Literature Digest
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Highlights of the 2004 SPIE Microlithography Symposium
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For this summary, we selected five topics among the presented material: CD measurement technology, CD control techniques, line edge roughness effects, immersion lithography and nanoimprint. Compared to last years review (Literature Digest vol. 7), we added CD control techniques which due to the progress in optical CD measurement become more and more prevalent. The number of papers on immersion lithography was significantly larger compared to last year's conference. Immersion lithography now seems to be widely acknowledged as the mainstream lithography method for 65 nm and below. In this summary, we focus mainly on the interaction of the resist with the immersion fluid since this could influence the properties of the subsequent plasma etch. We added nanoimprint as another promising emerging candidate for pattern transfer.

Advanced Critical Dimension (CD) Measurement Techniques

B. J. Rice et al (paper 5375-16 by **Intel** and **UC Berkely**) presented a study of various metrology technologies including **CD-SEM**, **scatterometry**, and **AFM** to measure structures with dimension representative of the 45 and 32 nm nodes. The structures were fabricated at the Center of X-Ray Optics at Lawrence Berkeley Optics. The smallest isolated lines are 16 nm and the smallest holes are around 45 nm. The authors conclude that CD SEM will be capable at 16 nm lines and 45 nm holes, that Scatterometry can predict the CD correctly for 16 nm lines, but profile fidelity is still an open question, and that AFM encounters roadblocks at these technology nodes.

J. Foucher et al (paper 5375-49 by **CEA-LETI**) compared the capabilities of 3D **AFM** and 3D **CD-SEM** for advanced cross sectional analysis. The main measured parameters were line edge roughness (LER), sidewall angle, top and bottom CD as well as thickness (depth).

J.-A. Kim (paper 5375-56 by **SAMSUNG** Electronics) reported on the use of angular **scatterometry** (**ACCENT** Optical Technologies) for process control of sub 100 nm DRAM devices.

In another contribution on the use of **scatterometry** to dRAM applications, T. Hingst et al. (paper 5375-63 by **Infineon** Technologies and **KLA-Tencor**) applied scatterometry to the characterization of poly-Si filled **deep trenches** (deep trench capacitors) which comprise complex 3D structures.

M. Sendelbach et al. (paper 5375-60 by **IBM** and KLA**-Tencor**) presented a study correlating post gate etch **scatterometry, CD-SEM and electrical gate length measurements**. Scatterometry is shown to be competitive with CD-SEM when both are correlated to the electrical gate length measurements.

C. Raymond et al. (paper 5375-61 by **Accent** Optical Technologies, Inc.) gave a comparison of the library and the model optimization approaches for the solution of the **inverse scatterometry problem** (the modeling of the measured structure based on the optical signal). They find the library method more robust but more time consuming then the model optimization approach.

A study on using **scatterometry** for measure **shallow trench** structures was presented by P. Leray et al. (paper 5375-62 by **IMEC** and **KLA-Tencor**). The main subject is the optimization of the library (size vs. generation time).

Another two papers on the use of **scatterometry** for **shallow trench** process control were presented by R. Peters et al. (paper 5375-85 by **KLA-Tencor** and **Texas Instruments**) and I. Dudley and A. Somadder (paper 5375-117 by **FASL** LCC and **Timbre Technologies**). The TI paper states that all critical parameters (film thickness, trench depth, and CD) were obtained in a single measurement. OCD is currently being used for process control and product disposition in two fabrication facilities at Texas Instruments.

In a fourth paper on the use of **scatterometry** for **shallow trench** characterization by Y. Feng (paper 5375-143 by Nanometrics and SELETE, Inc.), normal incidence polarized reflectometry was applied to sub-50 nm grating lines. Rigorous Coupled Wave Analysis (RCWA) was used for the real time regression without the need of library generation. Good correlation with CD-SEM data was obtained.

S. Fu et al. (paper 5375-139 by **KLA-Tencor** and **UMC**) reported on the application of **spectroscopic ellipsometry** towards the detection of poly-Si gate **profile excursions** at the 130 and 90 nm technology nodes. The method was able to flag a notch wit a height of 30 nm and a width of 15 nm.

CD control techniques

Q. Zhang et al (paper 5375-26 by **AMD** and **UC Berkely**) showed the CD uniformity improvement by using a combined control of die-by-die exposure and multizone (6 zones) PEB temperature control.

J. E. Tiffany and B. Cohen (paper 5377-79 by **Infineon** Technologies and **SensArray** Corporation) focus in their paper on the **dynamic behavior** of the individual channels of a **multi-channel PEB** plate. The current practice to setup each plate to match the steady-state target temperature is insufficient.

M. Sendelbach et al. (paper 5375-73 by **IBM** and **TEL**) promoted **integrated metrology** (scatterometry) for enabling **wafer-to-wafer CD control**. The method was applied to a special hardmask TRIM process (Chemical Oxide Removal – COR) after the hardmask open and resist removal processes. The COR process chamber is integrated into the etch system. The wafers were measured again after gate etching with integrated scatterometry and stand-alone CD-SEM.

B. Brill et al. (paper 5375-124 by **Nova** Measuring Instruments and **LAM** Research) reported on the use of **scatterometry for process control and fault detection**.

K. Barry et al. (paper 5375-130 by ***TEL*** *and* ***Timbre*** *Technologies) find that integrated* ***3D scatterometry*** *is viable production metrology solution for* ***contact hole lithography****. They report the successful measurement CD, film thickness, profile variations, as well as scumming of the contacts.*

D. Mui et al. (paper 5378-02 by ***Applied Materials****, Inc.) report on feed forward and* ***feed back gate CD control*** *with in* ***integrated OCD*** *measurement system. One-parameter and two parameter (resist CD and sidewall angle) feed-forward control schemes are compared.*

O. Krog et al. (paper 5378-03 by ***Blue Control Technologies****) reported on experimental results* ***multivariable CD control****.*

Line edge roughness

*K. Shibata et al. (paper 5375-94 by **SELETE** Inc.) studied the correlation of **LER** and transistor performance (**Vth, Ion, and Ioff**) with a specially designed test layout. The design had about 1000 transistors in an area of 3 mm^2. Each transistor could be selected for measurement independently. The area was small enough to exclude intra chip variations. 193 nm and 248 nm resists were used to fabricate 40 nm devices. It was shown that a LER 0f 6 nm did not not influence 100 nm devices but impacted negatively the 40 nm transistors.*

*M. Williamson and A. Neureuther (paper 5376-43 by **UC Berkeley**) presented evidence that the **background exposure dose** is key to image-induced line edge roughness.*

*J.-Y. Lee at al. (paper 5376-45 by **SAMSUNG**) reported that the **aerial image contrast** and the **plasma etch process** had largest effect on line edge roughness.*

Immersion lithography

W. Hinsberg et al. (paper 5376-03 by **IBM**, **Clariant Corp.**, and **Motorola**, Inc.) discussed results of near-edge X-ray adsorption (NEXAFS) and secondary ion mass spectrometry (SIMS) surface analysis to characterize the **extraction of resist components** and the **permeation of water** into the polymer films. The impact of these processes on the lithographic and imaging properties has been evaluated.

In a study on the same subject (**interaction of water with 193 nm resists**), J. C. Taylor et al. (paper 5376-04 by **IBM** and **U. of Texas / Austin**) used C14 labeling to measure to amounts of the casting solvent (propylene glycol methyl ether acetate), the photo acid generator (triphenylsulfonium nonaflate), and the base quencher (triethanolamine) leached into the water.

S. Kishimura et al. (paper 5376-05 by **Matsushita**) studied the **interaction** of various 193 and 157 nm resists with **water** and **perfluoropolyethers**. Various interaction have been found including resist swelling and dissolution. RDA (resist development analyzer), QCM (quartz crystal microbalance), and FT-IR were used to study the interactions.

C. L. Soles et al. (paper 5376-06 by **NIST** and **IBM**) found that the **moisture uptake** of 193 nm resist in water is different for **thin resists** (50 nm) when compared to thicker resists.

T. Honda et al. (paper 5377-27 by **Canon**, Inc.) report on the issues related to ArF immersion lithography, specifically on the **formation and dynamics of bubbles** in the immersion liquid.

Nanoimprint

A paper by G.-Y. Jung et al. (paper 5374-20 by **Hewlett-Packard** and **Applied Molecular Systems**) reported on the fabrication of the smallest rewritable, **nonvolatile memory** using nanoimprint technology. The active molecular layer was deposited by the Langmuir-Blodgett technique.

EV Group presented a paper on **Hot Embossing** (HE), Nanoex Corporation on **UV-curable nanoimprint lithography** (UVC-NIL), and Molecular Imprints Inc. on **Step and Flash Imprint Lithography** (S-FILTM) (papers 5374-21 to 5374-25).

D. J. Resnick et al. (paper 5374-120 by **Motorola**) presented a report on the evaluation of the S-FILTM tool from Molecular Imprints.