Highly spatially resolved chemical metrology on latent resist images

Maarten van Es, Selman Tamer, Elin Bloem, Laurent Fillinger, Elfi van Zeijl,
Klára Maturová, Jacques van der Donck, Rob Willekers and Diederik Maas.
*Netherlands Organisation for Applied Scientific Research (TNO), Delft,
Netherlands*

Patterning photoresist with extreme control over dose and placement is the first crucial step in semiconductor manufacturing. However, how can the activation of modern complex resist components be accurately measured at sufficient spatial resolution? No exposed nanometre-scale resist pattern is sufficiently sturdy to unaltered withstand inspection by intense photon or electron beams, not even after processing and development.

To control the quality of a lithographic exposure step in a semiconductor factory, and thus maintain a high yield, the critical dimensions (CD) of the pattern are regularly measured, e.g. using optical metrology, SPM or CD-SEM. Before a pattern in an exposed EUV resist can be measured, several consecutive steps are needed to let the pattern materialize by removing (un)exposed resist material, as summarized in Figure 1. E.g. exposed EUV resist needs typically three or four process steps before any metrology can be performed. During each of these steps the high-resolution latent image is modified in both a wanted and an unwanted direction. The process parameters critically determine final pattern fidelity. Unfortunately, their effect on the latent image could hitherto not be monitored, because high-resolution metrology tools, such as EUV or X-ray radiation or electron microscopy, directly influence and alter the resist. In other words, current metrology tools need completely developed resist to generate a significant and reliable *physical* signal for imaging the patterns to enable quality control.

This paper presents experimental proof that infrared atomic force microscopy (IR-AFM) is sufficiently sensitive and gentle to *chemically* record vulnerable yet valuable lithographic patterns in a chemically amplified resist *after* exposure *prior* to development. Accordingly, IR-AFM metrology provides long-sought insights into changes in the chemical and spatial distribution per component in a latent resist image, both directly after exposure and during processing. With these to-be-gained understandings, a disruptive acceleration of resist design and processing is expected.

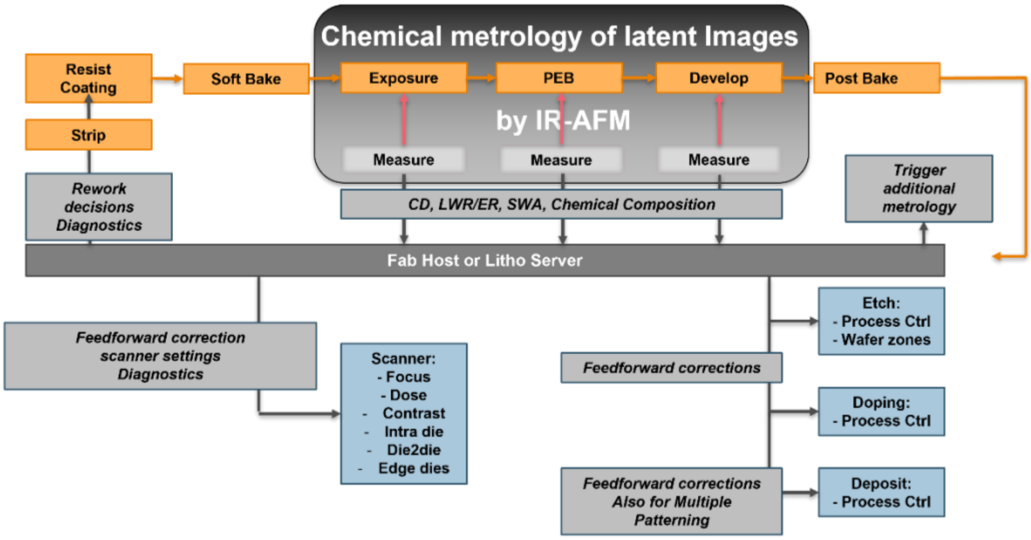

Figure 1 Schematic of the process flow for the repeated steps in an IC manufacturing factory. IR-AFM enables chemical metrology after exposure, Post-Expose-Bake and development of the latent image of the patterned resist, potentially for multiple resist components.

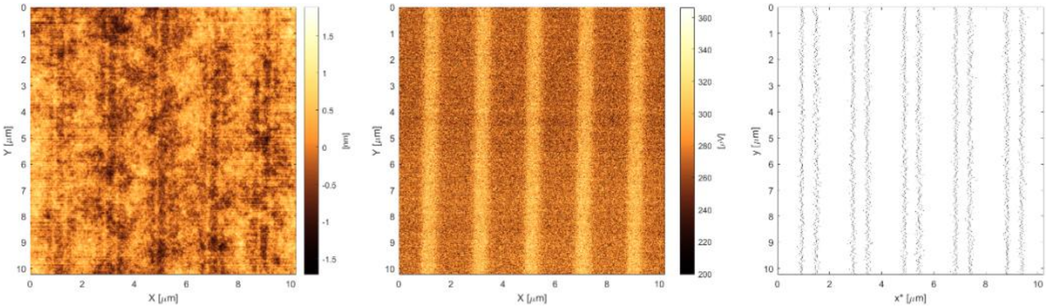

Figure 2 Images of 500 nm wide lines at 2 μm pitch in exposed and baked NEB22 chemically amplified resist. The pattern was exposed by electron-beam lithography at a dose of 40 μC cm-2. The AFM image (left panel) hints at the presence of some topography but is incapable of supporting metrology data extraction. The IR-AFM image (center panel), recorded at an infrared frequency of 984 cm-1, yields a clear 'chemical map' of post-bake undeveloped resist. The right panel shows line edges extracted from tilt-angle-corrected IR-AFM data.