Modulus Mapping in High Resolution Patterned Features

Prashant K. Kulshreshtha, Dominik Ziegler, Deirdre Olynick, Paul D. Ashby
Molecular Foundry, Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley, California 94720
pkkulshreshtha@lbl.gov

Ken Maruyama
JSR Micro INC, 1280 N. Mathilda Ave, Sunnyvale, CA 94089, USA

James Blackwell
Components Research, Intel Corporation, 2511 NW 229th Avenue, Hillsboro, Oregon 97124

Patterning failure due to line bending, wiggling, tearing and de-adhesion have been observed at various processing steps of device fabrication. For example, unbalanced capillary forces during the post-development drying of a patterned resist can force lines to collapse (see Fig. 1). Collapse is also observed in etched layers during plasma processing. Numerous factors, such as aspect ratio, substrate adhesion, and modulus influence the susceptibility to collapse. However, these properties are not easy to evaluate, specifically at the scale of current state-of-art lithographic processes. Here we evaluate new techniques for high-resolution modulus mapping towards modulus characterization of high resolution patterned features.

In this study, we have extensively evaluated two different methods towards quantitative mechanical measurements in patterned materials: 1) Bruker's Peak Force™ Tapping method, and 2) Asylum Research's AM-FM method. Measurements were made on lithographically patterned resists and plasma patterned low-k dielectrics. With both methods, extensive calibration, references, and technique tuning are needed to acquire meaningful data.

Data on patterned resists acquired using Bruker's Peak Force™ Tapping method is shown in Figure 2. Modulus, adhesion and topographical morphology images are shown for 1:1 lines in an electron-beam exposed negative-tone chemically amplified (CA) Noria based resist (Fig. 2(a)). Image contrast is easily acquired but quantitative analysis between images (Fig. 2b) required accurate measurement of k (spring constant of the tip), deflection sensitivity of cantilever (Z_o), and tip radius (R). Even with careful calibration, errors in the range of 10-25% are commonly observed. Errors are evaluated and minimized with several approaches including in-fluid measurement which reduces erroneous tip-sample adhesion. Similarly, we have evaluated the Asylum Research's AM-FM technique. Utility and limits of each technique will be discussed in the context of high-resolution lithographic and plasma patterning.

Acknowledgements: Part of this work was performed at the Molecular Foundry which is supported by the U.S. Department of Energy, Office of Basic Energy Sciences, under contract DE-AC02—05CH11231.

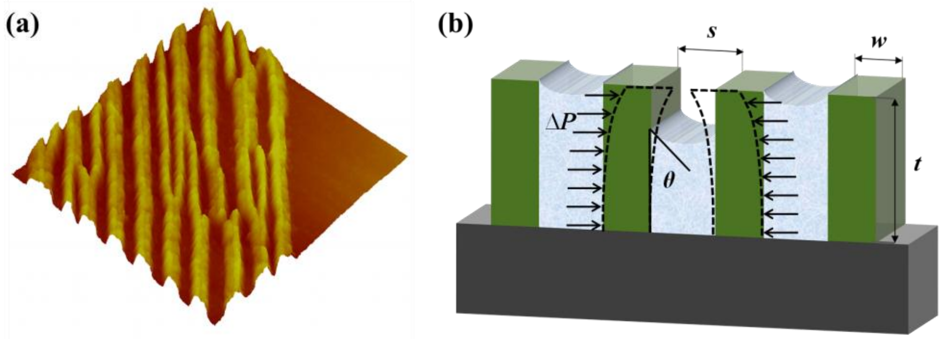

Figure 1 - (a) 3D rendering of an AFM for collapsed resist pattern showing resist tear, folding, line breakages. (b) Schematic depicts an example of pattern collapse due to unbalanced capillary forces acting on linear features of the resist during drying stage.

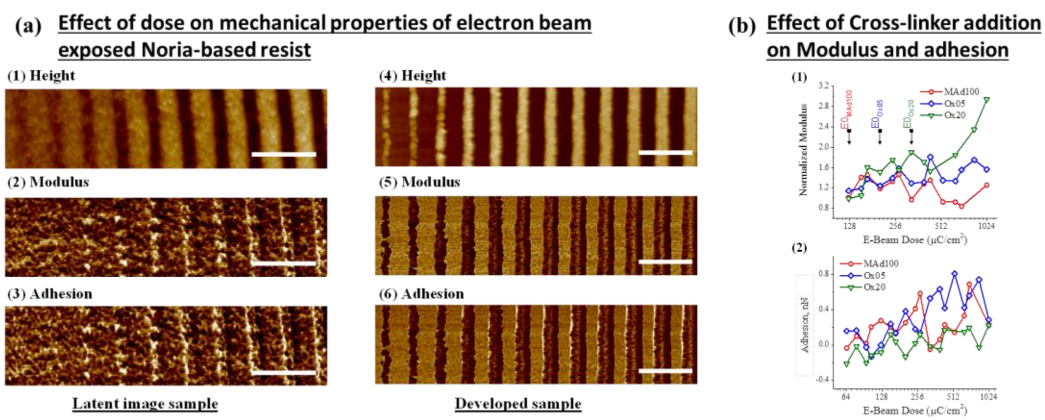

Figure 2 – (a) Modulus and adhesion contrast observed on an e-beam exposed latent image and developed sample at100 nm HP pattern. Scale represents 400 nm. (b) Modulus and adhesion measurements on developed cross-linked Noria resist (0, 5 and 20%) at different e-beam exposure doses. Arrows represent the minimum dose required to pattern a full-thickness of resist.