model.