In-situ pre-development latent resist exposure measurements based on focus sensor and nanopositioning machine

Xinchang Zou*, Rostyslav Mastylo*,Thomas Kissinger*
*Institute of Process Measurement and Sensor Technology, Technische Universität Ilmenau
mailto:xinchang.zou@tu-ilmenau.de

This work presents a differential focus sensor for detecting exposed patterns in pre-developed photoresist. Based on the differential Foucault knife-edge principle, the technique achieves superior sensitivity compared to confocal sensors, differential interference contrast (DIC) microscopy, and scaning electron microscope (SEM). The method enables precise alignment for Mix-and-Match lithography and demonstrates robust performance across various resist types and thicknesses. This approach provides real-time, in-situ pattern registration for advanced resist positioning metrology.

1 Introduction

This work presents a non-destructive technique exploiting material property shifts in exposed pre-developed resist using the differential Foucault knife-edge principle.[1, 2] The method outperforms differential imaging contrast (DIC) microscopy and scanning electrode microscopy (SEM), enabling real-time pattern registration.[3, 4]

2 Setup

The setup integrates a differential focus sensor[2, 5] with the NMM-1 nanopositioning and nanomeasuring machine NMM-1 [6] (0.1 nm resolution). The sensor uses a 650 nm laser through a 50X objective, operating on the differential Foucault knife-edge principle to detect optical changes in exposed photoresist with real-time feedback.[7]

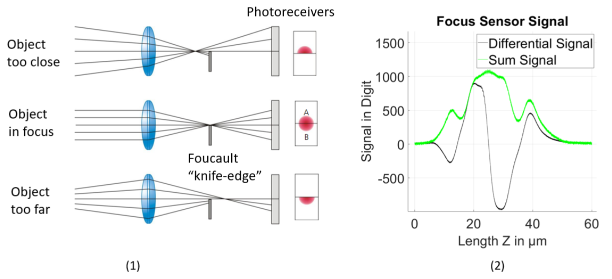

Fig. 1 *Foucault knife-edge principal is illustrated in (1). The whole laser spot (both A and B parts) can only be detected when object is in focus; when object is too close, only part A of laser spot can be detected; when object is too far only part B can be detected. The detected focus signal then is internally processed to get characteristic curve (2) of differential signal (black) and sum signal (green) which is comparable with confocal sensor signal. [8].*

3 Material and methods

Silicon wafers (25 mm × 25 mm) were treated with HMDS and spin-coated with AZ1505 or AZ ECI3007 photoresist at 2000-4000 rpm, yielding 0.68-0.96 μm thicknesses. Patterns were exposed using MLA150 (Heidelberg Instruments Mikrotechnik GmbH) at 80-160 mJ/cm². The pattern consisted of gratings with 2 μm lines and spacing from 97 μm to 1 μm. Latent patterns were characterized using a differential focus sensor with NMM-1, DIC microscopy and SEM.

4 Results

The focus sensor, as a real-time method, achieved distinct valley signals for exposed areas with signal-to-noise ratio (SNR) of 12.5 (Fig. 2), outperforming offline methods such as DIC microscopy and SEM. In dense regions (spacing < 3 μm), feature overlap occurred due to the 1 μm spot size limit, but single-scan clarity demonstrated superior performance for latent metrology.

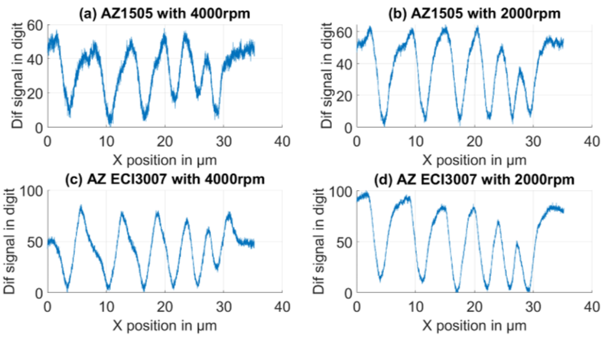

Fig. 2 *Comparison of measured signal among different photoresist type and thickness: (a) photorosist AZ1505 coated with spin speed 4000rpm; (b) AZ1505 coated with 2000rpm; (c) photoresist AZ ECI3007 coated with 4000rpm; (d) AZ ECI3007 coated with 2000rpm. The scan direction is always perpendiculer to the grating line direction.*

DGaO Proceedings 2026 – http://www.dgao-proceedings.de – ISSN: 1614-8436 – urn:nbn:de:0287-2025-P010
submitted: 17.07.2025 – published: 30.09.2025

DIC microscopy resolved grating patterns but 1 μm averaged profiles showed SNR of only 1.8, requiring 30-pixel averaging for clarity (Fig. 3). Dense regions exhibited partial feature overlap, indicating resolution limits.

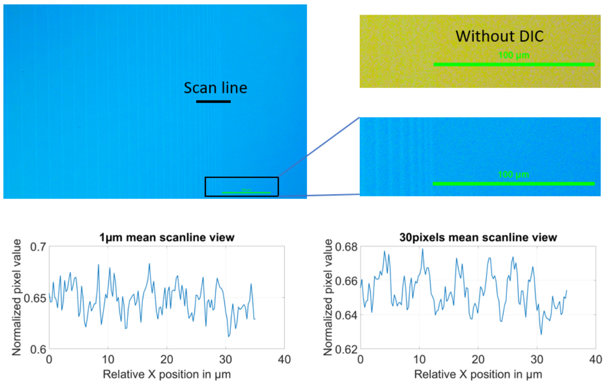

Fig. 3 *Exposed area of photoresist shows different color compared with unexposed area by DIC microscope (upper). Although the variable grating signal is overwhelmed in noise for the single scan line view (bottom left), it becomes more visible after 30 pixel width averaging. (bottom right)*

SEM provided coarse grating visualization with SNR of 2.1 after 1 μm averaging (Fig. 4). Single scan line view were dominated by noise, and signal distortion reduced precision compared to other methods.

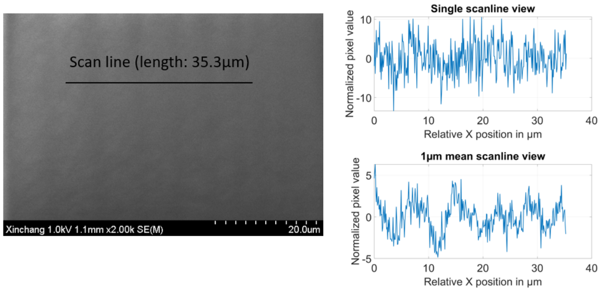

Fig. 4 *SEM image (left) of the sample captured by S-4800 (Hitachi); the exposed area is visible as valley in 1 µm-width averaged scan line view (right bottom) but is overwhelmed in noise in the single scan line view (right upper).*

5 Conclusion

This study introduces a high-sensitivity metrology technique for detecting exposed patterns in pre-developed photoresist using a differential focus sensor. The method achieves SNR of 12.5, significantly outperforming compared approaches, with robust performance across diverse resist types and thicknesses. Its real-time, in-situ capability enables immediate process monitoring, critical for micro- and nanofabrication. The technique shows potential for Mix-and-Match lithography pattern registration, where seamless alignment across multiple exposure tools is essential. By providing a non-destructive, high-sensitivity alternative to offline methods, it supports scalable process control. Future refinements addressing lateral resolution limitations could further expand its impact as a metrology tool in micro- and nanoscale technologies.

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submitted: 17.07.2025 – published: 30.09.2025