MECHANISM OF PATTERN COLLAPSE IMPROVEMENT USING TBAH DEVELOPMENT

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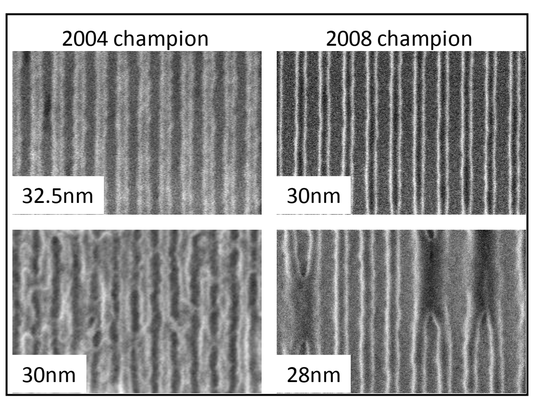
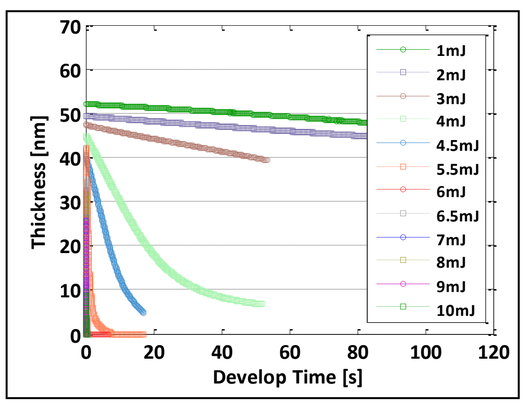
Introduction

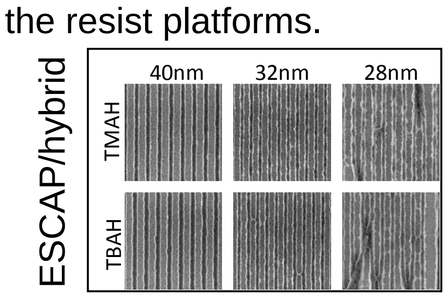
Pattern collapse has emerged as primary failure mode in current advanced EUV resists (left figure).
Development using 0.262*N* tetra-butyl ammonium hydroxide (TBAH) instead of conventional 0.262*N* tetra-methyl ammonium hydroxide (TMAH) has been proposed for pattern collapse mitigation.[1,2] Reduction of resist swelling during development has been proposed as the operating mechanism. In separate experiments using a development rate monitor we have not been able to find support for this mechanism (right figure).[3] In this paper an alternative mechanism is proposed to explain the observations.

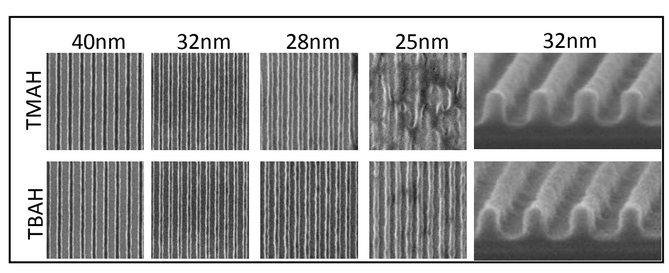


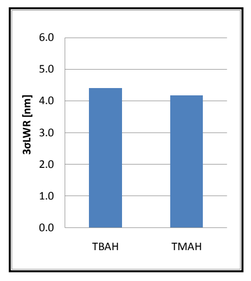


Pattern Collapse and LWR impact

In our hands we have confirmed improved pattern collapse (without significant impact on the dose) for TBAH development for some processes. TBAH typically allowed targeting 3-5nm smaller CD before collapse. For other resists, no impact of the developer chemistry was found. The general trend appeared that acrylate resists show good response to TBAH, while it has no impacts for ESCAP materials.
In contrast to earlier reports[1,2] we have found no impact of the developer chemistry on LWR for either of the resist platforms.
In a dedicated experiment an ESCAP chemistry was compared to 3 acrylate chemistries: a blended PAG, an anion and a cation-bound PAG formulation.
The acrylates all showed similar collapse improvement and the ESCAP none.

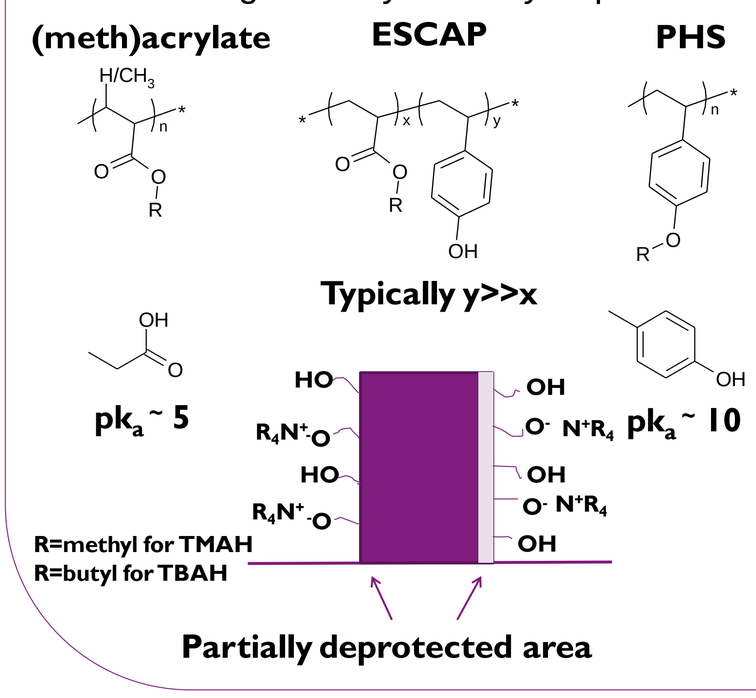






Proposed Mechanism

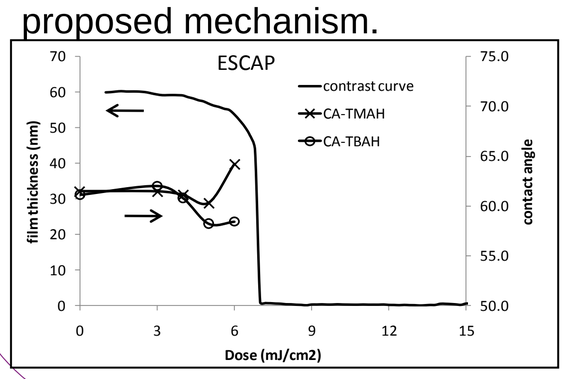
The contact angle of the rinse liquid with the resists material is a primary parameter that determine the extent of pattern collapse. Poor interaction of the rinse material with the resist, resulting in a high contact angle is beneficial for collapse reduction. A more hydrophobic surface will thus show less collapse. The cation in TBAH is significantly more hydrophobic than that in TMAH.

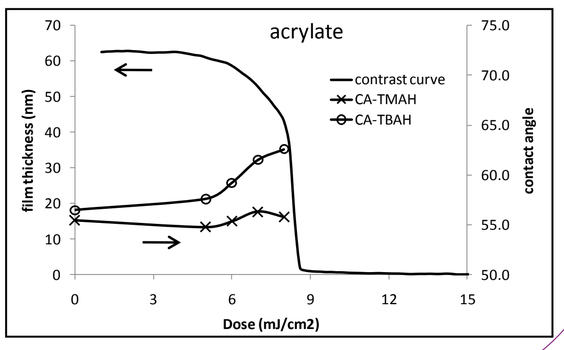


Due to the high acidity of the resist surface in acrylate chemistries, modification of the partially deprotected resist surface at the line edge by the developer cation may be likely. For the far less acidic ESCAP materials, the resist surface will be largely reprotonated after rinse.

Developer Impact on Resist Contact Angle

Supporting evidence for the proposed mechanism was sought from contact angle (CA) measurements. Sub-E0 open frame exposures on ESCAP and acrylate platforms were performed and the wafers were developed with TMAH and TBAH using a standard develop flow and DI water rinse. After spin-drying the wafer, the DI water contact angle was measured for each dose.
In the ESCAP material (left) no significant difference in CA between TMAH and TBAH development was found, indicating no significant surface modification. The increased CA for TMAH near E0 is attributed to surface roughening. For the acrylate material (right), CA rises with dose upon TBAH development indicating that the surface hydrophobicity increases. This is in agreement with the proposed mechanism.





Conclusions

We have confirmed with exposures on the ASML ADT that using TBAH instead of TMAH as developer chemistry may have beneficial impact on pattern collapse. Lines may be targeted to 3-5nm smaller CD (depending on film thickness) before collapse and resolution may be improved. We have not found any impact of developer chemistry on LWR. No independent evidence has so far been found to support the originally proposed swelling mechanism. An alternative mechanism based on surface modification by the developer has been proposed to explain these observations. This mechanism also explains why it works for some chemistries but does not for others. Independent contact angle measurements are in agreement with the new mechanism. It should be noted that swelling and surface modifications may both operate in determining lithographic differences between TMAH and TBAH.

References

1) Itani, T.; Oizumi, H.; Kaneyama, K.; Kawamura, D.; Kobayashi, S.; Santillan, J. J. *J. Photopolym. Sci. Technol.* **22**(1), 59-64 (2009).
2) Matsunaga, K.; Oizumi, H.; Kaneyama, K.; Shiraishi, G.; Matsumaro, K.; Santillian, J. J.; Itani, T. *2009 EUVL Symposium*, Prague, Czech Republic.
3) Fonseca, C.; Shite, H.; Head, B.; Nafus, K.; Winroth, G.; Gronheid, R. *2010 EUVL Symposium*, Kobe, Japan.