Metrology for Low-k Materials

Technos S-MAT

Outline

- Technos S-MAT
- Measurements
  - Thickness
  - Roughness
  - Density and Porosity
  - Pore Size
- Conclusion

Technos Semiconductor Materials Analysis Tool (S-MAT)

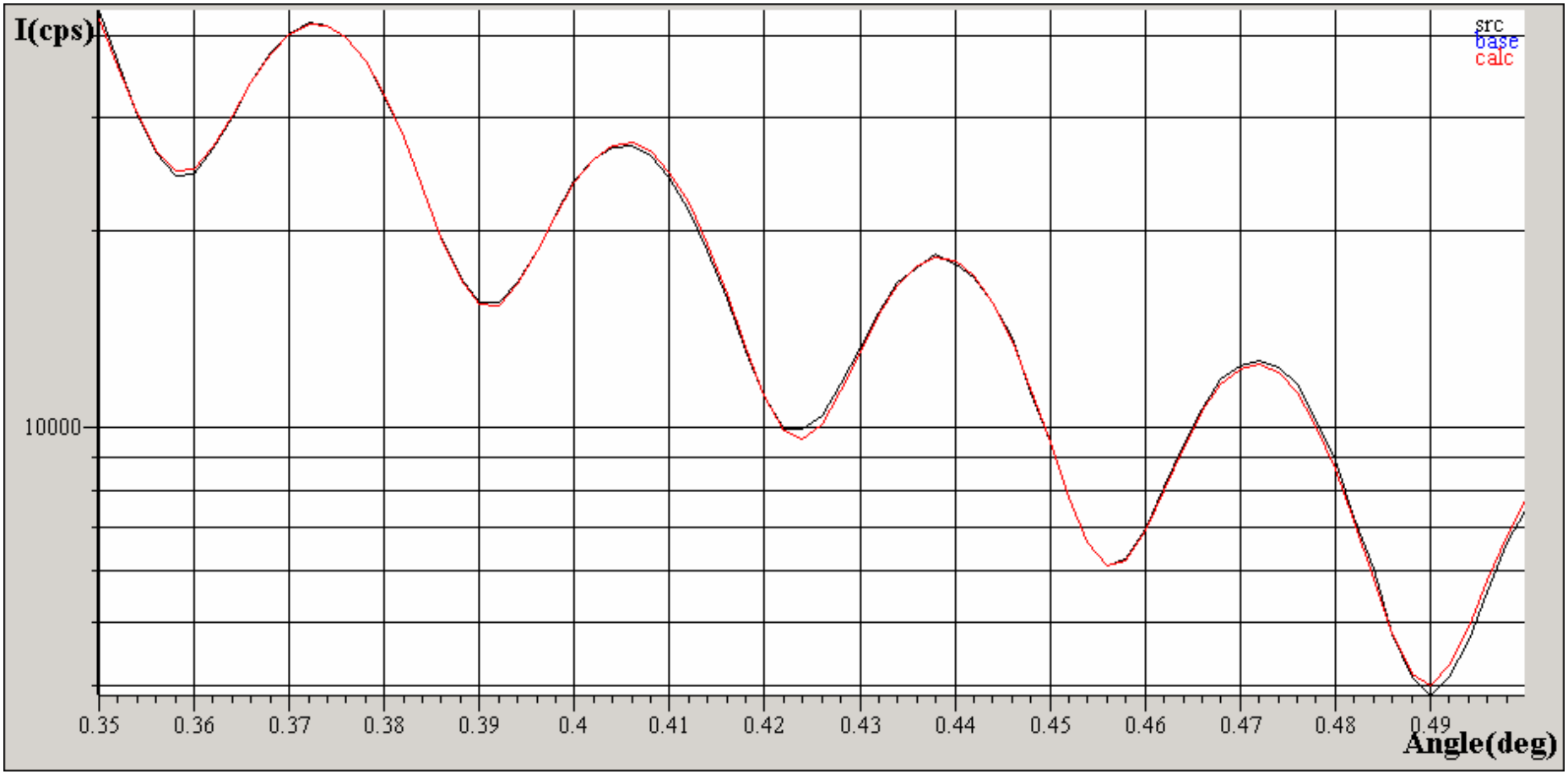
- 200 – 300 mm wafers
- Open cassette, FOUP, or SMIF
- Suitable for fab and lab use

Thickness

- Thickness is determined from the fringe spacing present in XRR measurements independently of all materials properties using the follow equation:

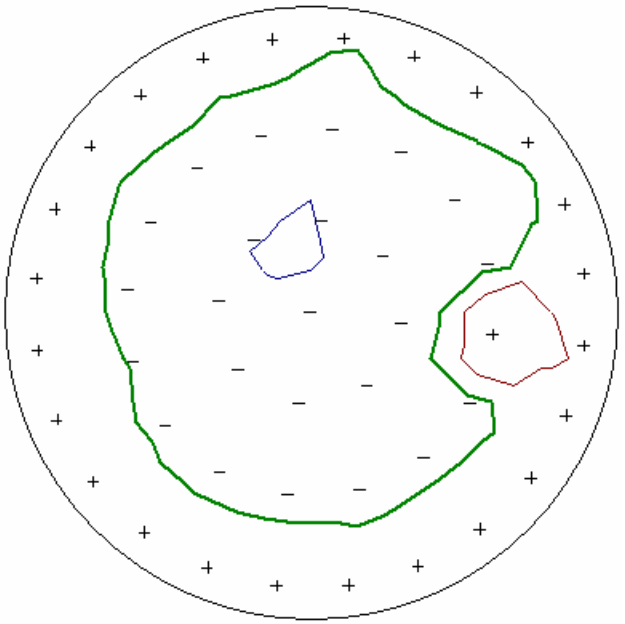
$$R(\theta) = B(\theta) \cdot (1 + A(\theta)\cos(\frac{4\pi t\theta'}{\lambda}))$$

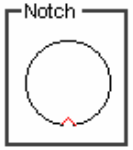
Porous SiLK Data



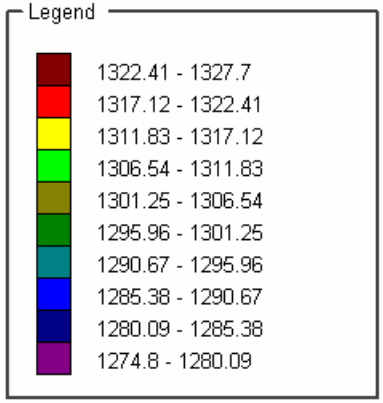
Thickness – 1278.7 Å

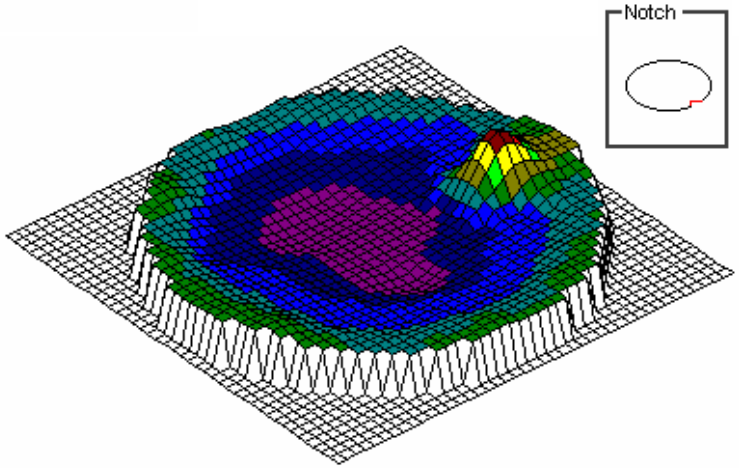
Porous SiLK Thickness Map





Maximum (Å)	1327.7
Minimum (Å)	1274.8
Average (Å)	1290.5
Standard Deviation (Å)	9.380
Relative Standard Deviation (%)	0.73





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Thickness for Wafer in the Same Lot

Maximum (Å)	Minimum (Å)	Average (Å)	Standard Deviation (Å)	Relative Standard Deviation (Å)
1327.7	1274.8	1290.5	9.380	0.73
1303.6	1271.7	1290.0	8.287	0.64
1335.6	1285.9	1300.1	7.657	0.59

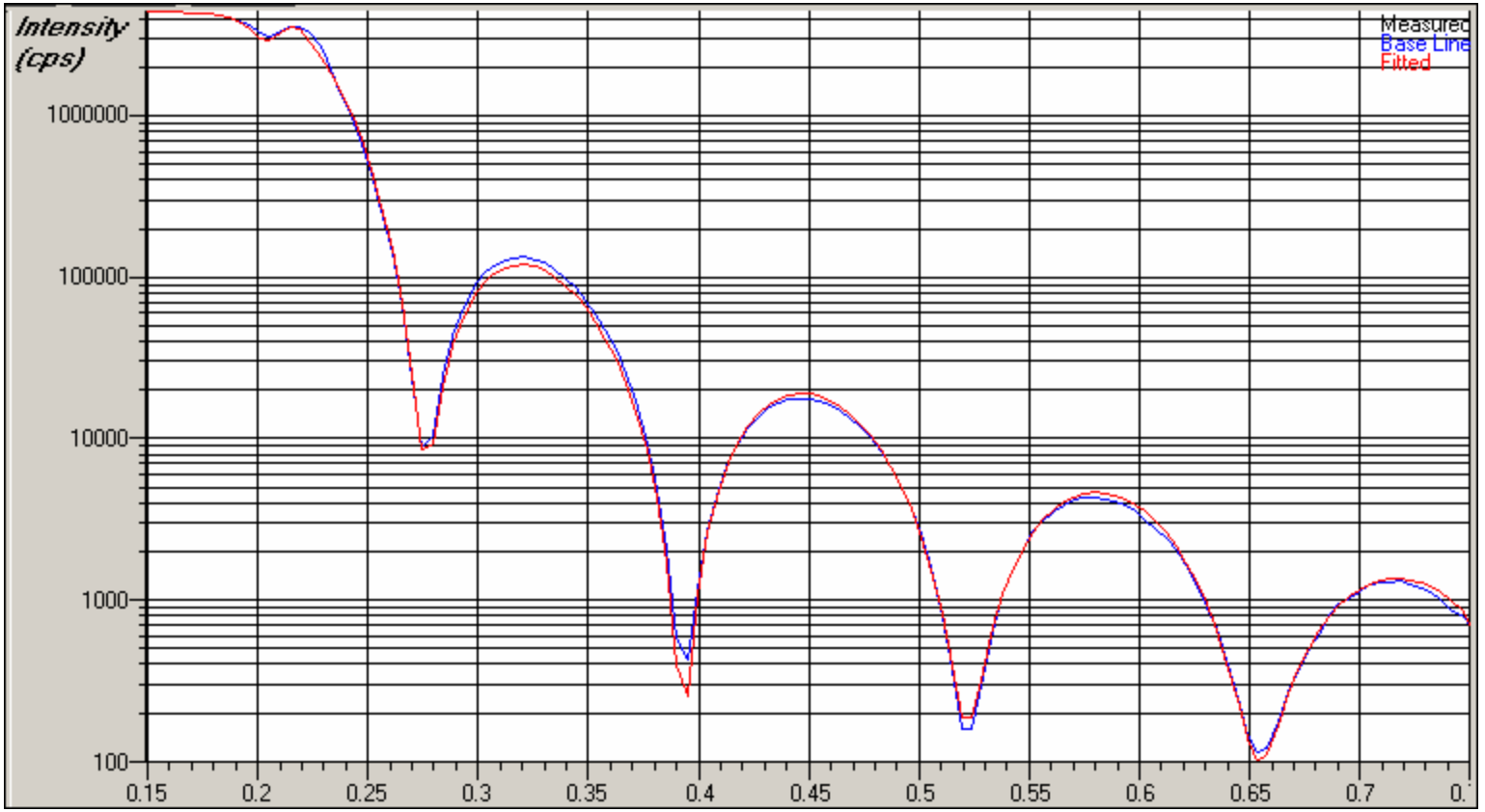
Thickness Repeatability

- 20 measurements collected at the wafer center point

Maximum (Å)	1292.9
Minimum (Å)	1290.6
Average (Å)	1292.1
Standard Deviation (Å)	0.74
Relative Standard Deviation (%)	0.06

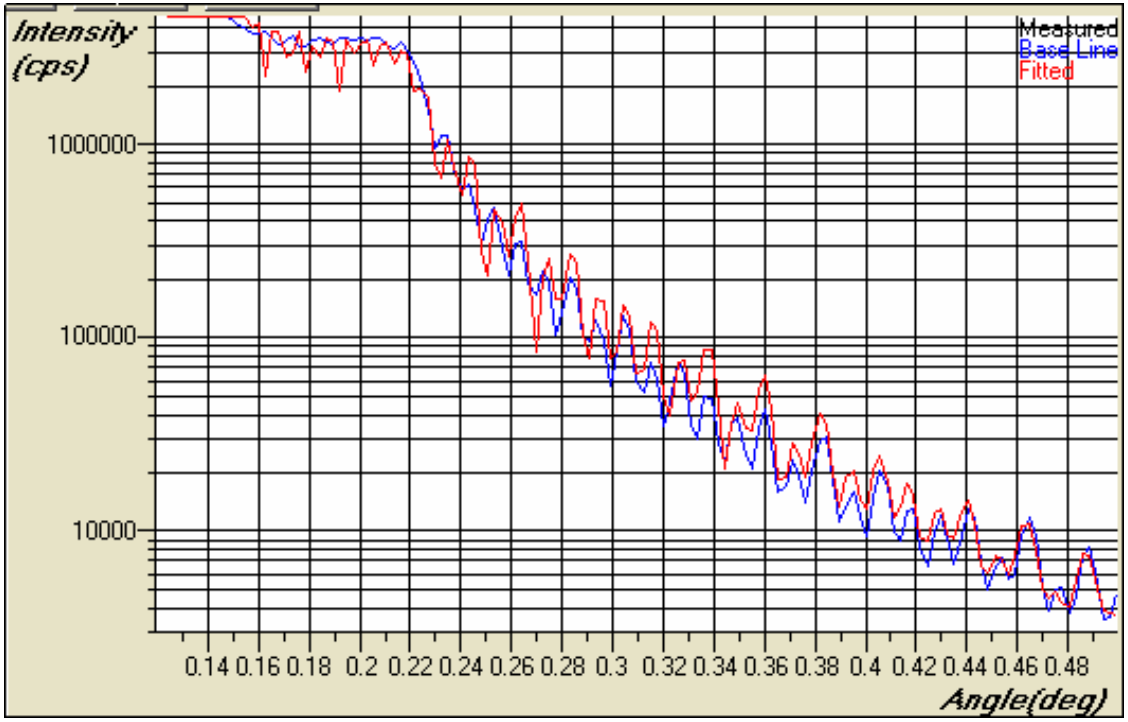
Ensemble* ES Etch Stop

Density – 1.49 g/cm^3
Thickness – 314.9 Å



*Ensemble ES etch stop is a trademark of The Dow Chemical Company

SiLK-I/Ensemble ES/SiLK-I



	Density (g/cm^3)	Thickness (Å)	Roughness (Å)
SiLK-I	1.17	1623.4	30.8
ES	1.42	348.4	22.1
SiLK-I	1.16	1545.2	14.9

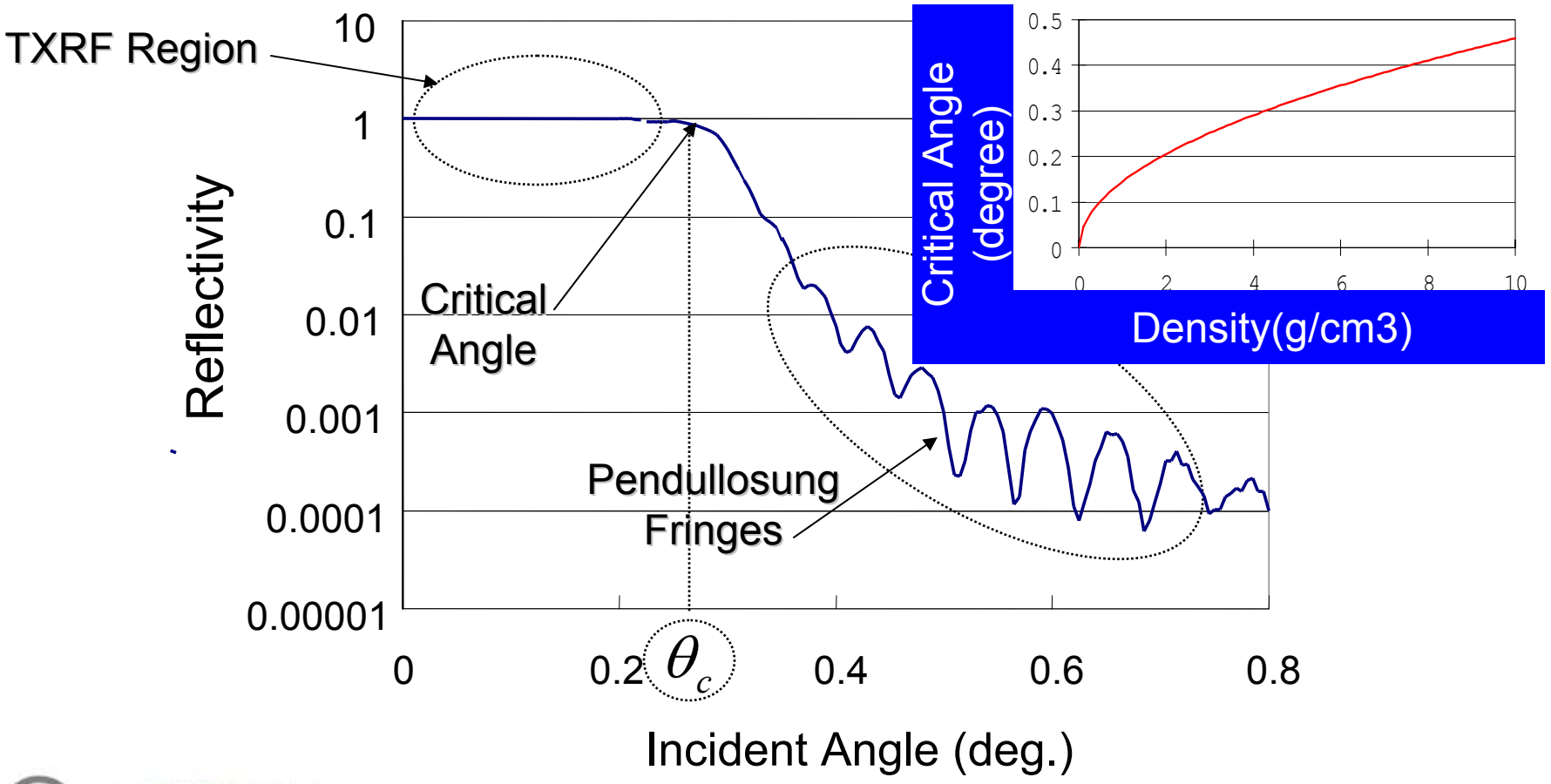
Density and Porosity

- Density can be determined directly from the critical angle of an X-Ray Reflectivity (XRR) measurement.
- Electron density is measured, and is converted to mass density with the following equation:

$$\rho_{(g/cm^3)} = \frac{7380 \cdot Z \cdot \theta_{c\,(rad)}^{\,2}}{A \cdot \lambda_{(nm)}^{\,2}}$$

- The only materials parameters are Z (atomic number) and A (atomic mass). These can be reasonably approximated as 0.5 for low-k materials

Density and Porosity

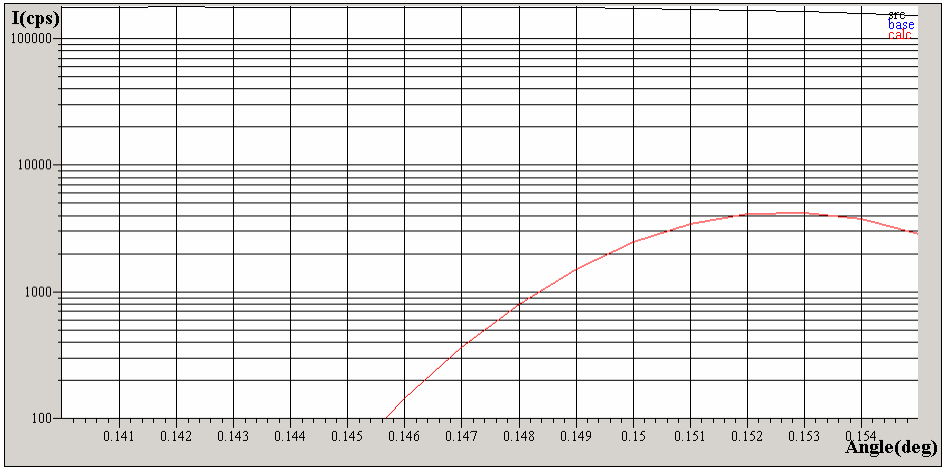


Density and Porosity

- The porosity can be calculated from the density using the following equation:

$$porosity_{(\%)} = 1 - \left(\frac{porous\_density}{dense\_density}\right) \bullet 100$$

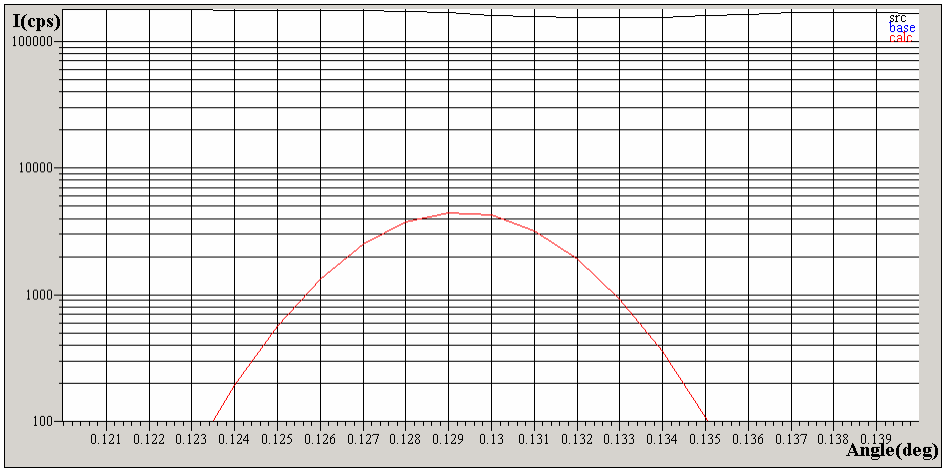
Porous SiLK Data



XRR Measurement of Critical Angle

SiLK Matrix
density - 1.10 g/cm^3
porosity – 0 %

Porous SiLK
density - 0.87 g/cm^3
porosity – 20.8 %



XRR Measurement of Critical Angle

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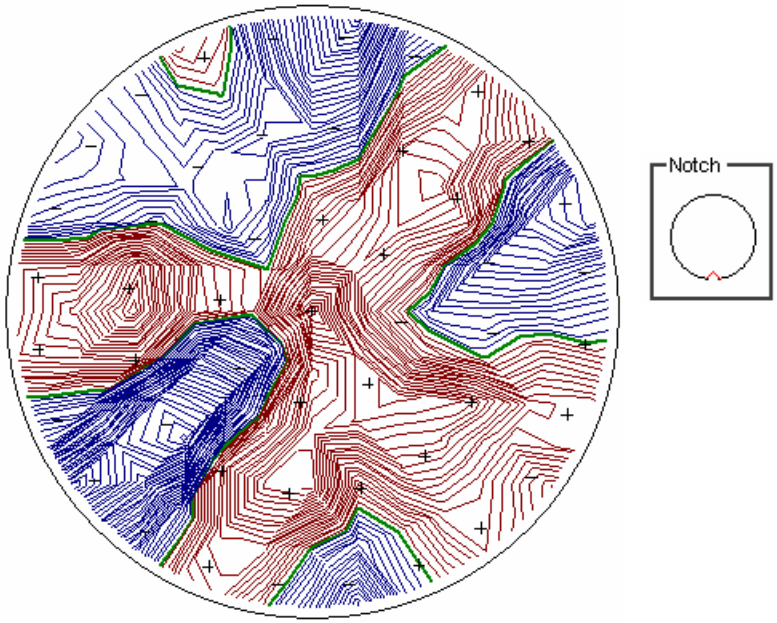
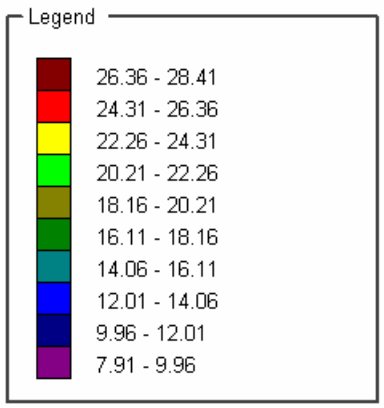
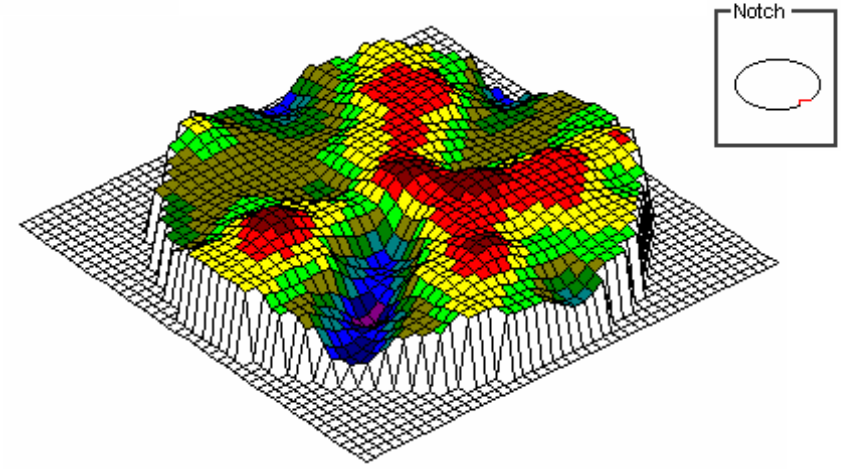
Porous SiLK Porosity Map



Maximum (%)	28.41
Minimum (%)	7.91
Average (%)	20.83
Standard Deviation (%)	4.720
Relative Standard Deviation (%)	22.66





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Porosity for Wafer in the Same Lot

Maximum (%)	Minimum (%)	Average (%)	Standard Deviation (%)	Relative Standard Deviation (%)
28.41	7.91	20.83	4.720	22.66
28.61	10.03	20.38	3.909	19.18
26.90	9.89	19.17	3.02	15.75

Porosity Repeatability

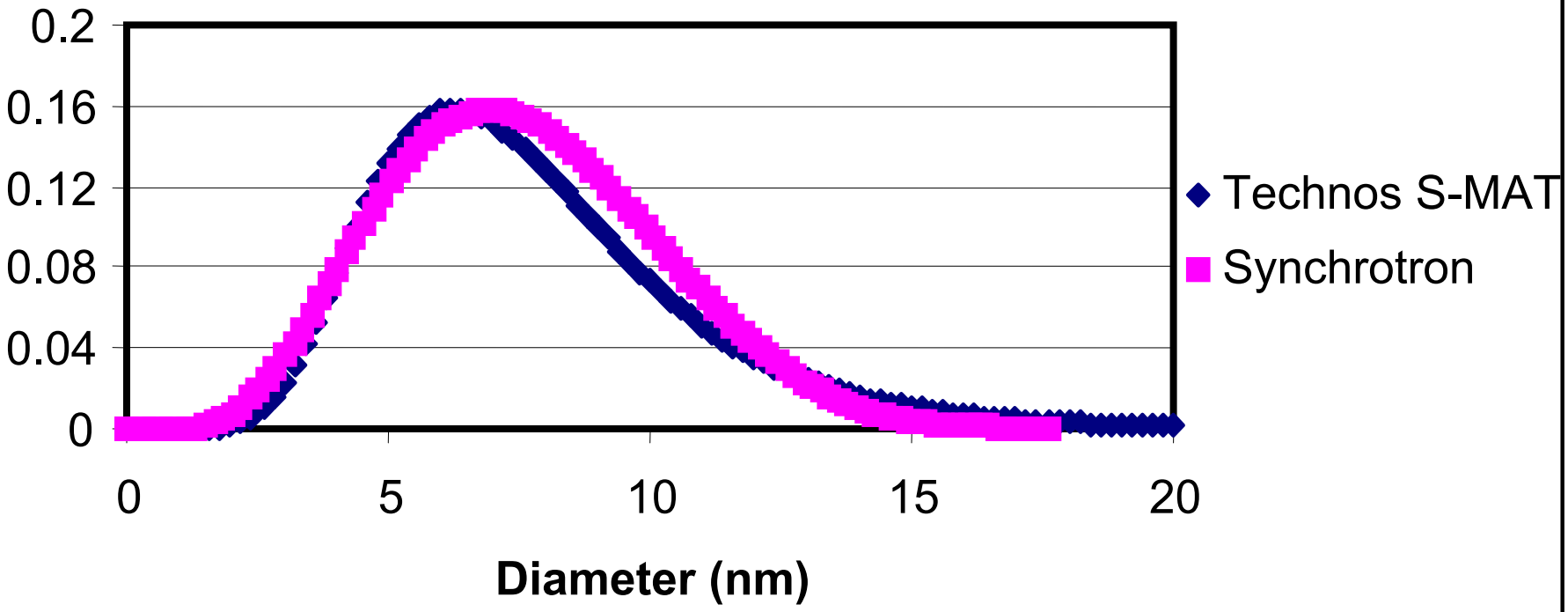
- 20 measurements collected at the wafer center point

Maximum (%)	25.56
Minimum (%)	24.72
Average (%)	25.13
Standard Deviation (%)	0.25
Relative Standard Deviation (%)	0.98

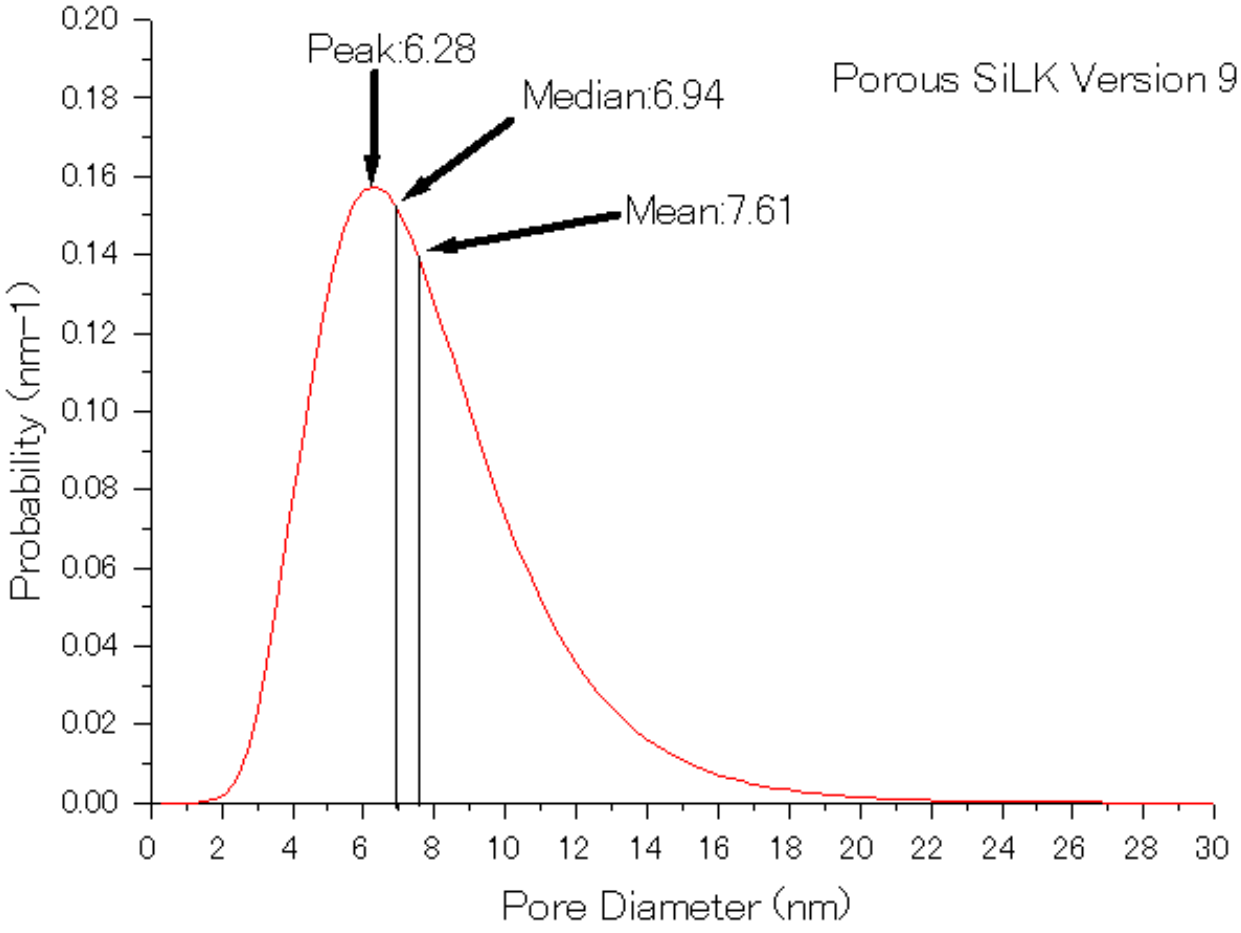
Pore Size Measurement

- Small Angle X-ray Scattering (SAXS) measurements are used to determine the following properties
  - Average pore size
  - Pore size distribution including the detection of killer pores
- Software for the analysis of SAXS measurements has been developed by Technos for closed pore systems and is currently being developed for innter-connected pores

Pore Size/Pore Size Distribution by SAXS



Pore Size/Pore Size Distribution by SAXS



Conclusion

- The Technos S-MAT can be used to measure density, porosity, thickness, roughness, average pore size and pore size distribution of low-k materials.
- The S-MAT is suitable for lab use during process development and for fab use during process monitoring
- The Technos S-MAT is also capable of measuring other layers including, etch stops, hard masks, barriers, and metals.