Development of Wet-etch Chemistries for Tungsten Word-line Recess

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2018 Surface Preparation and Cleaning Conference
April 09-11, 2018 in Boston, MA

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Agenda

✓ Introduction

- 3D NAND technical background
- 3D NAND technical challenge of W recess
  - Dry-etch methods
  - Conventional wet-etch methods
- Critical technical specification

✓ Wet etchants for 3D NAND W recess

- Design concept
- Etch rate performance

✓ Summary

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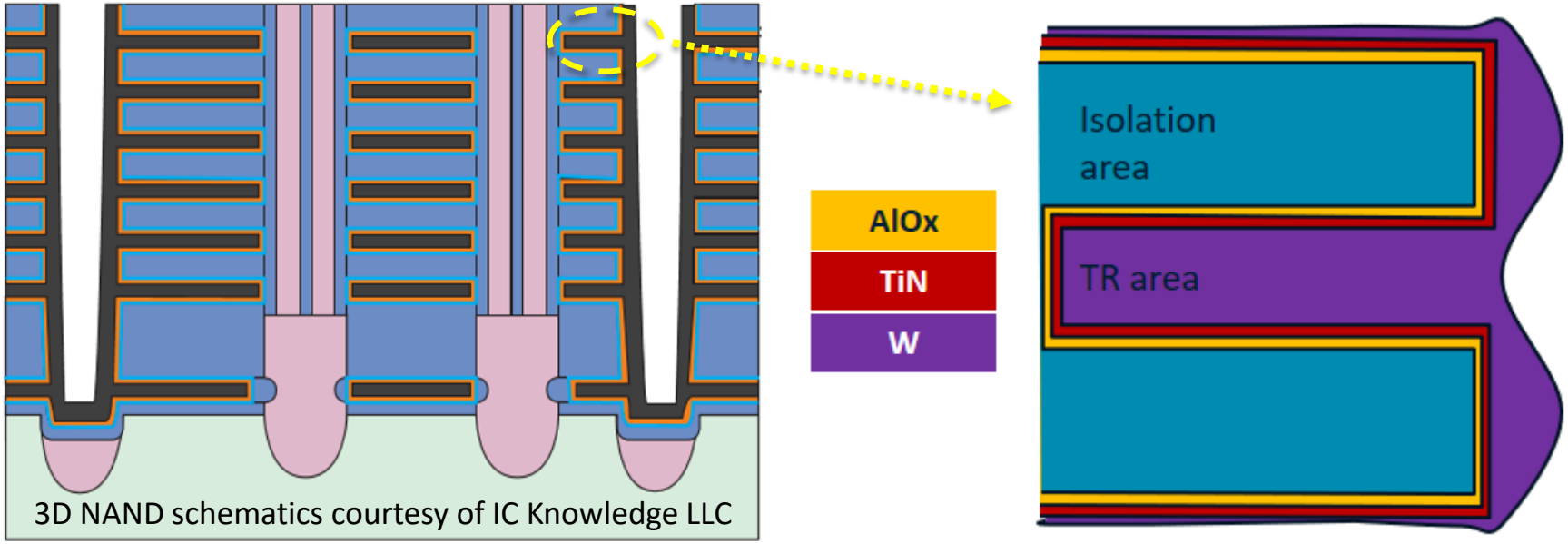
Technical Background



- During fabrication of the 3D NAND memory device, tungsten(W) recess for word-line(WL) isolation is one of the key processes. Typically, high-k/metal gate are used for the connection of tungsten control gate.

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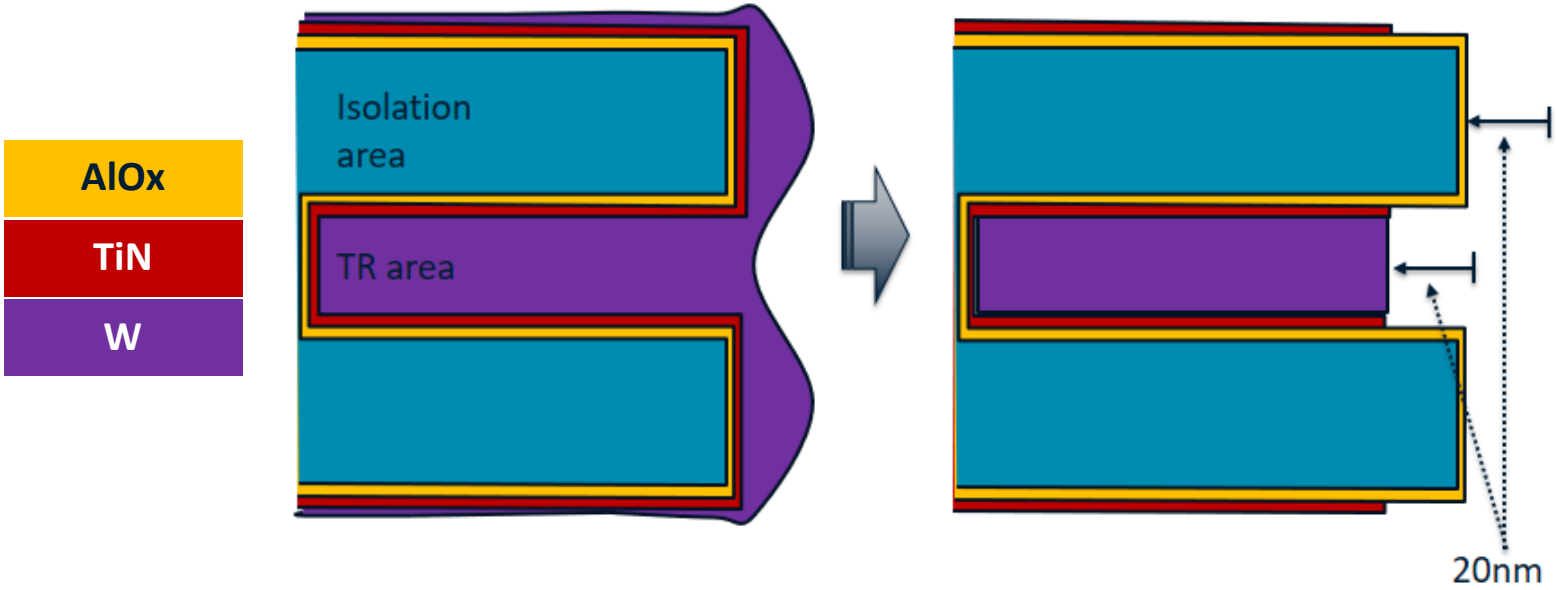
Technical Background



- In the recessing process, TiN and W should be simultaneously etched with equal thickness
- AlOx is the protecting layer that should not be damaged

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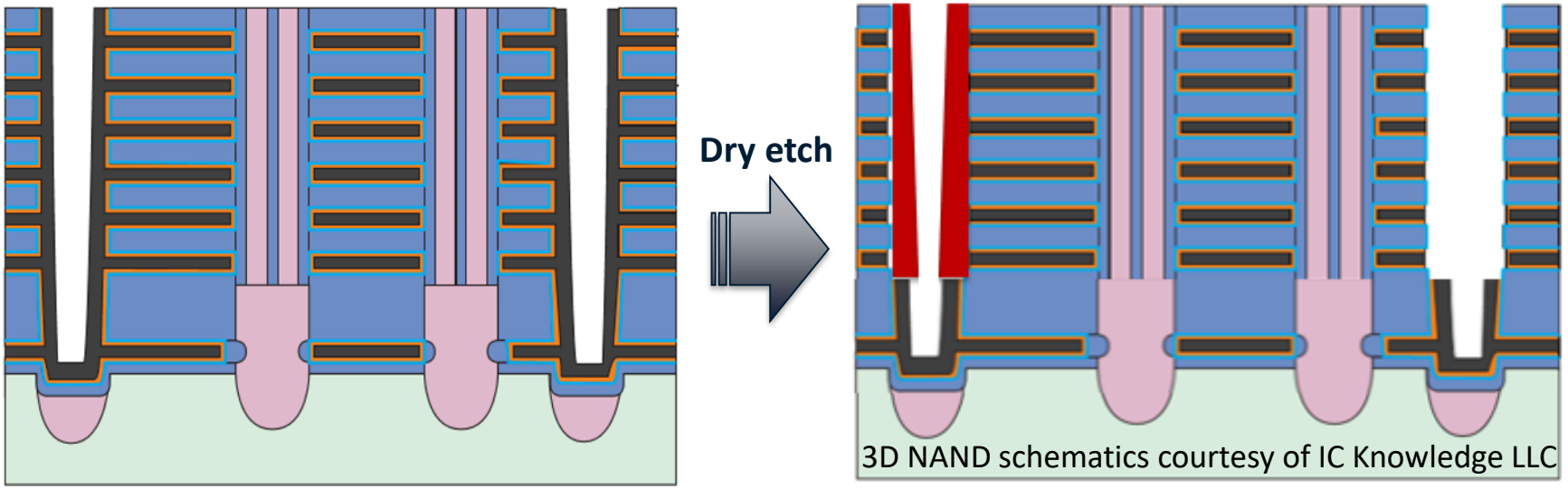
Technical Challenge of W recess - Dry-etch Methods



- As the number of layer increases, it's difficult to completely etch the bottom layer of W and TiN by dry etch-methods because the dry-etching byproduct from the top layer would remain in the trenches and restrict etching the bottom layer. Therefore, wet-etch method is proposed as an alternative for W recess.

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Technical Challenge of W recess
- Conventional Wet-etch Methods

- **AlOx compatibility**

  Typical wet-etch chemicals would easily etch the AlOx and cause a recess in the side wall of the channel at the AlOx layer that forms an undesirable floating gate, and results in an on-current degradation for the NAND string.

- **Long process time**

  Conventional wet etchants show low TiN or W etch rates that result in the extremely long process time(over 1 hr). The long process time means the application needs to operate in batch type tool and restricts the SWT application.

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Critical Technical Specification

	Target	Conventional Wet-etchant
TiN E/R (A/min)	>30	~2
W E/R (A/min)	>30	~2
TiN/W E/R selectivity	~1	~1
AlOx E/R (A/min)	<1	<1

- The wet etchant should perform equal TiN and W etch rates which means the TiN/W selectivity is close to 1
- AlOx is used as the protecting layer of transistors and barrier layer of plugs, so the chemical should be compatible with AlOx
- Conventional Wet-etchant shows low TiN and W etch rates, it needs extremely long time for processing
- Developing the etchants with higher TiN and W etch rates to shorten the process time is one of the important issues

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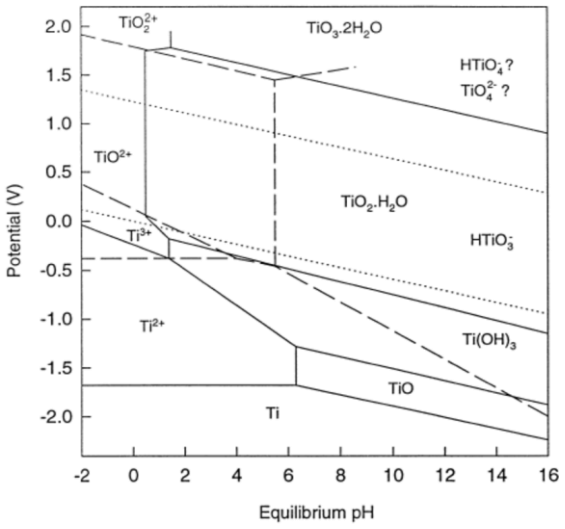
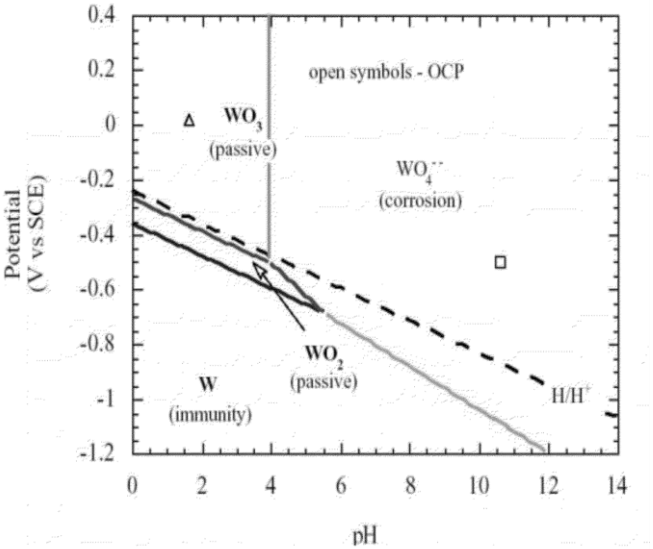
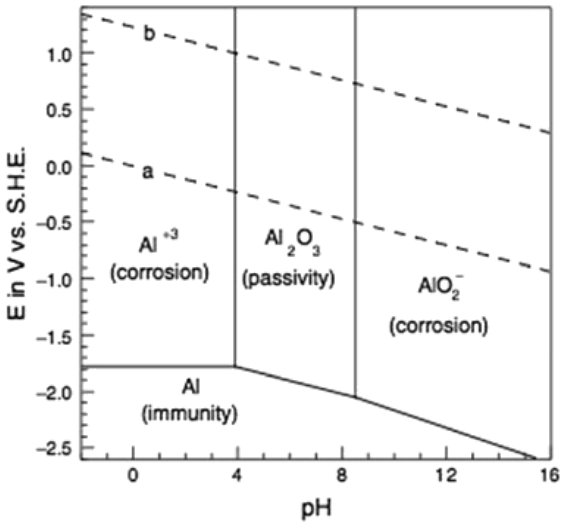
Novel Wet Etchants for 3D NAND W Recess - Design Concept







Key Components	Functions
A	Transform TiN to TiOx, and W to WOx
B	Adjust pH to control TiN, W and AlOx etch
C	Promote TiN etch rate, and improve TiN/W selectivity
D	Suppress TiN & W etch rates, and improve TiN/W selectivity

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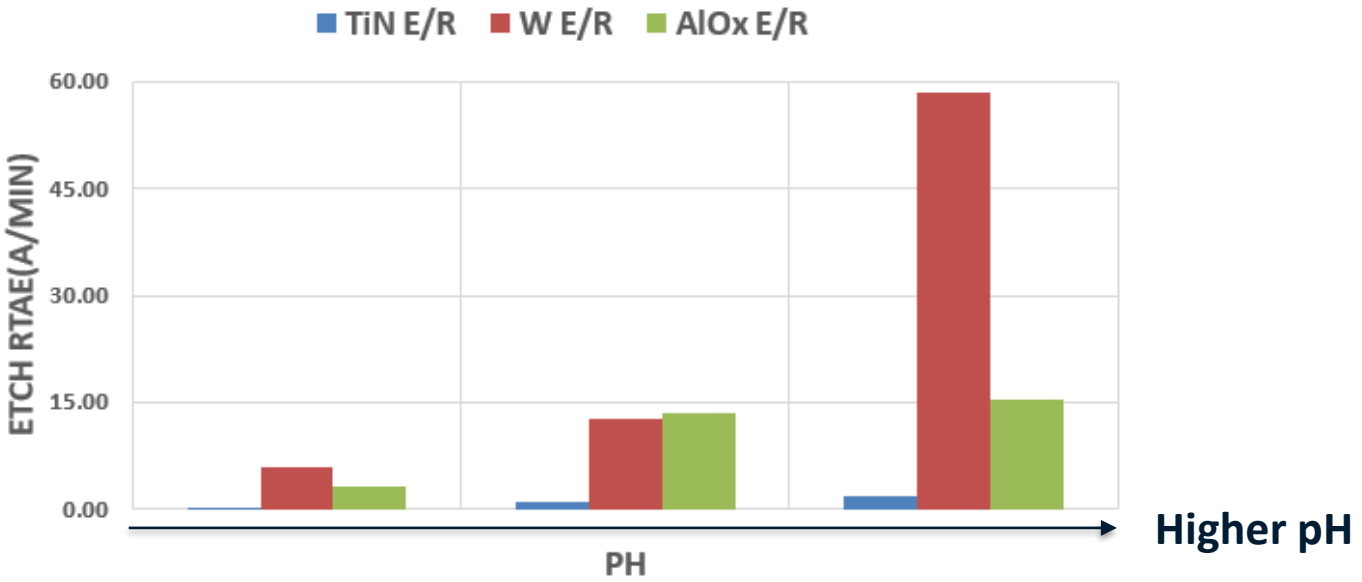
Novel Wet Etchants for 3D NAND W Recess - Design Concept (pH Effect)



- TiN, W and AlOx etch rates increased while pH was higher. especially, the impact on W is much greater
- Need to control the pH to avoid AlOx being damaged
- Need additional component or method to increase TiN etch, and improve TiN/W selectivity

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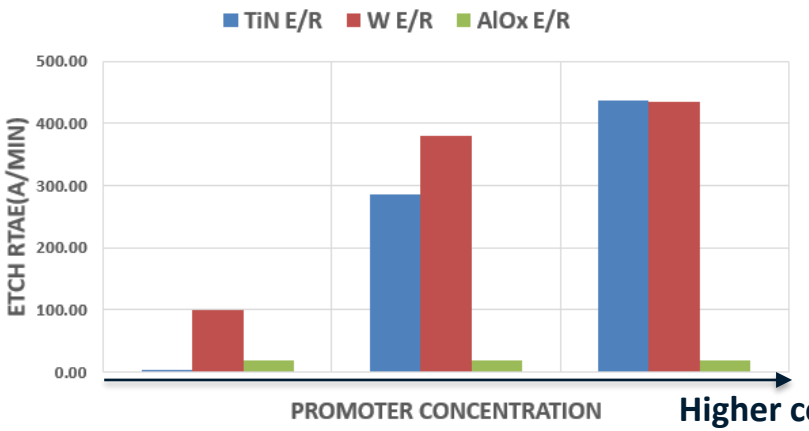
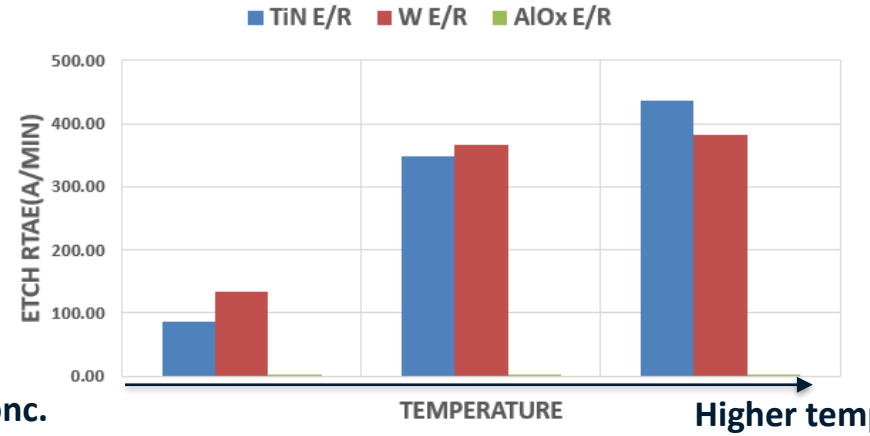
Novel Wet Etchants for 3D NAND W Recess

- Design Concept (TiN Promoter & Temp. Effect)





TiN/W selectivity	0.02	0.75	1.00

TiN/W selectivity	0.65	0.95	1.15

- TiN E/R can be boosted by two ways, adding promoter and adjusting process temperature. TiN/W selectivity can be also improved
- AlOx etch rate change was minimal

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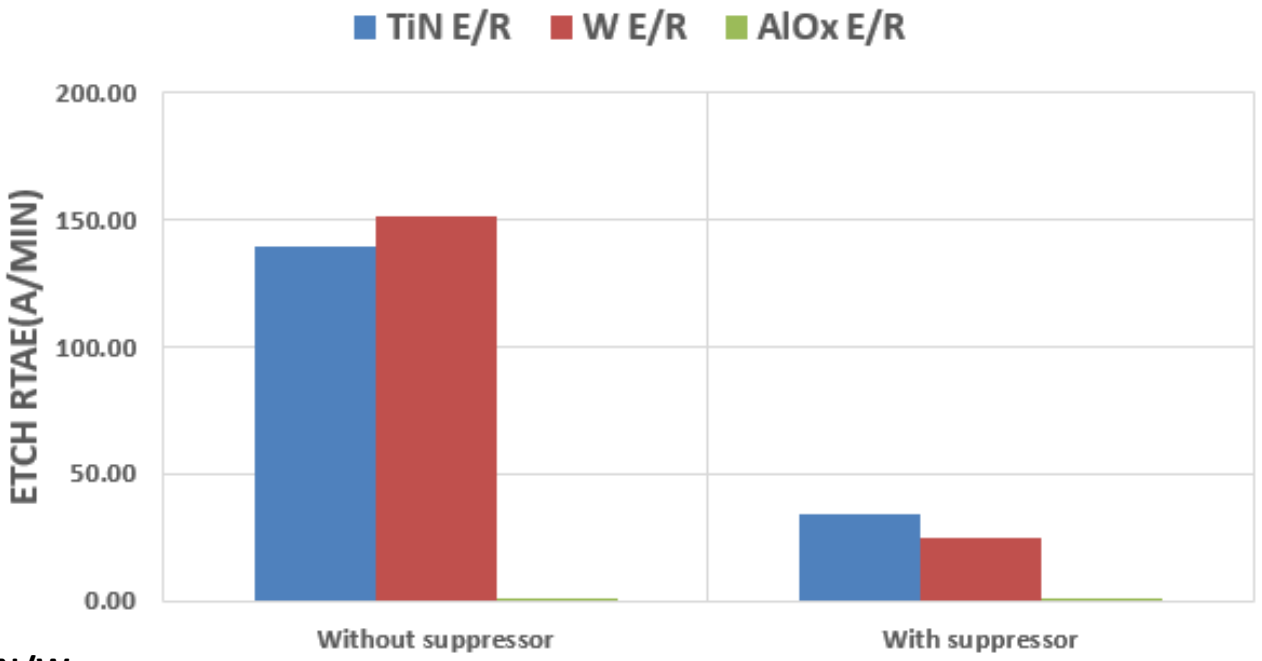
Novel Wet Etchants for 3D NAND W Recess - Design Concept (Etch Rate Suppressor)



TiN/W selectivity	0.92	1.39

- Both TiN and W etch rates would decrease while suppressor is added, and the TiN/W selectivity also gets higher
- No significant influence on AlOx e/r

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Novel Wet Etchants for 3D NAND W Recess - Etch Rate Performance

	Target	Etchant 1	Etchant 2	Etchant 3
Process temp. (°C)	-	35	25	30
TiN E/R (A/min)	>30	>300	>150	>50
W E/R (A/min)	>30	>300	>150	>50
TiN/W E/R selectivity	~1	0.95	0.92	1.20
AlOx E/R (A/min)	<1	<1	<1	<1

- The W etch rate could be adjusted to around 50A/min, 150A/min and 300A/min respectively, and meanwhile the TiN to W selectivity are close to 1
- Additionally, all three etchants are compatible with AlOx

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Summary

- We developed the wet-etch chemistries to replace the conventional chemicals and overcome technical issues for W recess application.
- The W etch rate could be adjusted to around 50A/min, 150A/min and 300A/min respectively, and meanwhile the TiN to W selectivity are close to 1.
- All of the etchants are compatible with AlOx (etch rate < 1A/min).
- With such high TiN and W etch rates, the wet-etch chemistries make the W word-line recess application possible to be operated on SWT.

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Acknowledgments

✓ **I would like to express my appreciation to all of the group members for supporting this research.**

- *Yi-Chia Lee*
- *Wen Dar Liu*
- *Amy Chen*
- *Shawn Chen*
- *Tino Li*
- *Ryback Lo*
- *Lan Shing Lee*
- *Ginny Chung*
- *Cindy Chou*
- *Sheng-Wen Wu*
- *Allen Huang*
- *Aron Chen*
- *George Peng*
- *Alan Hsu*
- *Aiping Wu*
- *Hoon Song*
- *Steve Ryu*

- **IC Knowledge LLC for providing the pictures of devices on pages 3 and 5**

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THANK YOU

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