

# Low Temperature Deposition of PECVD Dielectric Films

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# Outline



- Overview of SVTC
- Need for low temperature PECVD processing
- Experimental plan
- Results
- Conclusions
- Summary

# Bridging the Gap





Innovation Phase



# **Enabling Development Needs**



Low temperature PECVD processes developed and added into SVTC's process library

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# PECVD at SVTC



- Novellus Concept 1 uses a shower head plasma system
- Standard processes well characterized (Stress, non-uniformity, IR, particles...)

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Low temp (<250C) processes not characterized</li>



### **Need for Low Temperature Processing**

• Newer technologies and product classes often require backend PECVD, but at lower process temperatures

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# **Experimental Plan**



- Most customers have unique film requirements development desired to cover wide process space
- General requirements are:
  - Low stress
  - Low non-uniformity
  - IR close to standard  $Si_3N_4$  (~2.0)
  - Low defect levels
- Initial development included a customer sensitive to hydrogen content
- Performed DOE of SiH4-based PECVD silicon nitride film in the range of 160C-250C

# **Experimental Plan**

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#### • Parameters selected:

- Temperature
- Pressure
- HF/LF Power Ratio
- Total Gas Flow

#### • Responses:

- Stress (KLA Flexus)
- Non-Uniformity (KLA Aset F5x)
- Index of Refraction (KLA Aset F5x)
- Particles/Defects (KLA SP1)



## Experimental Results: Data Table

• Non-uniformity ranged from 4.3 to 29.2%, IR ranged from 2.0384 to 2.5042, and Stress ranged from -1.45E8 to -1.0E10

Run	Temp	Pressure	Total Gas Flow	HF/LF Ratio	Non-Unif	IR	Stress
1	160	-	+	+	4.3%	2.3712	-2.98E+08
2	205	+	+	-	4.7%	2.2296	-2.37E+09
3	160	+	+	-	5.5%	2.2647	-1.20E+09
4	160	+	+	+	5.9%	2.3271	-1.45E+08
5	160	+	-	-	6.7%	2.0571	-3.99E+09
6	205	+	+	+	7.1%	2.4635	-1.46E+08
7	250	+	+	+	7.7%	2.5042	-6.60E+08
8	250	+	-	+	7.9%	2.1889	-3.03E+09
9	205	-	+	+	8.1%	2.3853	-3.60E+09
10	205	+	-	-	8.4%	2.1033	-4.83E+09
11	160	-	-	+	8.7%	2.2535	-2.53E+09
12	205	+	-	+	9.8%	2.1493	-8.09E+08
13	160	+	-	+	11.3%	2.0772	-1.44E+09
14	160	-	+	-	11.5%	2.0758	-2.11E+09
15	250	+	+	-	13.0%	2.1713	-4.79E+09
16	205	-	+	-	14.8%	2.1057	-8.78E+09
17	250	-	+	-	15.3%	2.1033	-1.02E+10
18	250	+	-	-	16.8%	2.1316	-1.57E+09
19	205	-	-	+	17.7%	2.2457	-4.43E+09
20	160	-	-	-	18.7%	2.0384	-7.81E+09
21	250	-	+	+	18.8%	2.3788	-4.92E+09
22	205	-	-	-	20.9%	2.0479	-8.77E+09
23	250	-	-	-	23.5%	2.0489	-9.90E+09
24	250	_	-	+	29.2%	2.3234	-4.95E+09



## **Experimental Results: Stress**

- All factors and many interactions impact stress
- Most applications require minimal stress to avoid delamination



Effect Screening

Term

Pareto Plot of Transformed Estimates

Orthog

Estimate



Pareto Plot of Transformed Estimates

Term

Pressure(1,2) Temp[160]

TotalGas(2.575,5.15)

Pressure\*Temp[160]

Orthog

Estimate

-0.0361250

-0.0304145

-0.0262083

0.0140846

### **Experimental Results: Non-Uniformity**

- Pressure, temperature, and total gas flow important
- Low non-uniformity is desired





### **Experimental Results: Index of Refraction**

- All factors important including multiple interaction terms
- IR can be important for optical applications



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Interaction Profiles

HF/LF

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### **Experimental Results: Particles (defects)**

• Pressure and interaction of pressure and temperature important for defects

Minimal defects desired (no gas-phase reactions)

Interaction Profiles

Orthog Term Estimate Pressure(1,2) -1.958333 Pressure\*Temp[205] -1.001735 HF/LF\*Temp[205] 0.942809 Temp[160] -0.918559 HF/LF\*Temp[160] 0.816497 HF/LF\*TotalGas -0.791667 TotalGas\*Pressure -0.791667 Pressure\*Temp[160] -0.714435 TotalGas\*Temp[205] -0.648181 Temp[205] 0.294628 HF/LF\*Pressure 0.291667 TotalGas(2.575,5.15) 0.291667 TotalGas\*Temp[160] 0.102062 HF/LF(50,75) 0.041667 **Bayes Plot** Defects ranked as 0 = worstNormal Plot and 10 = bestHalf Normal Plot 💙 3.0 Pressure(1,2) 1.5-

Pareto Plot of Transformed Estimates





### **Experimental Conclusions**

- Selection of process
  conditions depends on
  application
- Some response factors are negatively correlated
- Results show good
  process conditions exist
  in 160C-250C range (low
  stress, low non uniformity etc)
- Factors can be optimized based on desired outputs



### Summary



**SVTC** 

- Performed DOE of PECVD silicon nitride film in the range of 160C-250C
- Process window results show good film properties can be achieved <250C</li>
- Process can be optimized based on specific applications



# **Questions?**