ALUMINUM NITRIDE REMOVAL FORMULATION WITH MODIFIED ANISOTROPIC SILICON ETCHING PROPERTY

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Outline

1. **Background introduction**
   - Technical challenge of conventional AlN etchant
   - Anisotropic Si wet etching
2. **Design concept of novel AlN etchant**
   - Etch rate requirement
   - Formulation design
   - Experimental trails: solvent effect and additive effect
3. **Summary**

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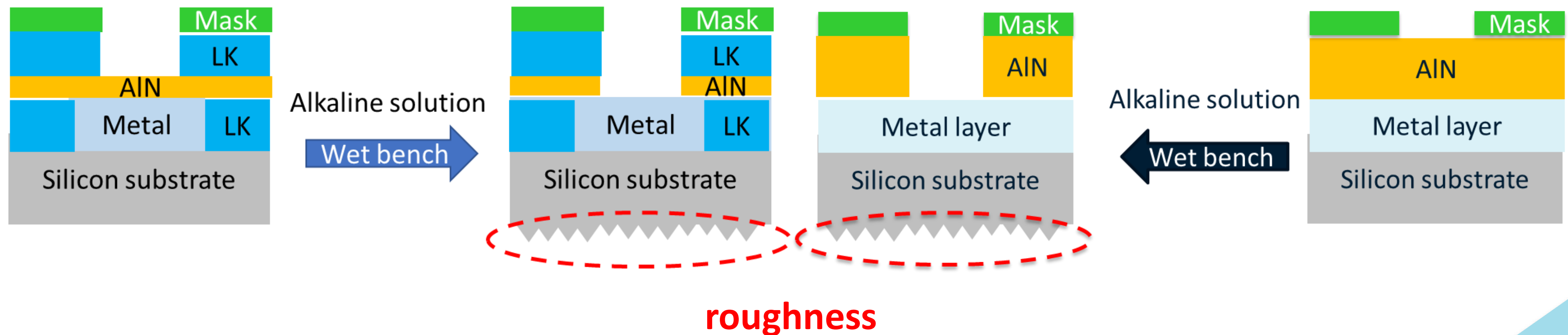
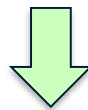
Technical challenge of Alkaline solution of AlN wet etching

- Issue of conventional AlN wet etchant on silicon substrate.

  High alkalinity solution was used in AlN etching widely but with an undesirable anisotropic etching properties and high etching rate of silicon, leading to roughness at back side of substrate by forming pyramidal defect.



1. Silicon etching rate suppression
2. Adjusting the Si(110) to Si(100) etching rate ratio



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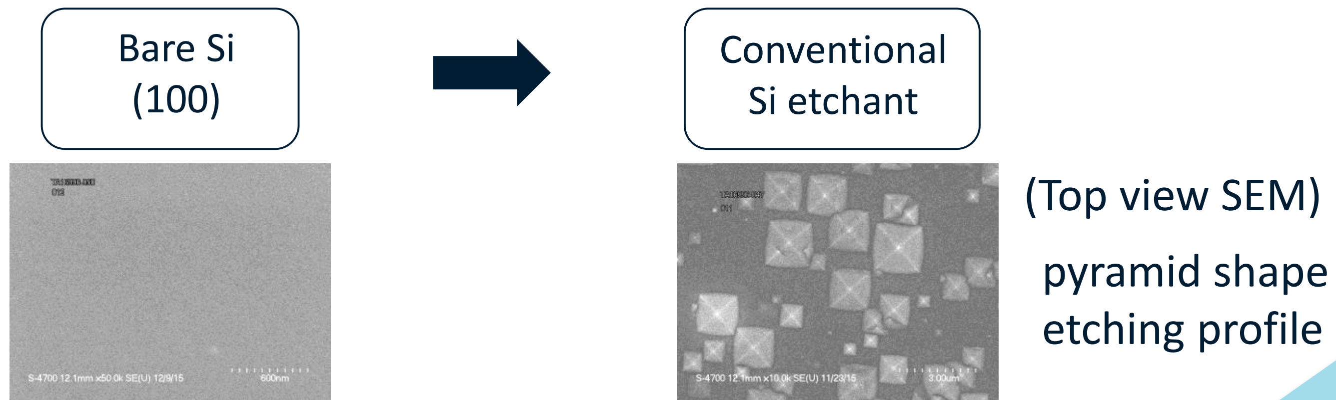
Aluminum nitride and Silicon etching by alkaline solution

- Etch rate of conventional AlN wet etchant

	Silicon E/R(A/min)				Etching selectivity		
	AlN	Si(100)	Si(110)	Si(111)	AlN/Si(100)	Si(110)/Si(100)	Si(111)/Si(100)
Conventional etchant	18241	12074	6367	1989	1.51	0.53	0.16

For conventional alkaline wet etchant, the etch rate in Si(100) direction is much higher than in (111) which results in pyramid shape etching profile.



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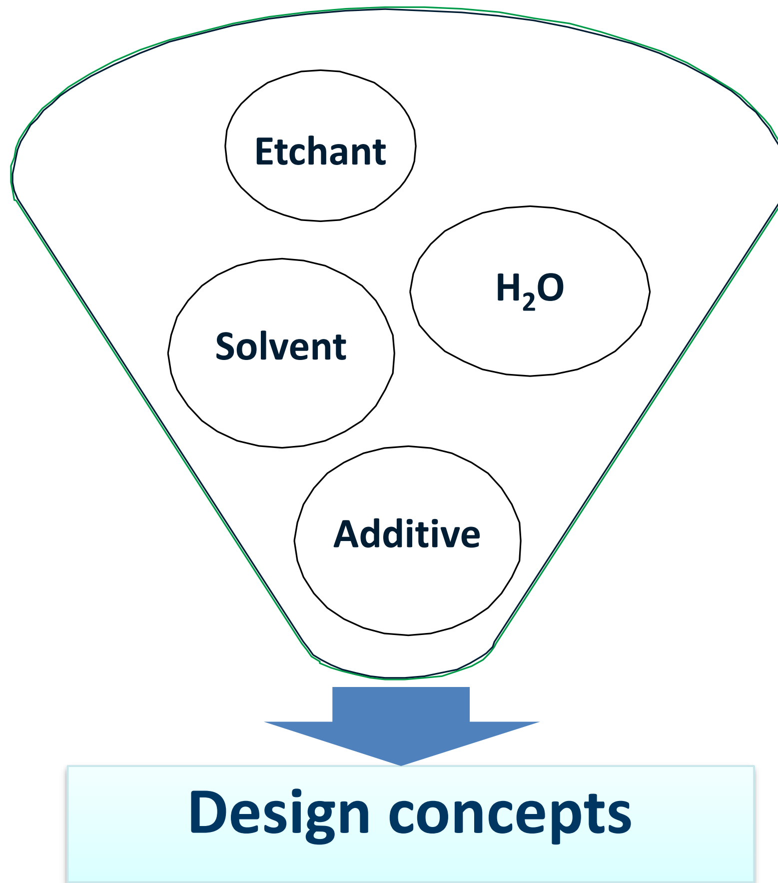
Etch rate requirements

➢ Etch rate requirements of new AlN wet etchant

	Silicon E/R(A/min)				Etching selectivity		
	AlN	Si(100)	Si(110)	Si(111)	AlN/Si(100)	Si(110)/Si(100)	Si(111)/Si(100)
Requirements	>15000	<3000	<3000	<1000	>5	>1	>0.3

To address the etch residue issue, both silicon etching rate and selectivity of Si(110)/Si(100) and Si(111)/Si(100) should be increased.

Formulation design



Etchant:
To dissolve AlN

Additive :
To suppress silicon E/R

H2O:
Hydrolysis medium

Solvent:
To adjust solution polarity

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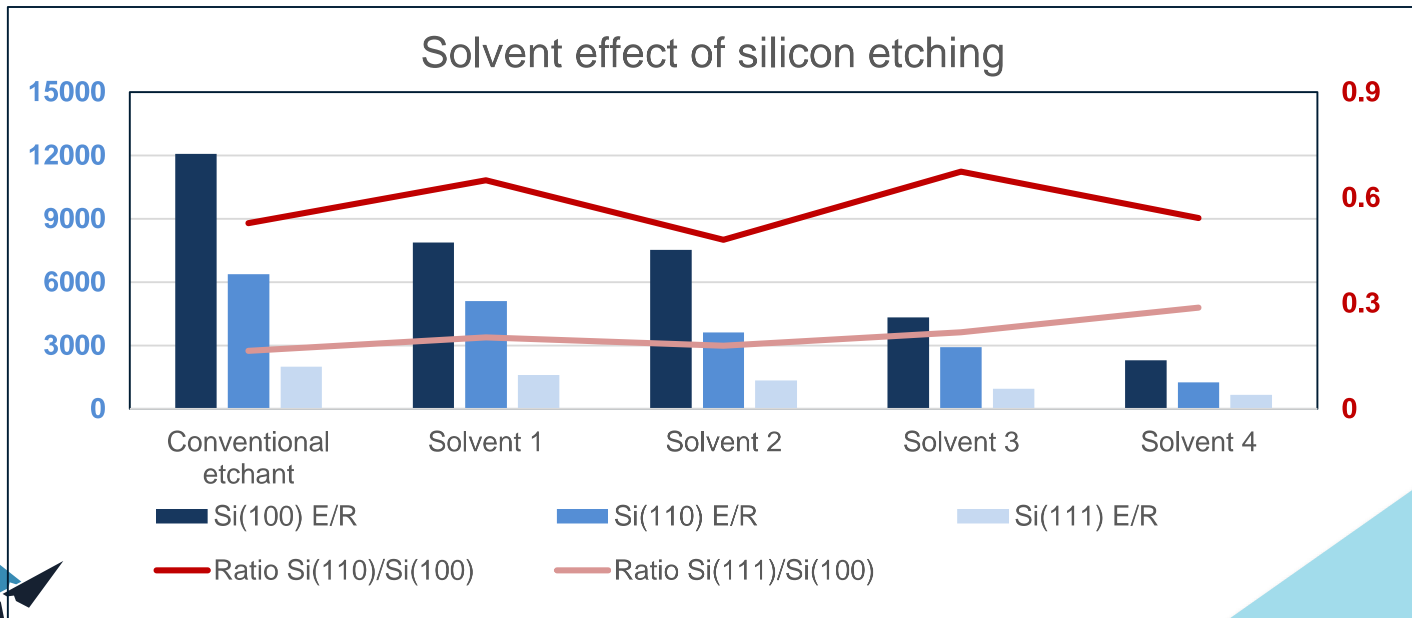
Solvent effect in silicon etching rate suppression

- An effective solvent decrease all different orientation silicon e/r but cannot increase the Si(110)/Si(100) and Si(111)/Si(100) ratio

Solvent effect	E/R(A/min)			Etching selectivity	
	Si(100)	Si(110)	Si(111)	Si(110)/Si(100)	Si(111)/Si(100)
Requirements	<3000	<3000	<1000	>1	>0.3
Conventional etchant	12074	6367	1989	0.53	0.16
Solvent 1	7867	5107	1597	0.65	0.20
Solvent 2	7529	3615	1349	0.48	0.18
Solvent 3	4331	2920	941	0.67	0.22
Solvent 4	2298	1245	661	0.54	0.27



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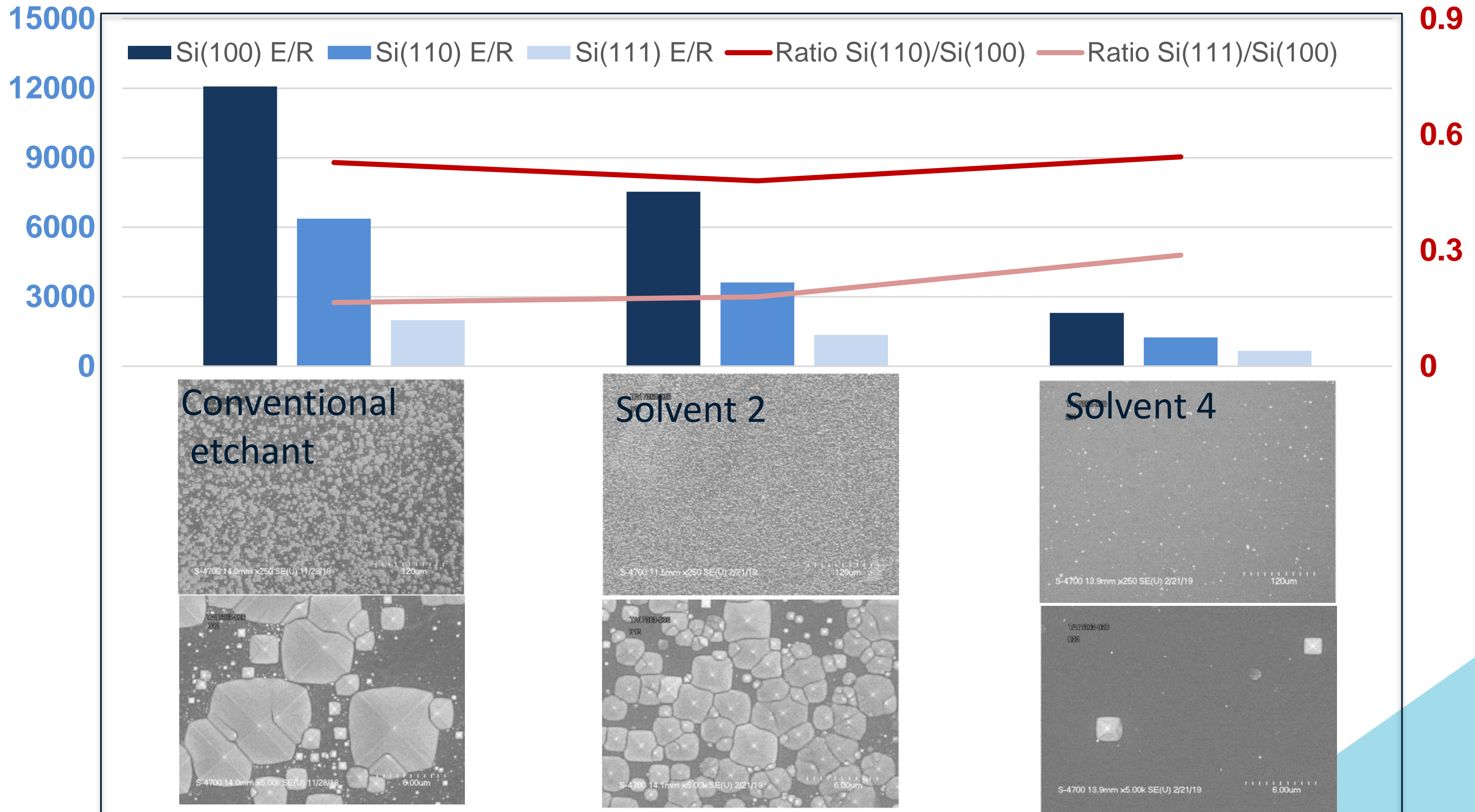
SEM result of solvent effect in silicon etching

- Decreasing silicon e/r by adding solvent can reduce amounts and scale of pyramidal defect but cannot eliminate it.



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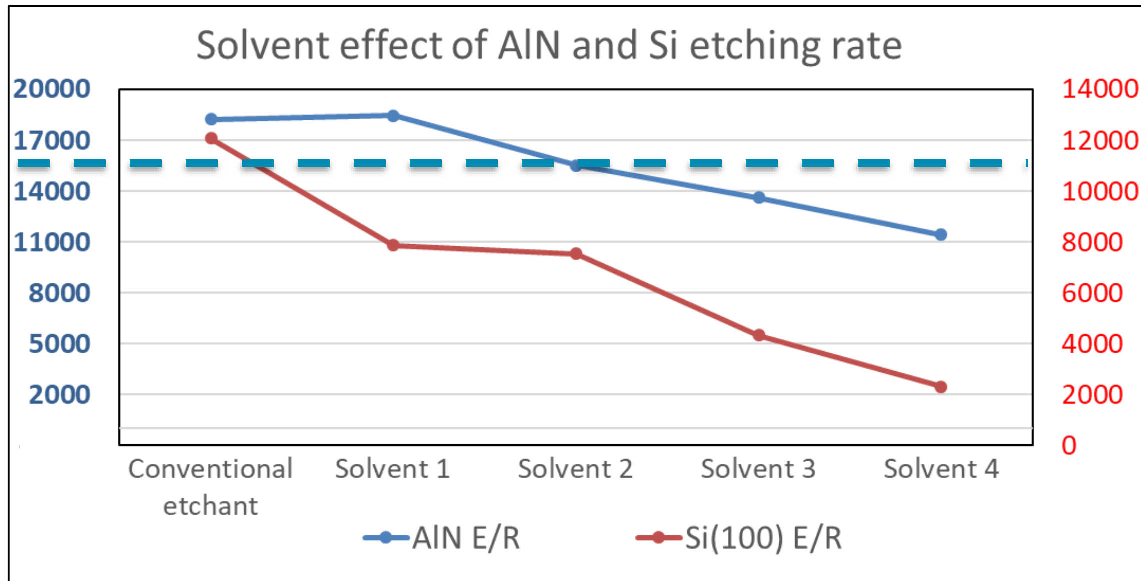
Need to improve selectivity of Si(110)/Si(100) and Si(111)/Si(100)

Solvent effect in AlN etching and Si etching

➢ AlN etching rate would be undesirably decreased by changing solvent.

Solvent effect	E/R(A/min)			
	AlN	Si(100)	Si(110)	Si(111)
Requirements	>15000	<3000	<3000	<1000
Conventional etchant	**18241**	12074	6367	1989
Solvent 1	**18441**	7867	5107	1597
Solvent 2	**15511**	7529	3615	1349
Solvent 3	13598	4331	**2920**	**941**
Solvent 4	11430	**2298**	**1245**	**661**

AlN E/R requirement



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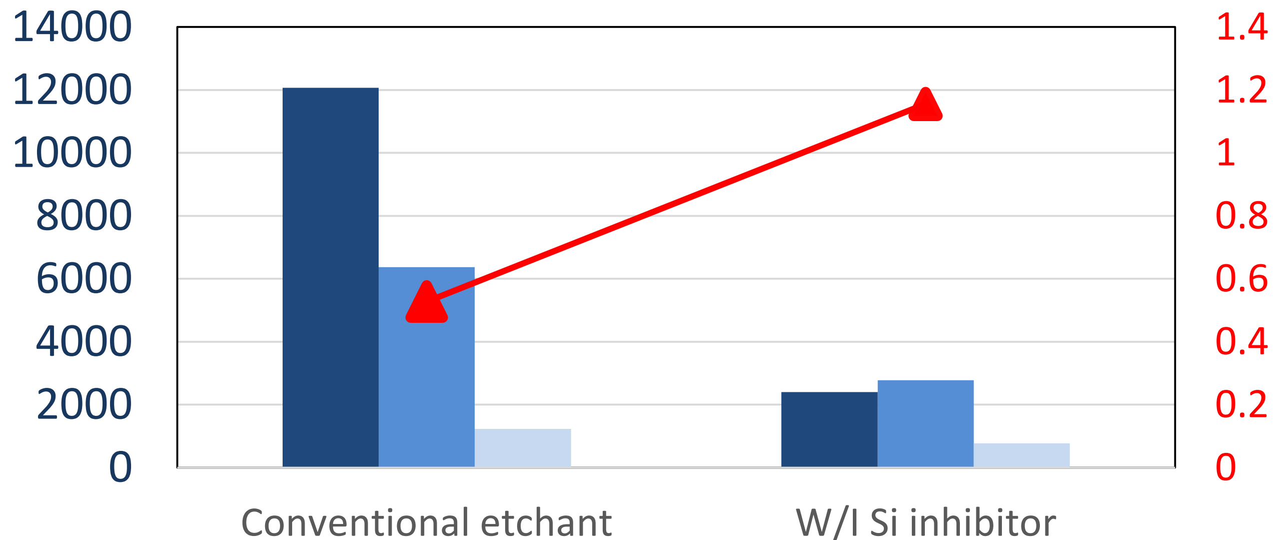
Additive effect: Silicon E/R study

- Si E/R can be suppressed by additive, beside the selectivity of Si(110)/ Si(100) and Si(111)/ Si(100) can be also increased.

Addtive effect	E/R(A/min)			Etching selectivity	
	Si(100)	Si(110)	Si(111)	Si(110)/Si(100)	Si(111)/Si(100)
Requirements	<3000	<3000	<1000	>1	>0.3
Conventional etchant	12074	6367	1989	0.53	0.16
Conventional etchant +addtive	**2398**	**2772**	**768**	**1.16**	**0.32**



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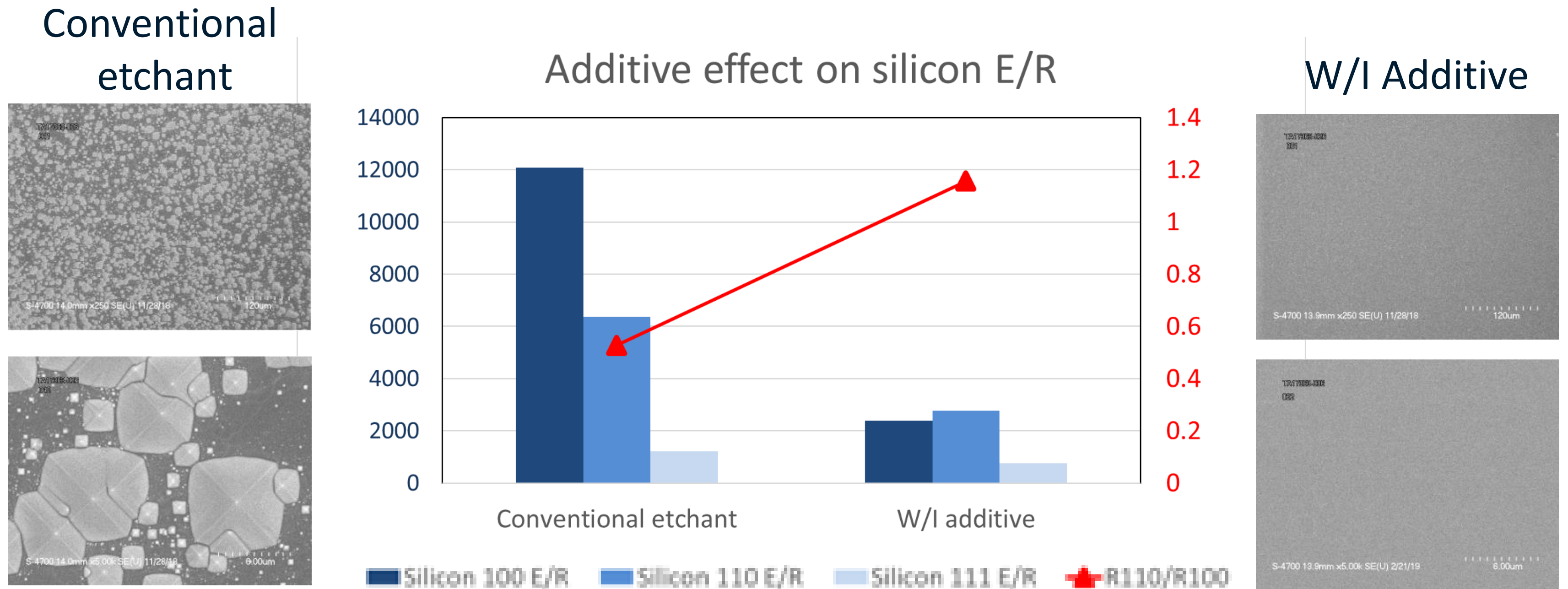
Additive effect : SEM result in silicon surface

- SEM result of additive effect in silicon etching



- Silicon roughness and pyramidal defect can be eliminated by suppression silicon etching rate and increasing Si(110) to Si(100) ratio.

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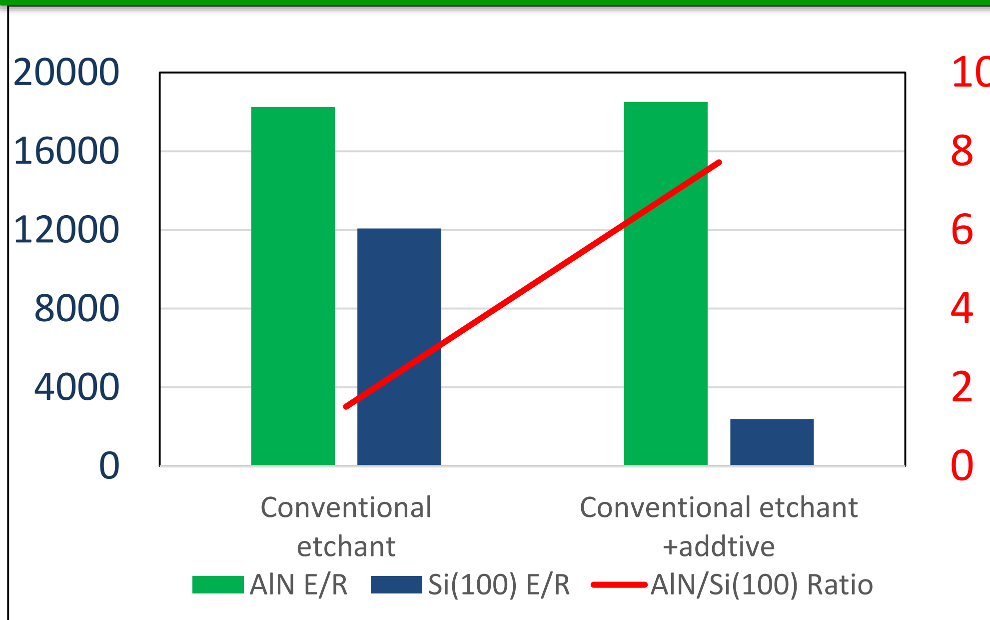
Additive effect : AlN etching performance

➢ Additive effect on AlN etching performance

Solvent effect	E/R(A/min)						Etching selectivity
	AlN	Si(100)	Si(110)	Si(111)	SiO2	SiN	AlN/Si(100)
Requirements	>15000	<3000	<3000	<1000	<30	<1	>5
Conventional etchant	**18241**	12074	6367	1989	23.8	0.43	1.5
Conventional etchant +additive	**18310**	**2397**	**2771**	**768**	19.0	0.15	**7.7**



➢ AlN e/r is kept at high level and Si e/r is suppressed resulting in high AlN/Si etching selectivity by adding additive.

➢ Better compatibility with silicon oxide and silicon nitride

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Summary

➢ For the studies of Versum Material's novel AlN etchant, we demonstrate the following achievements:

- ✓ High AlN etching rate and high etching selectivity of AlN/Si
- ✓ Etching selectivity of Si (110)/ (100) and Si (111)/ (100) reach 1.5 and 0.3 respectively, which results in roughness free on silicon surface
- ✓ Better compatibility with SiO_2 and SiN
- ✓ Applicable on wet bench tool

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