Opti-Probe Measurements of Low-k Porous SiLK Samples

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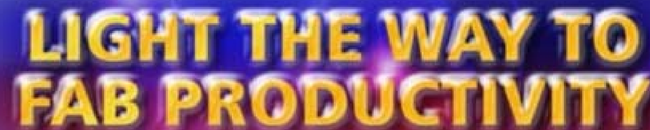


Description of SiLK

- SiLK is a low k organic polymer that is gaining attention
- Metrology methods are necessary to analyze the characteristics of SiLK
  - Metrology has been identified as the gating item for implementation of porous films
  - Properties include thickness, optical dispersion and porosity
- SiLK porosity can be characterized by three quantities
  - Void fraction
  - Mean pore size
  - Pore size distribution

Opti-Probe 7340 Description

- Thin film measurement tool manufactured by Therma-Wave, Inc.
- Tool contains multiple technologies for measuring optical properties of layers residing in a film stack
- Technologies used for this study include
  - Broadband spectrometer (BB) – measures reflection vs. wavelength
  - Spectroscopic Ellipsometer – measures the polarization or reflected light as a function of wavelength

Critical Point (CP) Dispersion Model

- The CP model is a representation of the complex dielectric function, $\varepsilon_1 + i\,\varepsilon_2$
- It is an exact physical calculation of n&k based on the interaction of light with the oscillating motion of bound electrons in a material
- Parameters of the CP model include
  - E = resonance/absorption energy for each peak
  - F = oscillator strength for each peak
  - G = damping constant for each peak
  - S = phase of the oscillator strength for each peak
  - H = asymptotic value of the dielectric function as frequency goes to infinity

Bruggeman Effective Medium Approximation (BEMA)

The BEMA model has been used widely in the field of ellipsometry.

$$f_1\,[(k_1 + k_e) / (k_1 + 2k_e)] + f_2\,[(k_2 - k_e) / (k_2 + 2k_e)] = 0$$

f_1 = volume fraction of component 1

k_1 = dielectric constant of component 1

k_e = the material's effective dielectric constant

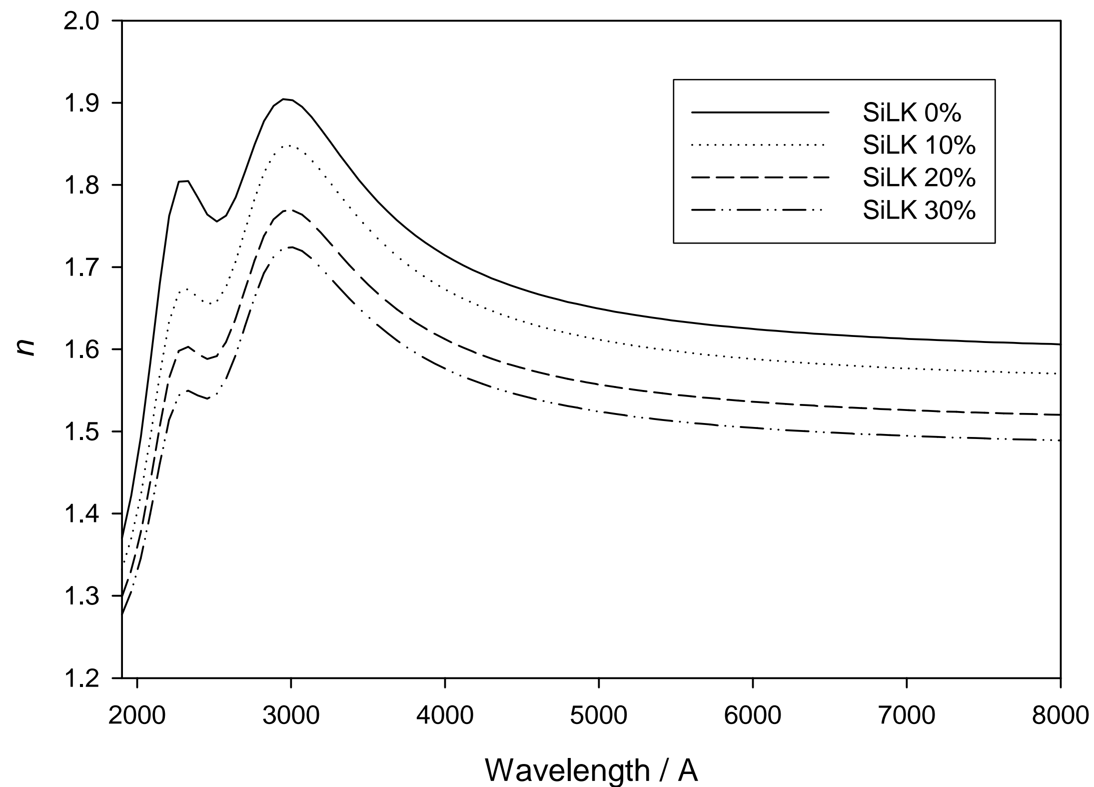
Precision

Thirty-point precision measurement results (t and f_{void}) for different loading percentages with BEM SE recipe.

Sample No.	Reported porogen loading (%) from sample manufacturer	t / Å (avg)	σ_t	f_{void} (avg)	σ_{fvoid}
1	0	4319.84	0.64	0.0001	0.0001
2	10	3473.55	0.94	0.1848	0.0004
3	20	3866.39	0.80	0.1292	0.0003
4	30	4110.04	1.49	0.0527	0.0005

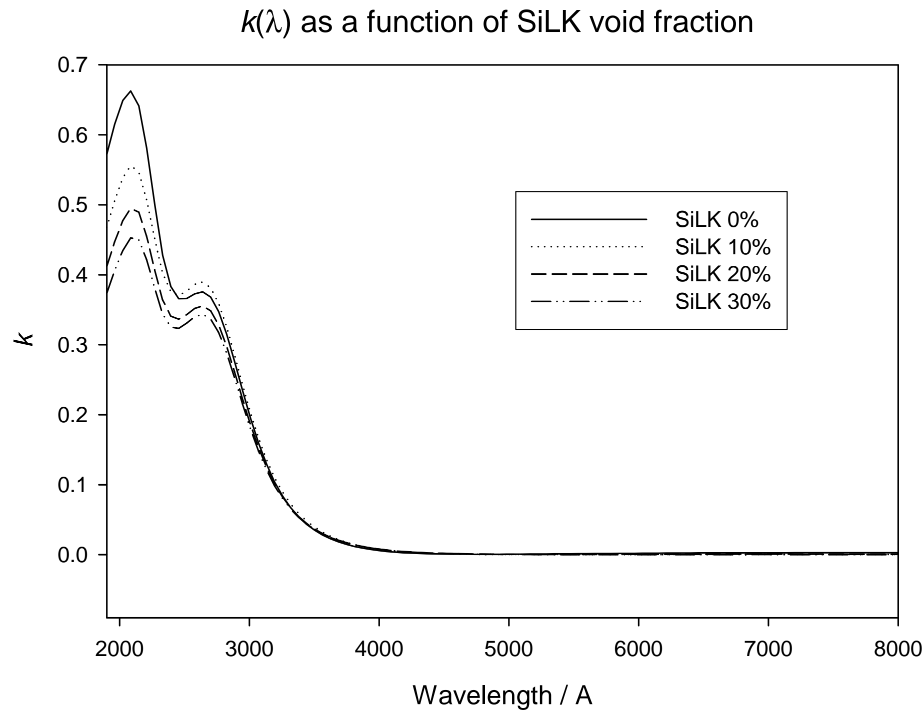
Optical Dispersion

The $n(\lambda)$ curves of 4-point critical point model.



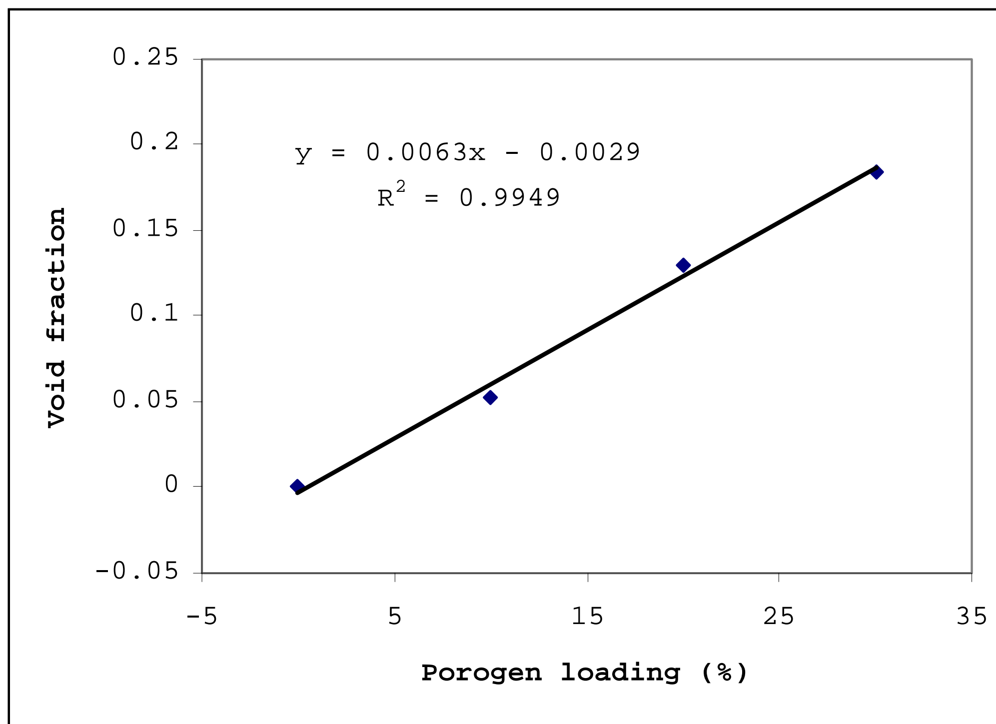
Absorption Curves

The *k*(*λ*) curves were obtained by using a 4-point critical point model. In the wavelength range of 2000 to 3000 Angstroms, differences in the *k*(*λ*) curves are observed for different SiLK void fractions. Above 3000 Angstroms, the SiLK void fraction has no discernable impact on *k*(*λ*).



Void Fraction vs. Loading

Correlation between calculated void fraction from the BEMA SE recipe and the reported porogen loading percent from the sample manufacturer.



Summary and Directions

- SE and BB, which are incorporated into the Opti-Probe tool, are powerful technologies for measuring thickness, dispersion, and porosity of SiLK.
- The dispersion of SiLK is calculated via a combination of two models: BEMA and CP.
- Analysis of additional SiLK samples with known values of both mean pore size and void fraction is planned.