Optical properties of sputtered fluorinated ethylene propylene

P. D. Keathley, J.T. Hastings
Dept. Electrical Engineering, University of Kentucky, 453 F. Paul Anderson Tower, Lexington KY 40506

Fluoropolymers, such as PTFE or Fluorinated Ethylene Propylene (FEP), have a number of potential applications in sensor and optical device fabrication where low index thin films are needed. Beyond excellent optical properties, such films would also be very hydrophobic and chemically inert, making them ideal for medical and biological applications. A specific example is found in the production of dual mode surface plasmon resonance (SPR) sensors.[1,2] When a low index film is introduced between glass and a thin film of gold it is possible to excite surface plasmons at two different wavelengths in the visible to near IR spectrum thus making the sensor self referencing. Directly sputtering such films would provide a cost efficient and less cumbersome approach to existing methods of deposition, such as spin coating or PECVD. Others have shown[3] that a side effect of sputtering PTFE is the formation of C-CF and C-F bonds, thus reducing the amount of Fluorine in the deposited film resulting in a fluorine to carbon ratio closer to one. Optically this results in the film having a slightly higher index than the bulk target, as was found in all of our sputter coated FEP films [Fig. 1,2].

To study the optical characteristics of directly sputtered FEP films a custom target was fabricated and exposed to Ar plasma at 40 W of RF power. Films of 100 nm to 300 nm thickness were deposited on both silicon and BK7 glass. The films were then analyzed using a J.A. Woollam M2000 spectroscopic ellipsometer and WVASE software to determine the index dispersion over the visible to near IR spectrum. It was determined that the films were best simulated using a Cauchy equation with an Urbach extension. When modeling the data, the best fits for the Si substrates were observed using a surface roughness approximation [Table 1], showing either actual surface roughness or a sharp decrease in film index near the surface of the deposited film. The roughness layer tended to decrease in thickness with an increasing film thickness. For the BK7 substrates, surface roughness modeling was negligible, however large intermix (Bruggeman effective medium approximation of an interfacial mixture) values were found [Table 1] suggesting different film formation on BK7 than on Si. Films on both BK7 and Si demonstrated a slight overall decrease in index with film thickness. We also compare atomic force microscope measurement of film surface roughness to optical modeling and demonstrate the effectiveness of sputtered FEP for dual mode SPR sensors.

---

[1] J.T. Hastings, J. Guo, P.D. Keathley, P.B. Kumaresh, Y. Wei, S. Law, and L.G. Bachas, Optics Express, Vol. 15, No. 26 (2007)

[2] R. Slavik, J. Homola, and H. Vaisocherova, Measurement Science & Technology **17,** 932-938 (2006)

[3] Dhananjay S. Bodas, A.B. Mandale, S.A. Gangal, Applied Surface Science **245**, 202-207 (2005)

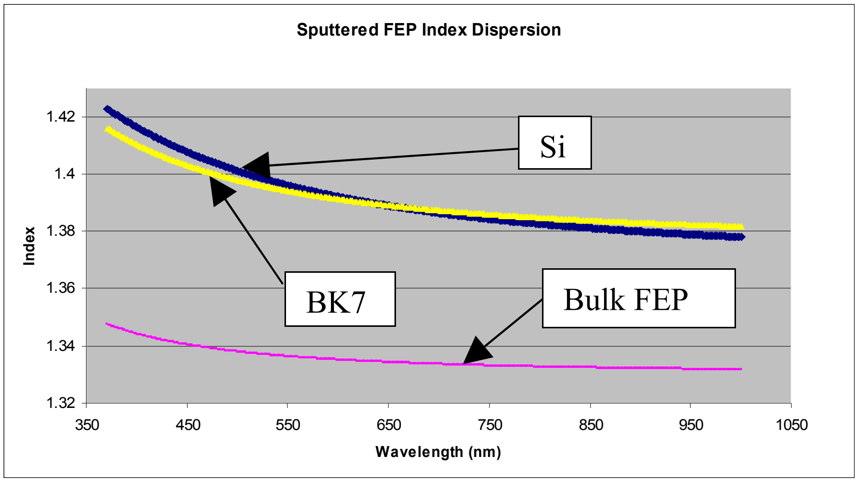

Fig. 1 Index dispersions for sputtered FEP on BK7 and Si using Cauchy modeling with an Urbach extension. The sputtered film is 100 nm thick on Si and 140 nm thick on BK7. Both samples were created in the same sputtering cycle, thus demonstrating higher deposition rates on BK7. The Bulk FEP line is a measure of the FEP target material index.

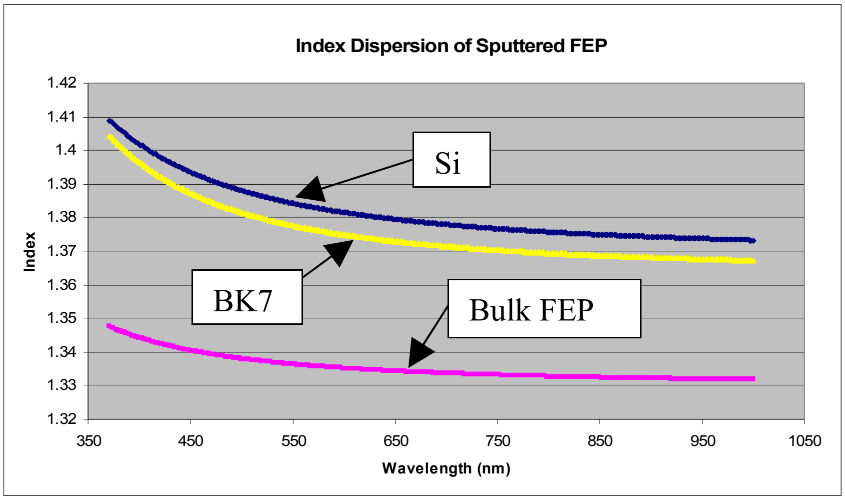

Fig. 2 Index dispersions for thicker depositions of FEP on BK7 and Si. Once again Cuachy modeling with an Urbach extension was used. The sputtered film is 210 nm thick on Si and 300 nm thick on BK7. Note the slight decrease in index from the thinner samples, and the higher speed of deposition on BK7 as both films were deposited in the same sputtering cycle.

Table 1

FEP on Si, 100 nm: MSE=3.283		**FEP on BK7, 140 nm: MSE=7.882**	
Layer	**Thickness Estimation (Å)**	**Layer**	**Thickness Estimation (Å)**
FEP Roughness	97.06±2.07	FEP Roughness	10.21±7.15
FEP	942.94±1.25	FEP	1376.24±8.51
Intermix	19.84±0.464	Intermix	214.21±38.3
FEP on Si, 210 nm: MSE=5.388		**FEP on BK7, 300 nm: MSE=8.650**	
Layer	**Thickness Estimation (Å)**	**Layer**	**Thickness Estimation (Å)**
FEP Roughness	48.01±2.05	FEP Roughness	N/A
FEP	2072.31±0.974	FEP	2964.00±12.3
Intermix	20.78±0.344	Intermix	176.15±51.3

Table 1 Model stacks used to generate the best Cauchy fits for Fig. 1,2 are shown, as well as layer thickness and uncertainties for each quantity, as generated by J.A. Woollams WVASE software. The MSE value is the total mean squared error for each fit. Due to the fact that the signal was much weaker reflecting off of the BK7 samples there was much more noise and higher gain was necessary. As a result, the MSEs are consistently higher for BK7 than Si.