

TaN and Cr EUV Mask Fabrication and Characterization

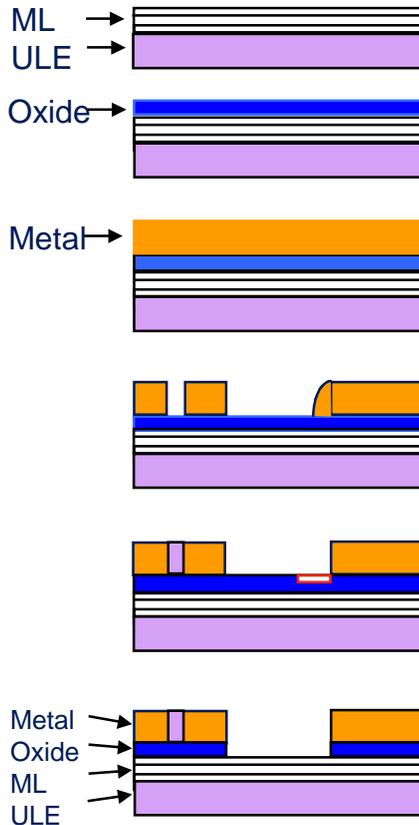
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Components Research
Intel Corporation**

Outline

- **Introduction**
- **Experimental results and discussion**
 - **Mask process conditions**
 - **TaN film stress reduction**
 - **TaN film cleaning results**
 - **Mask patterning results: TaN and Cr masks**
 - **Mask printing results: TaN and Cr masks**
- **Conclusions**

Introduction: EUV Mask Patterning Flow



1. Substrate preparation

2. Thin LTO deposition (300A - 900A)

3. Metal deposition (500A - 1000A)

4. Metal patterning and etch

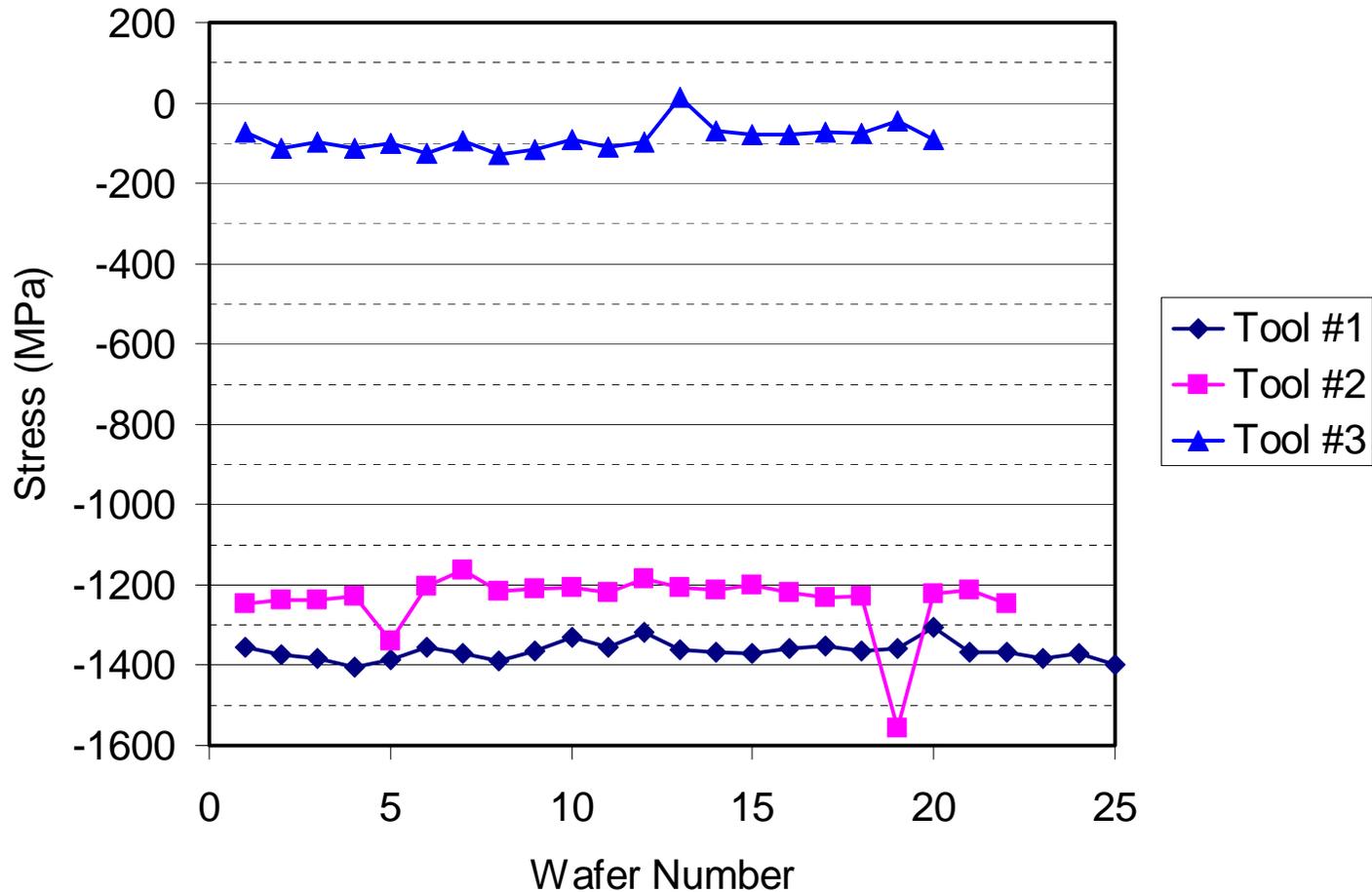
5. Defect inspection and repair (FIB)

6. Buffer oxide etch

TaN and Cr Mask Process and Exposure Conditions

	TaN Mask	Cr Mask
Mask Blanks		
- Substrate	8" Si wafer	
- ML	40 pairs Mo/Si (2.8nm Mo/4.2nm Si)	
- Buffer layer	300A SiO ₂	0 and 900A SiO ₂
- Metal layer	500A TaN	700A Cr
Mask Patterning		
- Patterning tool	I-line stepper, NA=0.5	
- Resist	I-line positive resist, thickness = 8000A	
- Metal etch	Cl ₂ based dry etch	Cl ₂ based dry etch
- Oxide etch	F ₂ based dry etch	
Mask Exposure		
- Resist	DUV thin resist, thickness = 1000 A	
- Exposure tool NA	0.088	
- Reduction	10x	

TaN Film Stress Reduction Results



✓ TaN stress of ~ -100Mpa achieved via tool configuration and process change

TaN Film Cleaning Results – Sulfuric Acid Clean

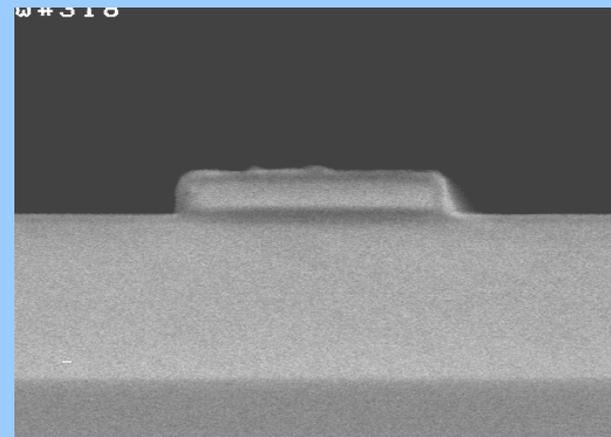
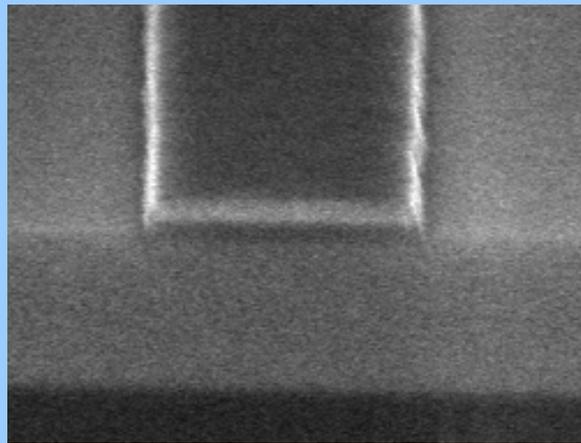
Compared with TiN film

Material		No Clean	80C			100C		120C
			10min	20min	30min	10min	20min	20min
TiN	Resistivity	45.99	66.74	111.54	347.56			
	Thickness	910A	636A	528A	*			
TaN	Resistivity	26.24	26.33	26.24	26.24	26.06	26.19	26.18

- TaN film clean showed no issue in solvent based solution (Bacus/Japan'00)
- TaN film also showed no issue in sulfuric acid clean. It is compatible with current Cr mask technology
- TiN film is not stable in sulfuric acid clean. It is not compatible with current Cr mask technology.

TaN Absorber EUV 10X Mask

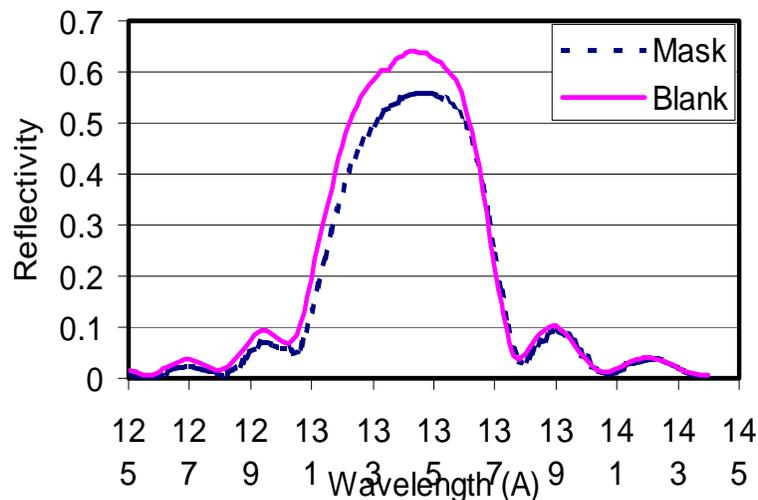
**280nm Mo/Si ML + 300A SiO₂ + 500A
TaN**



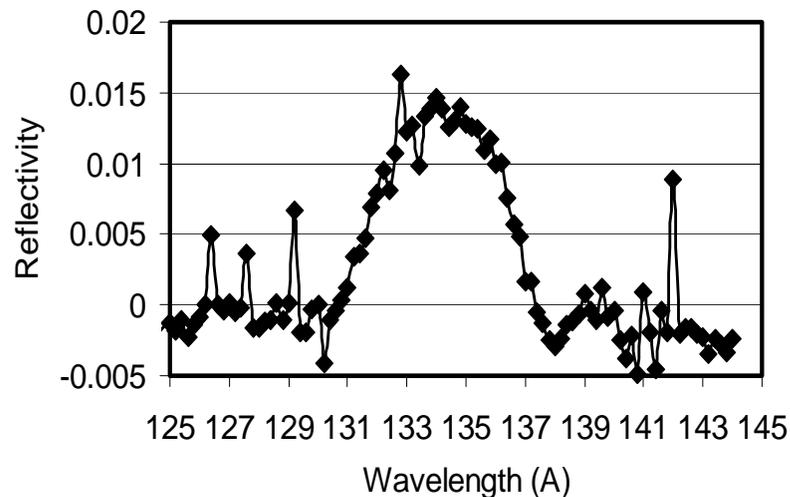
0.5 μm L/S (1x)

Reflectivity Result of TaN mask

Clear region

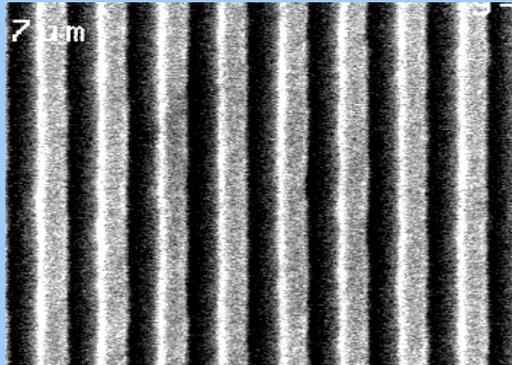


Dark region

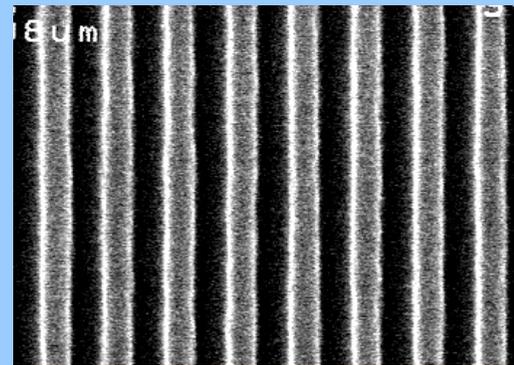


- 500Å TaN attenuated EUV light down to 1.5%
- Reflectivity drop after patterning is most likely due to surface contamination
- Additional study is under going to identify the contamination

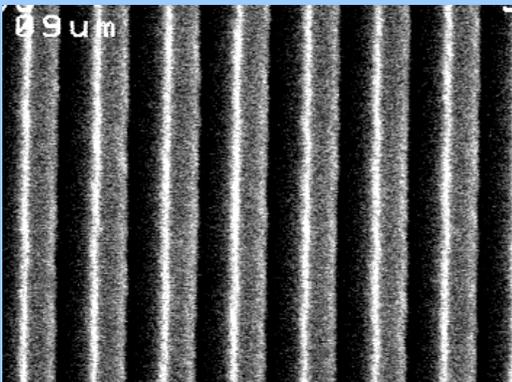
TaN 10X EUV Mask Exposure Results



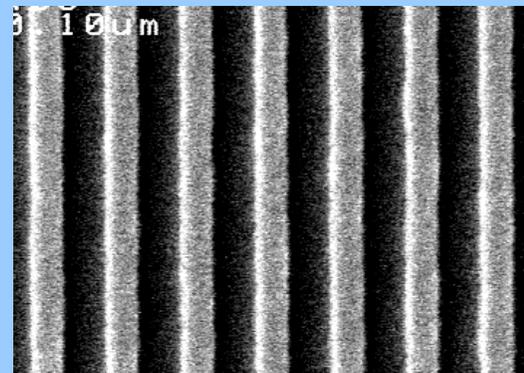
70 nm L/S



80nm L/S



90 nm L/S

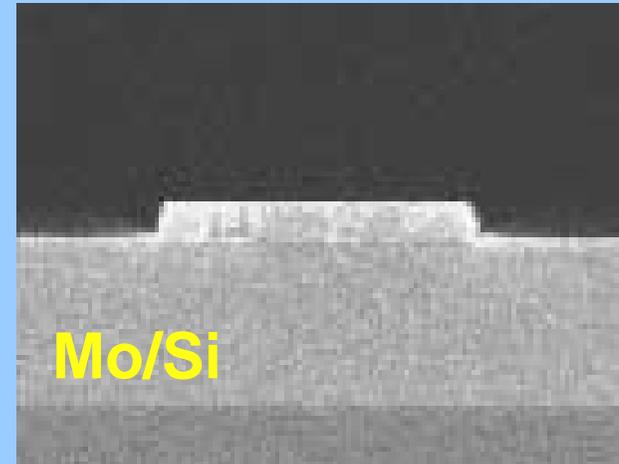
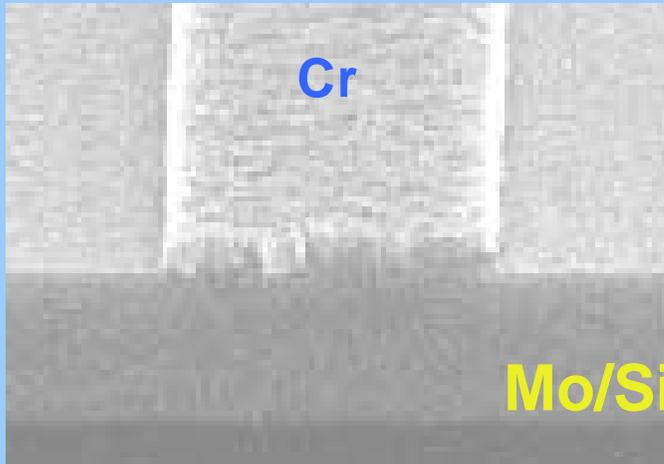


100nm L/S

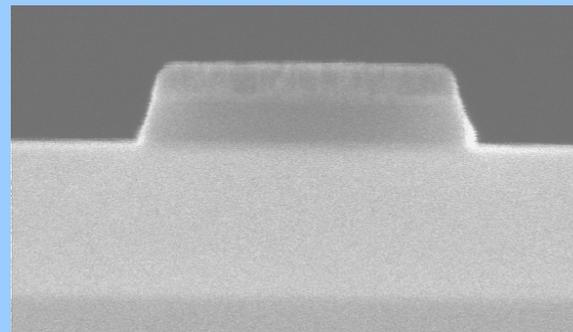
Cr 10X EUV Mask with/without Buffer Layer

0.7 μm lines (1x)

280nm Mo/Si ML + 700A Cr (No buffer layer)

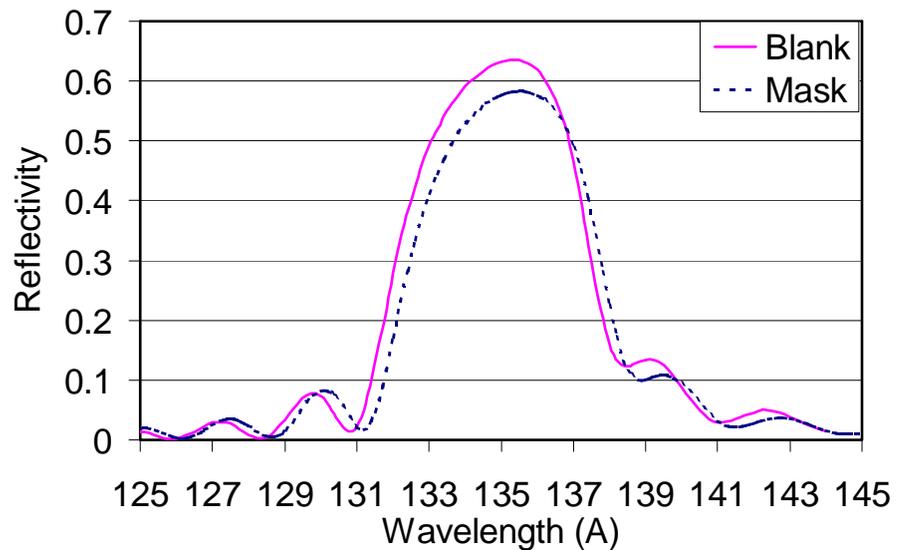


280nm Mo/Si ML + 900SiO₂ + 700A Cr

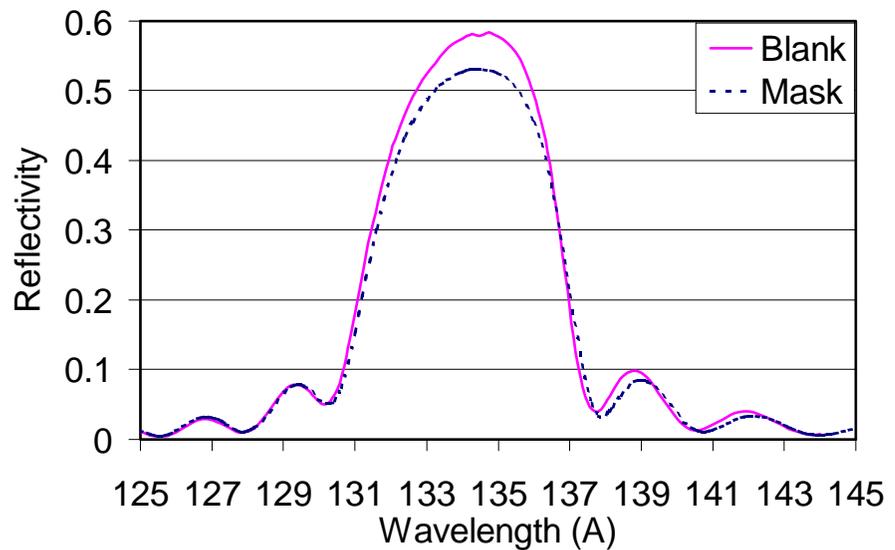


Reflectivity Results for Cr mask

No buffer layer



With 900Å SiO₂ buffer layer

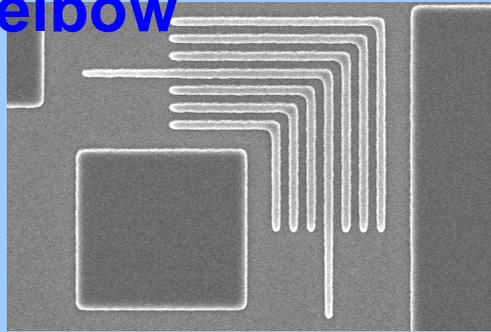


➤ Additional study is under going to identify the contamination that caused reflectivity drop

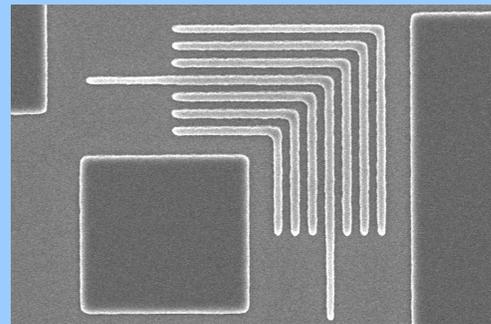
Cr Mask Printing Results

no
buffer layer

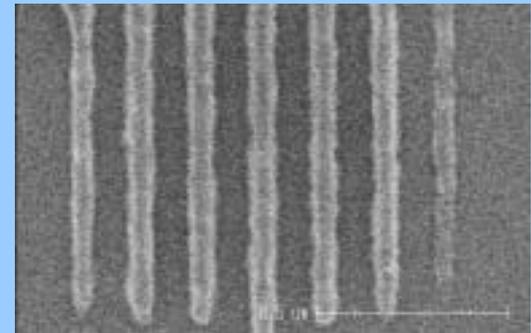
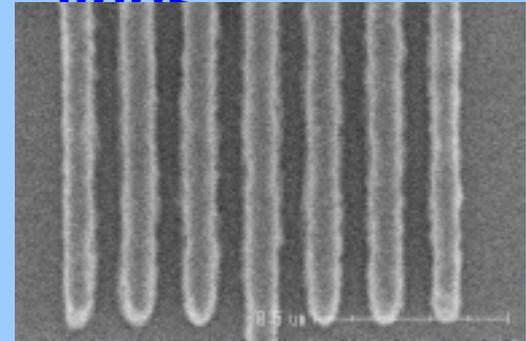
100nm resist
elbow



with
buffer layer



80nm resist
lines



EUV Mask Absorber Material Comparison Table

	Specification	Subtractive Metal Process					
		Al-Cu	Ti	TiN	Ta	TaN	Cr
Metal		Al-Cu	Ti	TiN	Ta	TaN	Cr
Buffer layer		SiO ₂	SiO ₂	SiO ₂	SiO ₂	SiO ₂	SiO ₂
Metal:buffer etch selectivity	> 5:1	-	-	0	+	+	0
Buffer:Metal etch selectivity	>20:1			0	-	0	0
Absorber LER	<10 nm 3sigma	-	-	+	-	+	+
Min. absorber thickness	<1500A (MT+50nm Buffer)	0	-	0	0	0	0
Cleaning	No material loss	-	-	-	-	0	0
Repair etch selectivity to buffer layer	> 2:1	0	+	+	-	-	-
DUV insp contrast	> 0.6	-	0	0	-	0	0
Emissivity (ML: 0.122)	Larger the better	-	-	+	+	+	+

0: Meets specification

+: Does not meet spec, it is advantageous in the comparison

- : Does not meet spec, it is disadvantageous in the comparison

➤ Cr and TaN absorbers identified as the best candidates

Summary

- **Two leading absorber materials, Cr and TaN, for EUV mask identified**
- **Total absorber height (buffer + metal) < 100 nm can be used**
- **Repair etch selectivity improvement via different etch chemistry for both TaN and Cr films is still needed**
- **EUVL mask technology risk reduced with the progresses made in mask fabrication**

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