Effect of Photo Acid Generator Concentration on the Performance of a Model EUV Photoresist

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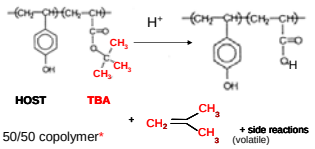
Michael Leeson[2], Heidi Cao[2], Manish Chandhok[2], George Thompson[3], Bryan Vogt[4]

Abstract

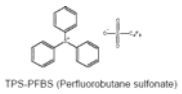
Current EUV photoresist materials do not yet meet requirements on exposure-dose sensitivity, line-width roughness, and resolution. Fundamental studies are required to quantify the trade-offs in materials properties and processing steps for EUV-resist specific problems such as high PAG loadings and the use of very thin films. Further, new processing strategies such as changes in the developer strength and composition may enable increased resolution. In this work, model EUV photoresists are studied to investigate the influence of photoacid generator (PAG) loading and developer strength on EUV lithographically printed images. Measurements of critical dimensions and pattern density of both the latent image and developed line-space patterns were examined for for features ranging from (30 to 120) nm by combined methods.

Model EUV Resist

Model EUV Photoresist



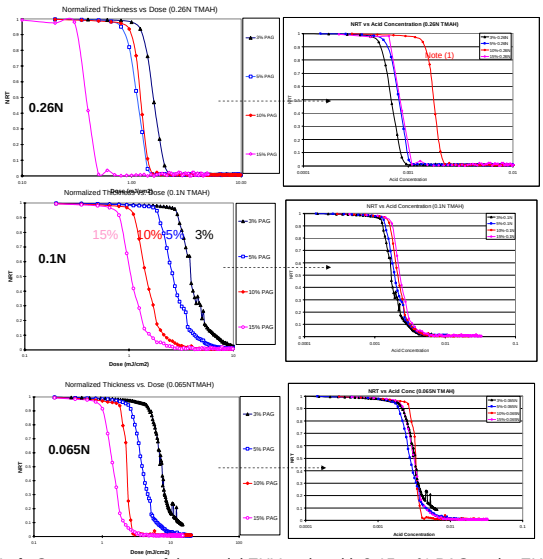
Photoacid Generator



- Allows pattern transfer study from latent to developed images with fewer materials parameters (not intended to maximize patterning resolution)
- No base quencher or other additives in photoresist
- Developed in TMAH developer of various strength (0.26/0.1/0.065N) without surfactant. Film thickness ~100nm, EUV Exposures at LBNL (ALS/MET- annular σ=0.3/0.55) and Albany Sematech North
- All PAB=130C/60sec, PEB=90C/30s, LWR analysis on 120/100nm 1:3 lines to minimize focusing effect
- Aerial image/ILS derived for ALS/MET using the aberration file provided by P.Naulleau (LBNL)

Results

Contrast Characteristics



Left: Contrast curves of the model EUV resist with 3-15 wt% PAG under EUV exposure developed with various TMAH strength

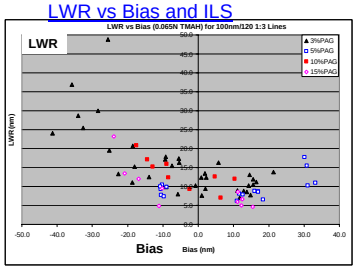
Right: dependency on estimated acid concentration.

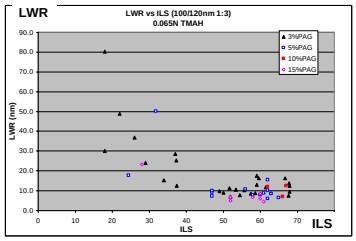
"Estimated acid concentration required to clear film" for all PAG loading similar for a given TMAH strength . Slight shift to a higher "acid concentration required" for higher PAG loading noticeable at the mid point NRT (normalized resist thickness) for 0.26N/0.1N TMAH developer.

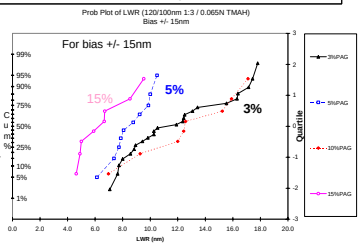
Note (1) anomaly with 10% PAG/0.26N TMAH data shift – no root cause explanation

(2) assumed acid efficiency = 2 (Ref 1)

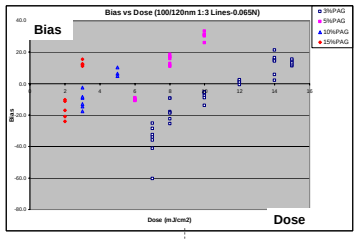
LWR vs Bias and ILS

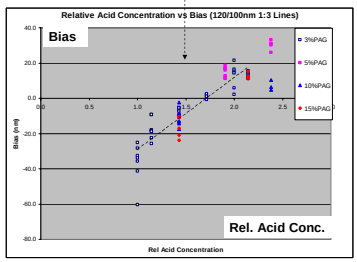






Bias vs Dose and Estimated Acid Concentration





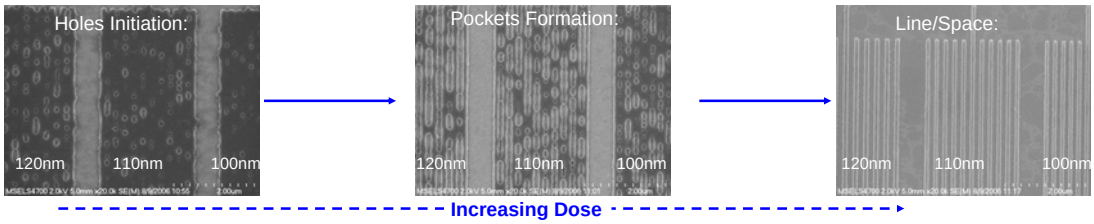
120/100nm (1:3) Line Bias (Design CD – Final Resist CD) with PAG loadings (3 to 15 wt%).

Final acid concentration required for zero bias similar for all PAG loadings investigated.

Note: slight shift to a higher relative acid concentration required for 15% PAG loading requires further investigation. (ref 2)

LWR comparison from a series of PAG loading samples exposed on the same day showing correlation to the bias and ILS. 15% PAG loading resulted in the lowest LWR for 0.065N TMAH developer strength.

Model Resist Line Formation



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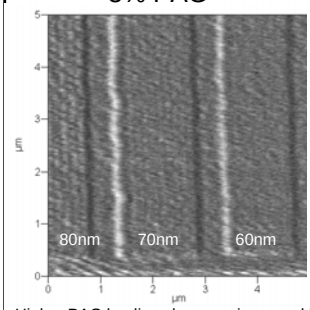
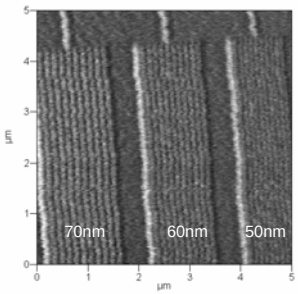
Latent Image Comparison of 70/60nm (1:1) Line/Space by Chemical Force Microscopy (Ref: Poster 02-RE41: John T. Woodward)

3% PAG

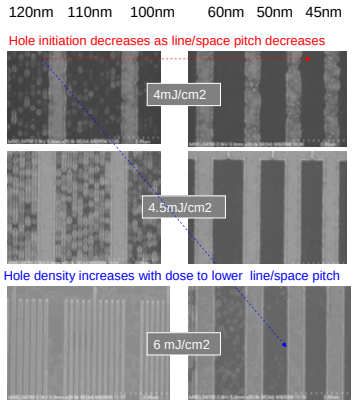


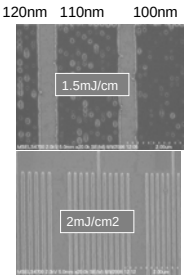
15% PAG



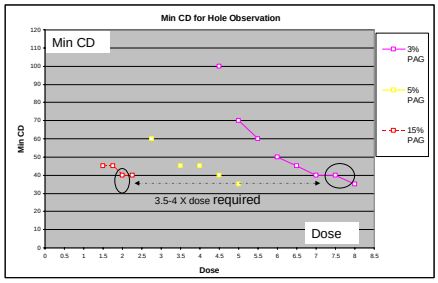
Higher PAG loading shows an improved latent image formation for the same EUV dose (before development). Deprotected image formation is PAG limited in this specific example.

3% PAG 0.26N TMAH/60s 15% PAG





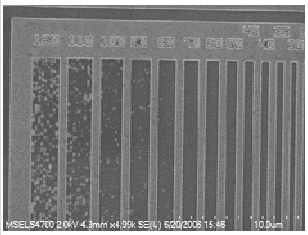
Hole formation/initiation dependents on line/pitch and shift with dose and PAG loading



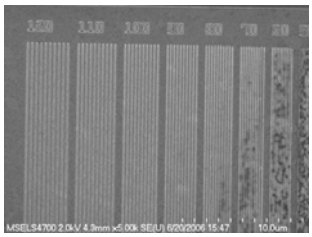
For 15% PAG loading: 1.5-2 mJ/cm2 to initiate a hole in 40/45nm 1:1 Line/Space vs 6.5-7mJ/cm2 for 3% PAG loading.

Expected a factor of 5X from 3% to 15% PAG loading difference.

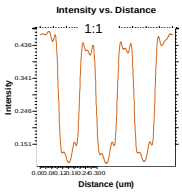
10%PAG-0.26N: 2.25 mJ/cm2: 1:1

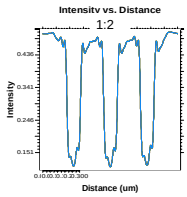


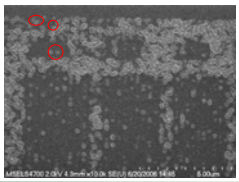
10%PAG-0.26N: 2.25 mJ/cm2: 1:2



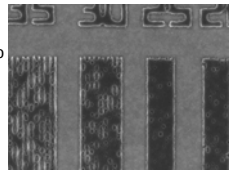
100nm Aerial Image







Holes formation also observed in open areas



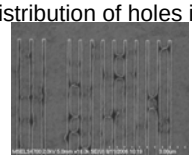
Holes/Pockets formation can be also observed in a commercial EUV photo resist

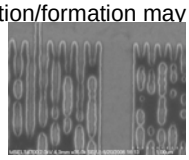
Implications and Conclusion

1. Demonstrated patterning capability of a model EUV resist system which can be used to study the development of latent images to final patterns – clarify sources of resolution limits and identify processing strategies for resolution enhancement.
2. Highlighted a sequence of line formation in the model EUV resist system:

   Initiation of hole formation is modulated by Dose/PAG Loading/Line-Pitch suggesting that the interaction between EUV photons and PAG distribution (final available acids required for deprotection).
3. Series of PAG loading and developer strengths comparison for the LWR on the model EUV resist suggests that a combination of higher PAG loading (15 wt%) with low 0.065N TMAH developer produces a better LWR.

   In this specific model system, all PAG (TPS-PFBS) loading up to 15wt% showed no performance issues.
4. Many partially formed lines/edges studied under SEM indicate a possible correlation of holes/pockets formation with final line edge fidelity. More detailed analysis and comparison of holes distribution/frequency to final line edge structure is required. However, further understanding and improvement of initial distribution of holes initiation/formation may potentially lead to the identification of strategies to improve LWR.





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(1) R. L. Brainard, P.Trefonas,J.H.Lammers, C.A.Cutler, J.F.Mackevich, A.Trefonas and S.A.Robertson, Proc. SPIE 5374, 74 (2004)

(2) A.Pawloski and P.F. Nealey, J. Vac. Sci. Technol. B 20(6), Nov/Dec 2002, 2413-2420

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