Characterization of EUV Resist Dissolution using *In situ* Analysis

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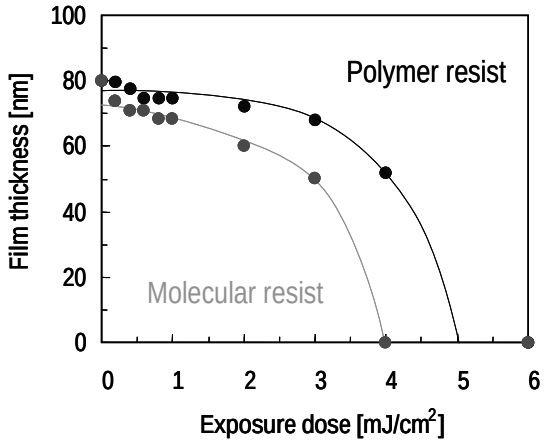
Outline

- Introduction / background
- Materials & processing
- Results and discussions
  - Polymer resists (PHS-based, Acryl-based)
  - Low molecular resist (Fullerene-based)
  - TMAH and TBAH developer
- Summary

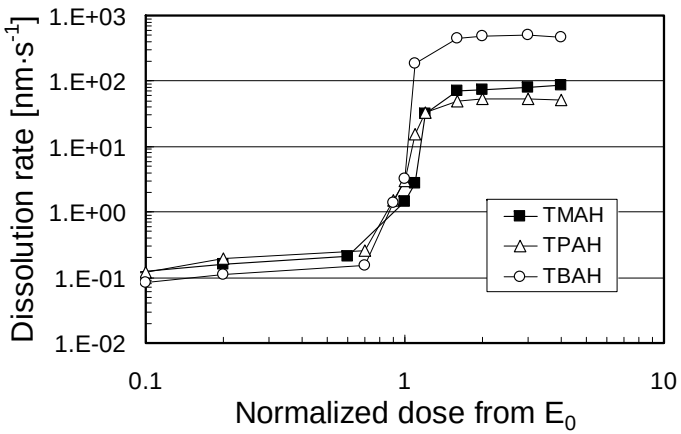
Analysis of dissolution characteristics (example)

Selete

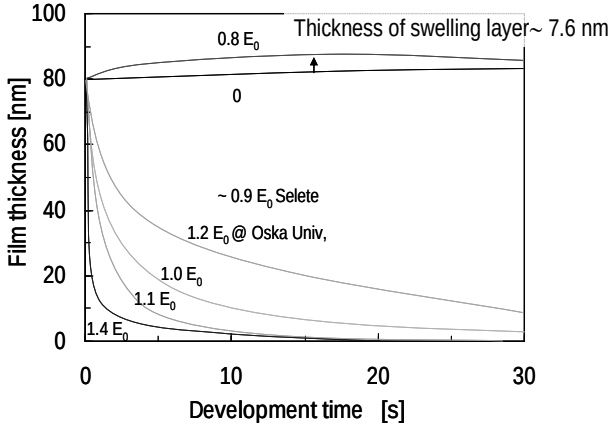
Sensitivity curves



Dissolution rate monitor



Quartz crystal microbalance



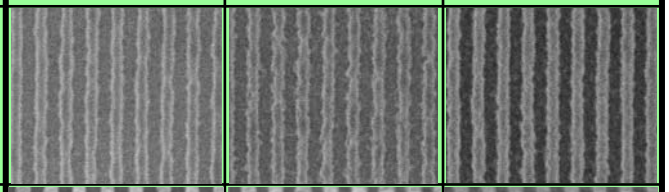
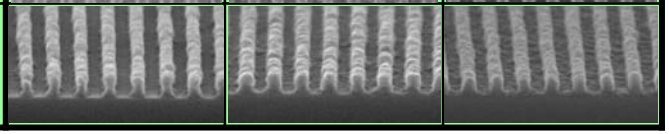
- Several methods have been utilized to understand the dissolution characteristics of resist films.
- However, no direct visual evidence of the actual dissolution process has been presented at this time.

- High speed atomic force microscopy (HS-AFM) has potential in *in situ* dissolution characterization.

Materials & processing

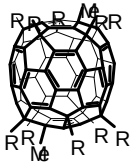
- Resist materials (Film thickness: 60nm)
  - Acryl-based polymer EUV resist (SSR4)
  - PHS-based polymer EUV resist (SSR5)
  - Fullerene-based low molecular resist (SMR601)

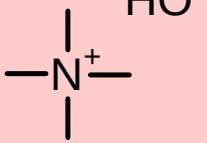
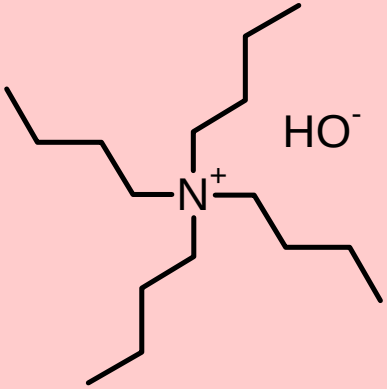
- Developers
  - Tetramethylammonium hyrdroxide (TMAH)
  - Tetrabutylammonium hydroxide (TBAH)

Resist name	SSR4	SSR5	SMR601
Dose (mJ/cm^2) @hp32nm	12.4	10.7	19.3
Resolution (nm L/S)	28	26	28
LWR (nm) @hp32nm	5.5	7.5	5.6
Top-down SEM (hp32nm)			
Cross-section SEM (hp32nm)			

Exp. Tool :SFET, NA0.3, Annular (0.7/0.3), Resist Thick. 60nm

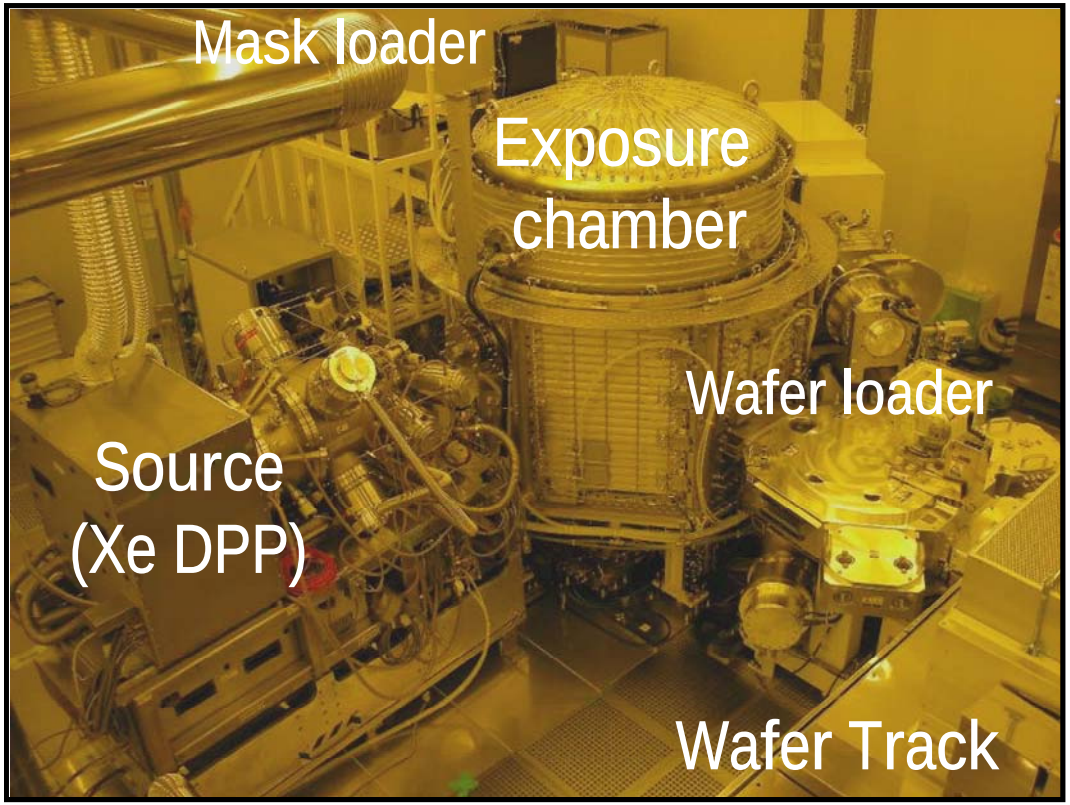
H. Oizumi, et.al: Proc. SPIE 7639 (2010) 76390R.



TMAH (Mw=91)	TBAH (Mw=259)
	

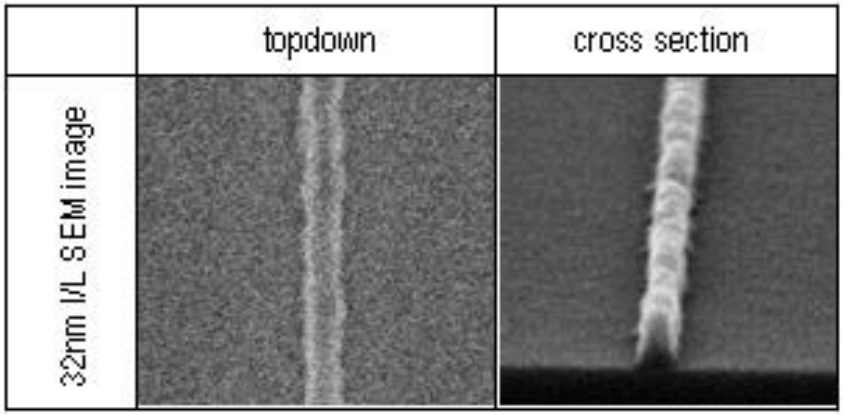
T. Itani and J. J. Santillan: J. Vac. Sci. Technol. B 27 (2009) 2986.

Lithographic evaluation conditions



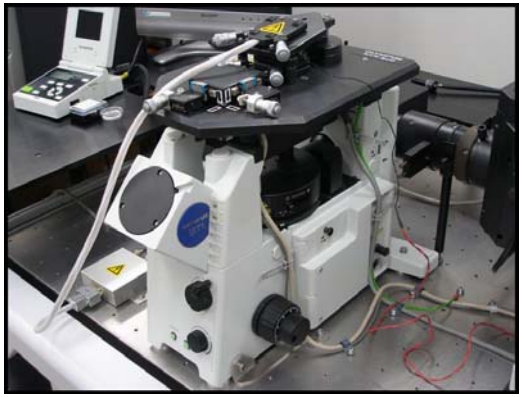
Exposure Condition

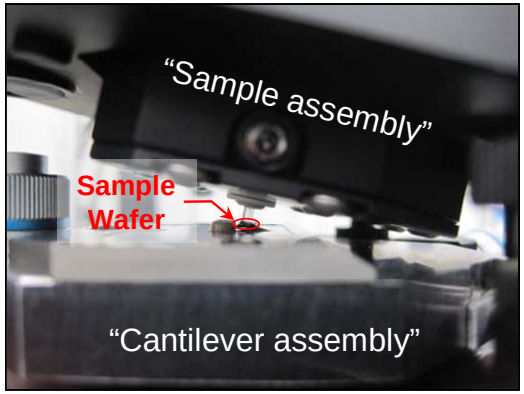
Tool	: SFET (Canon)
NA	: 0.3
Illumination	: Annular
σ	: 0.3/0.7

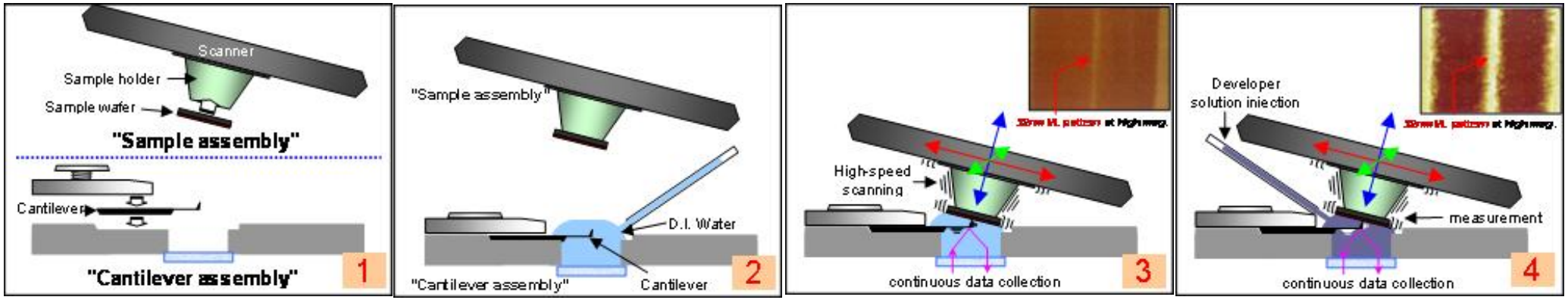


- Pattern exposures of 32nm Isolated line (I/L) prepared for analysis.

HS-AFM measurement system & procedure

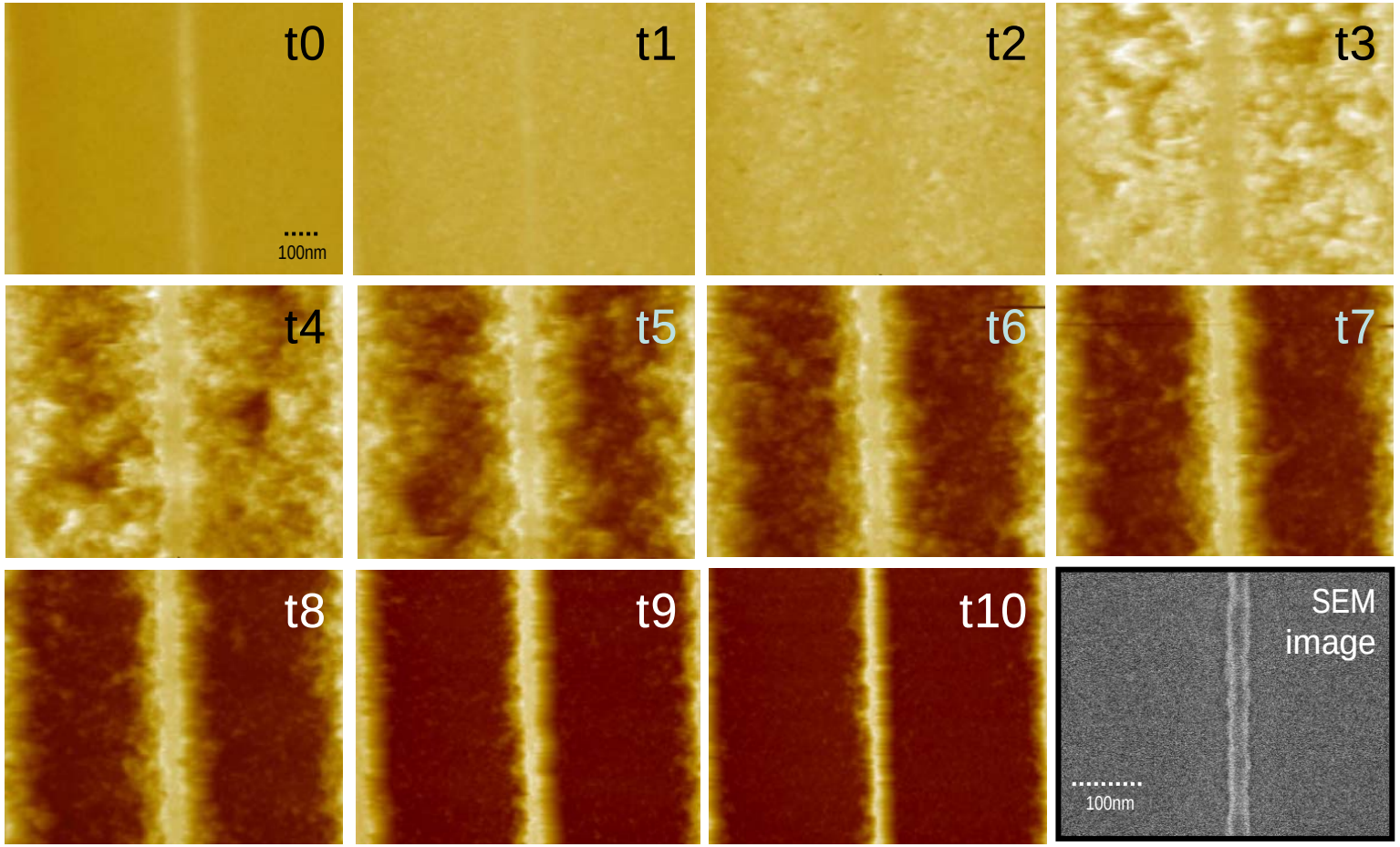






PHS-based polymer resist (SSR5)

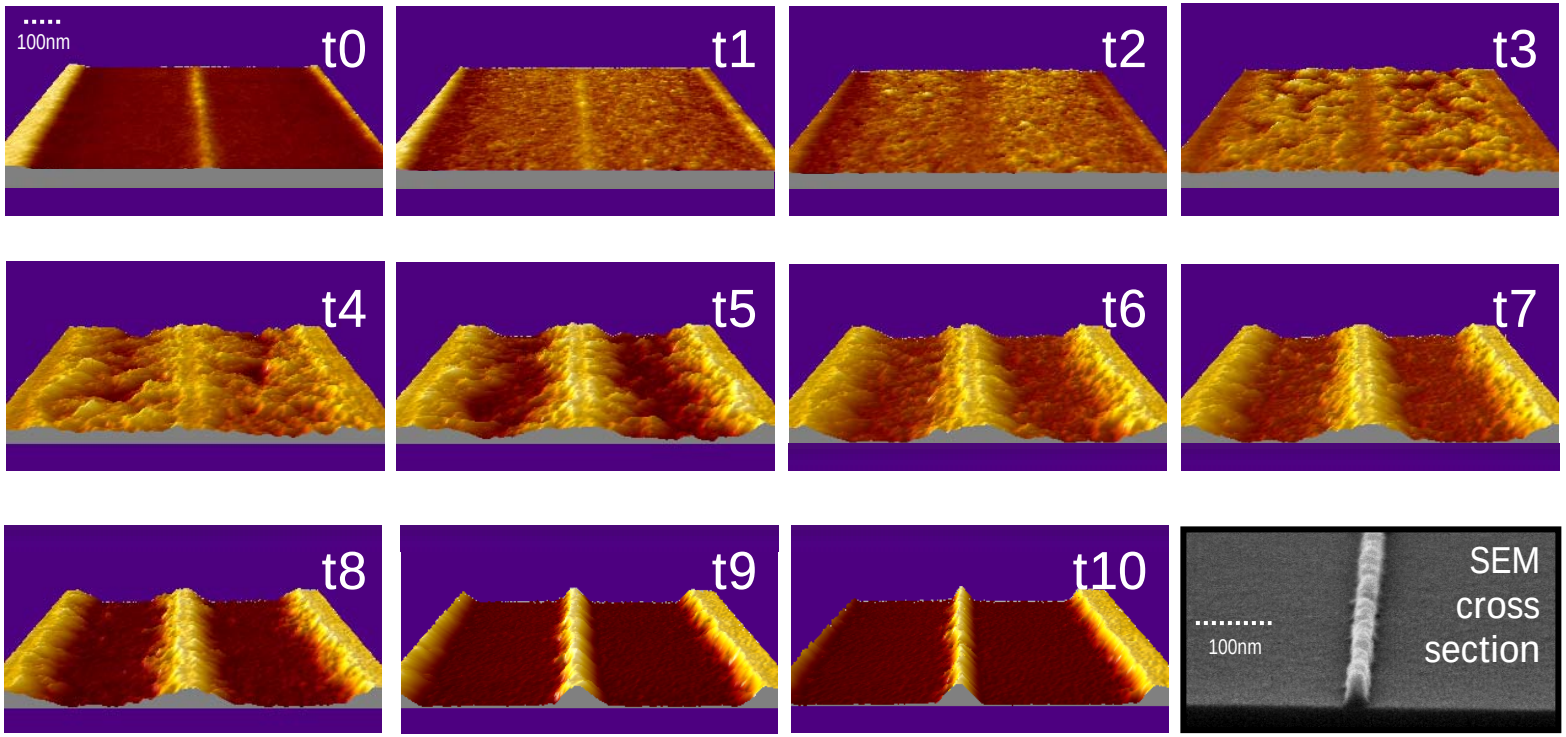
32nm I/L pattern - 2D images



- "Direct visual evidence" of resist dissolution was shown using the HS-AFM.
- Gradual dissolution characteristics were observed for the PHS-based polymer resist.

PHS-based polymer resist (SSR5)

32nm I/L pattern - 3D images

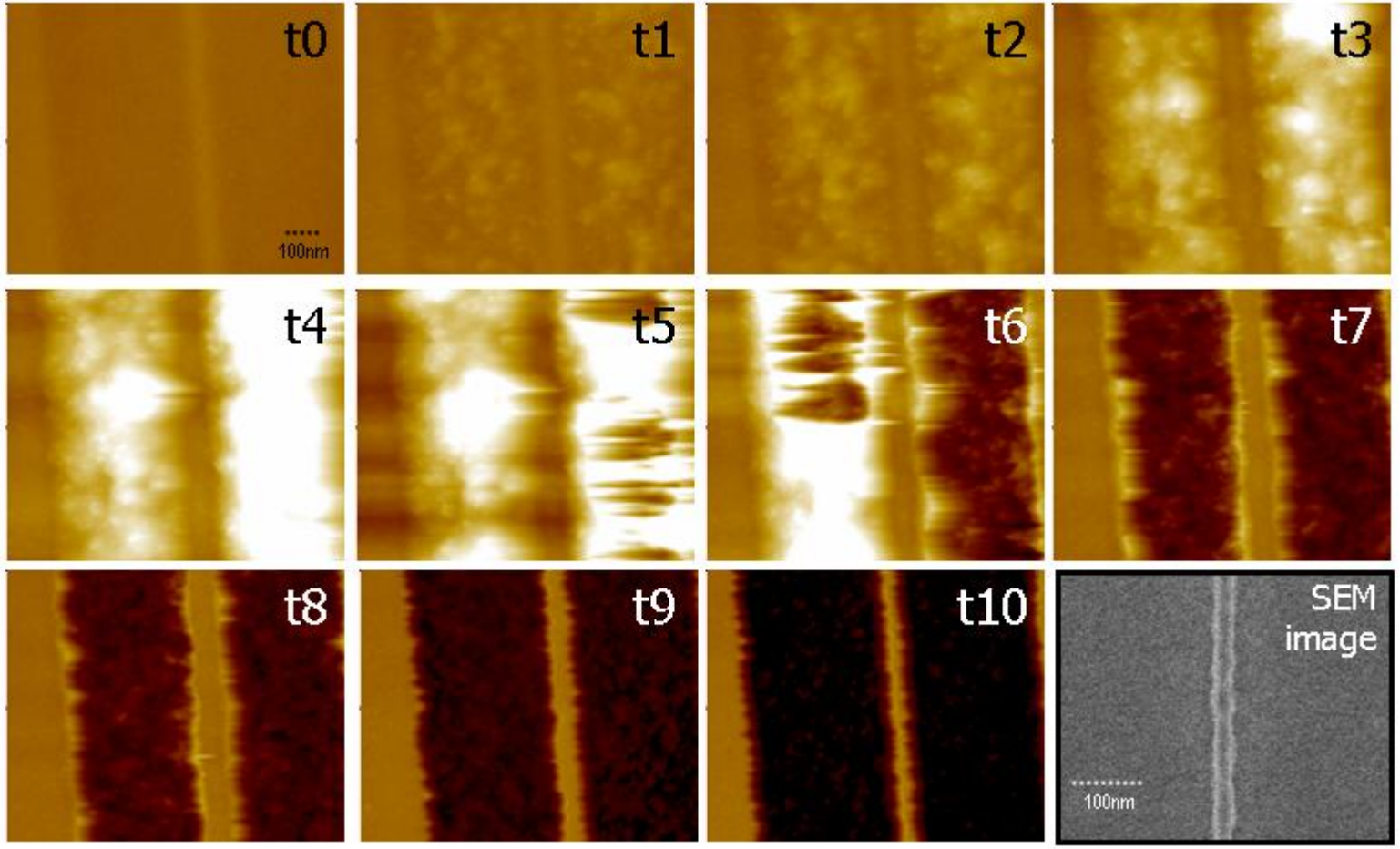


Swelling: 15.3 nm

- Gradual dissolution with slight "swelling" was observed for the PHS-based polymer resist.

Acryl-based polymer resist (SSR4)

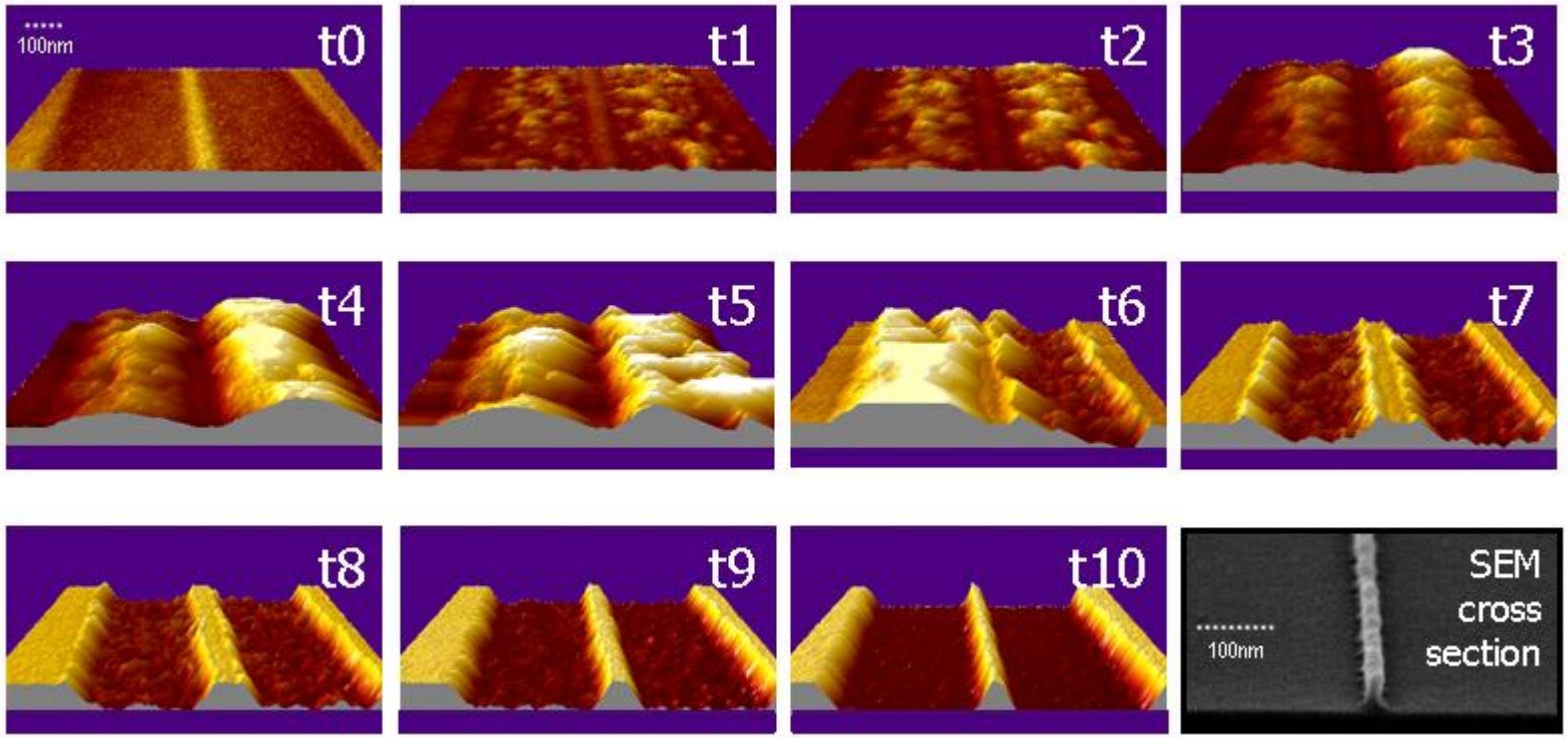
32nm I/L pattern - 2D images



- Significant “swelling” was observed with the acryl-based polymer resist.

Acryl-based polymer resist (SSR4)

32nm I/L pattern - 3D images

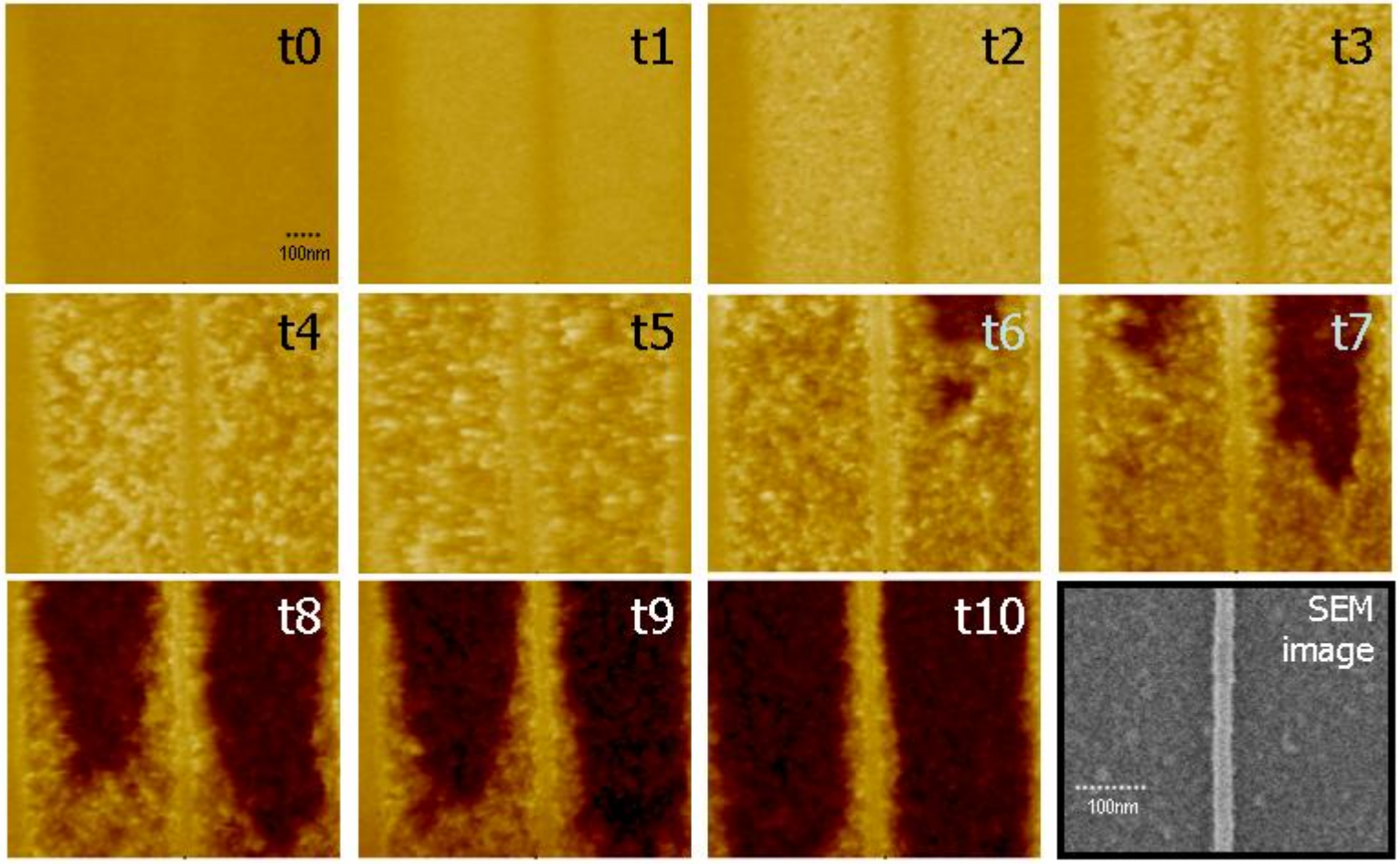


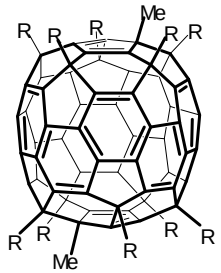
Swelling: 68.9 nm

- Significant “swelling” was observed with the acryl-based polymer resist.

Fullerene-based low molecular resist (SMR601)

32nm I/L pattern - 2D images





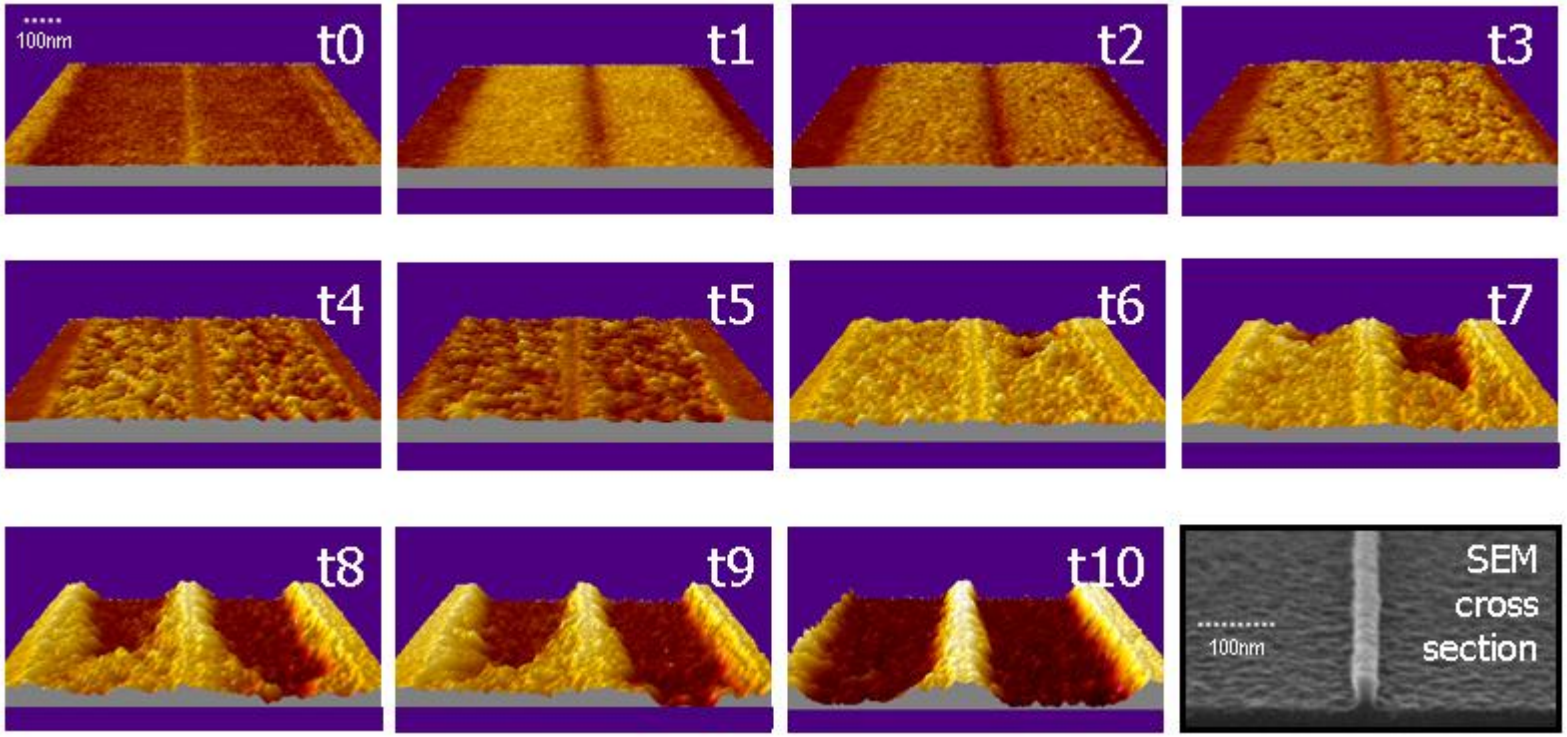
SMR601

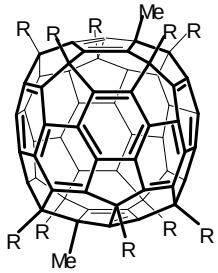
Mw: ～2300

■ Finer grains during dissolution were observed for the fullerene-based low molecular resist.

Fullerene-based low molecular resist (SMR601)

32nm I/L pattern - 3D images





SMR601

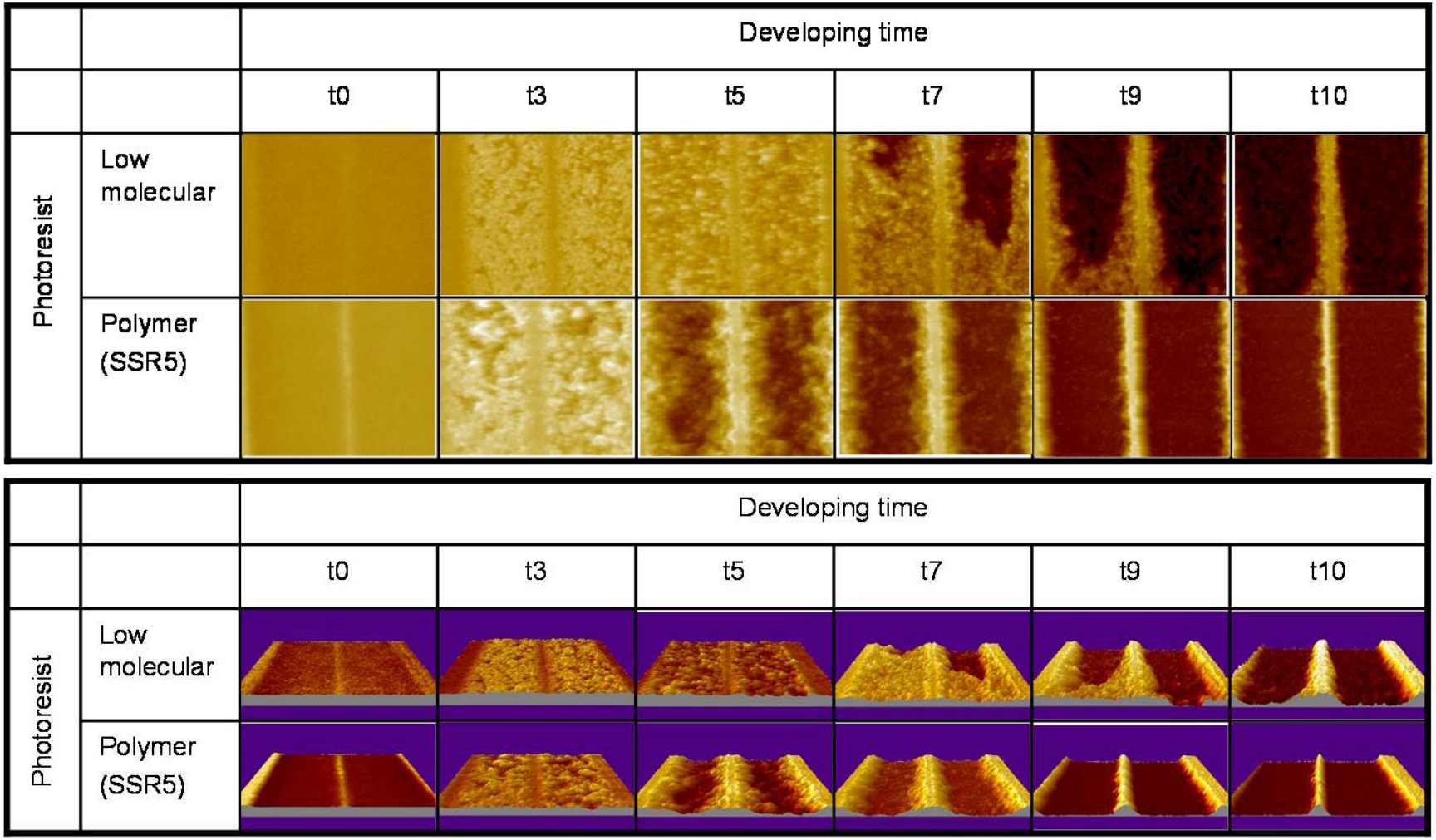
Mw: ～2300

Swelling: 10.3 nm

■ Gradual dissolution with almost no “swelling” with the fullerene-based low molecular resist.

Comparison of polymer and low molecular resist

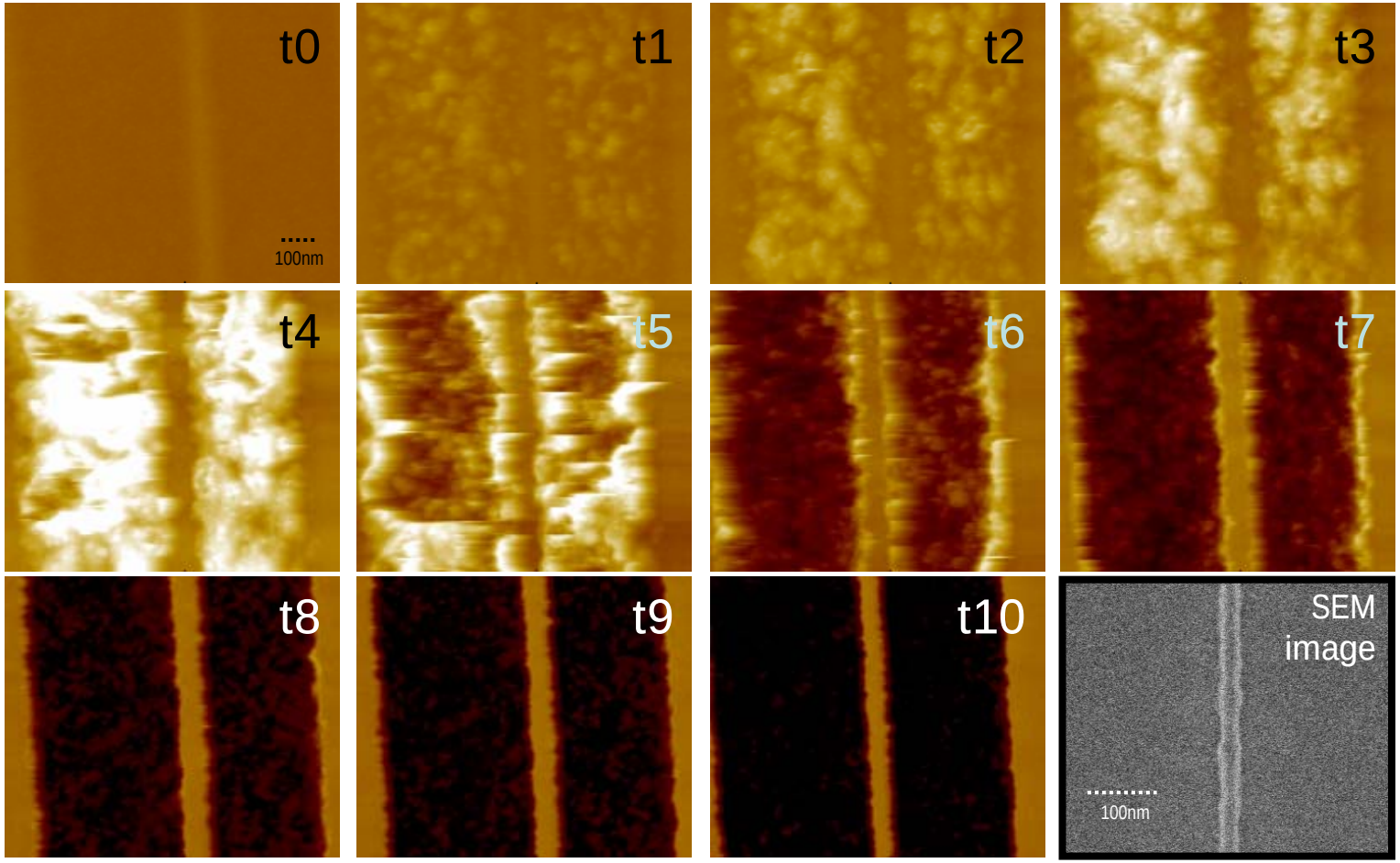
32nm I/L pattern - 2D & 3D images



- Finer film grains during dissolution was observed for the fullerene-based low molecular resist.
- No “swelling” was observed for the fullerene-based low molecular resist.

Acryl-based polymer resist (SSR4) @ TBAH

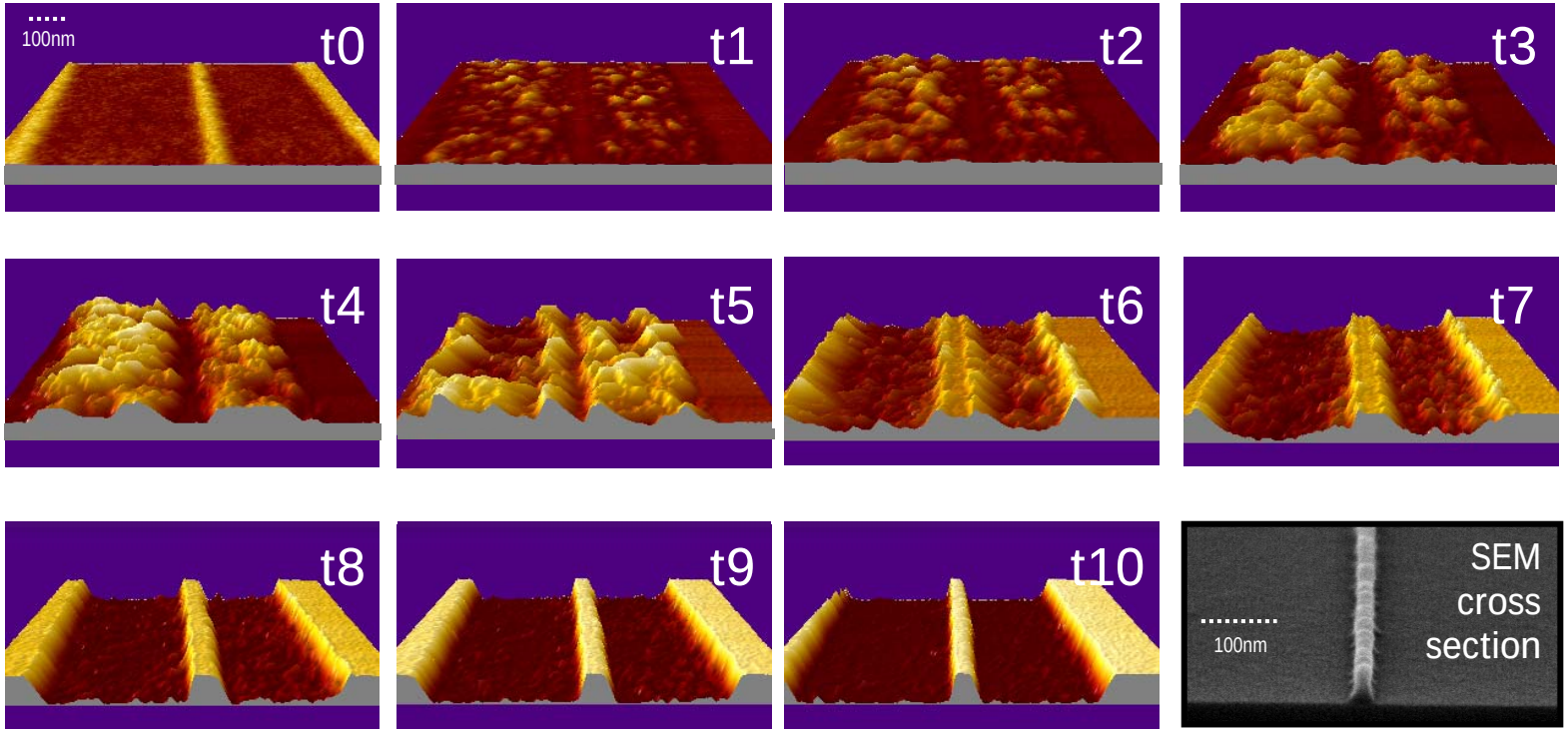
32nm I/L pattern - 2D images



"Swelling" was reduced using TBAH developer on the acryl-based polymer resist.

Acryl-based polymer resist (SSR4) @ TBAH

32nm I/L pattern - 3D images

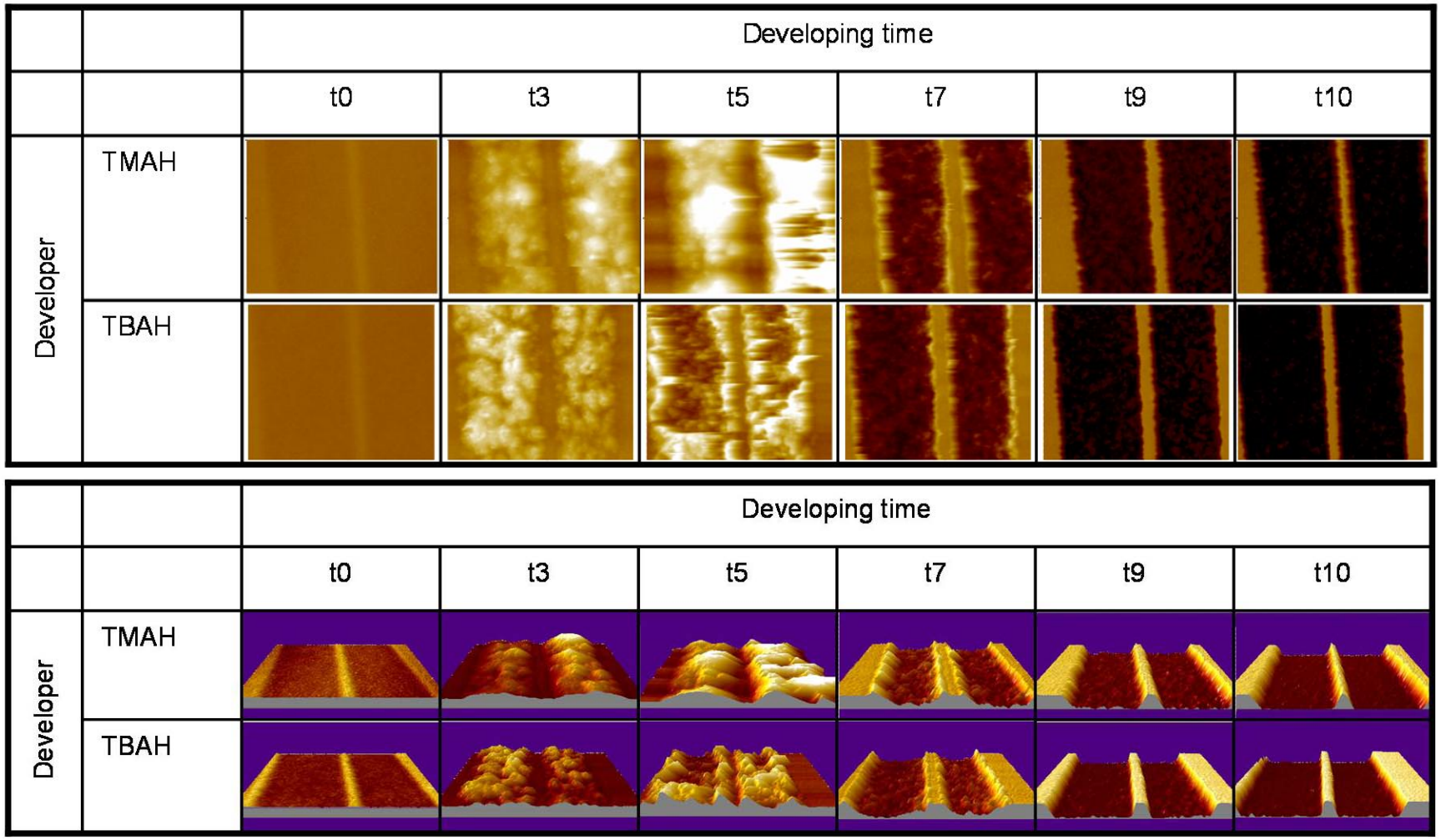


Swelling: 58.3 nm

"Swelling" was reduced using TBAH developer on the acryl-based polymer resist.

Comparison of TMAH and TBAH developer

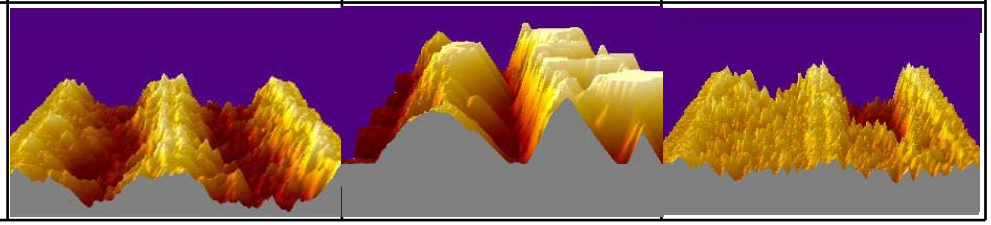
32nm I/L pattern - 2D & 3D images



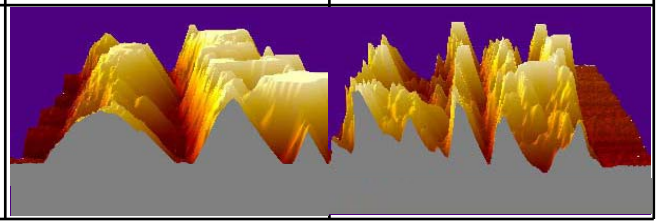
- "Swelling" was reduced using TBAH developer on the acryl-based polymer resist.
- Developer penetration into the resist film was lessened due to bulkier developer molecules.

Summary

- In situ analysis of dissolution characteristics using the HS-AFM was established and presented.
- Analysis of dissolution characteristics for various EUV resists showed:
  - PHS-based polymer resist have gradual dissolution with slight "swelling" properties.
  - Acryl-based polymer resist have significantly large "swelling" characteristics.
  - Fullerene-based low molecular resist have gradual dissolution at finer film grains.

Resist type	PHS	Acryl	Fullerene
Swelling (nm)	11.3	68.9	10.3
3D image			

- "Swelling" was reduced using TBAH developer on the acryl-based polymer resist.

Developer type	TMAH	TBAH
Swelling (nm)	68.9	58.3
3D image		

Acknowledgements

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- Selete member companies (EUV Lithomask program).
- Resist & Resin maker.

This work is in collaboration with RIBM

(Research Institute of Biomolecule Metrology Co., Ltd.)

References

- T. Itani and J. J. Santillan, Appl. Phys. Express 3, 061601 (2010). 1st paper
- T. Itani and J. J. Santillan, J. Photopolym. Sci. Technol. 23, 639 (2010).