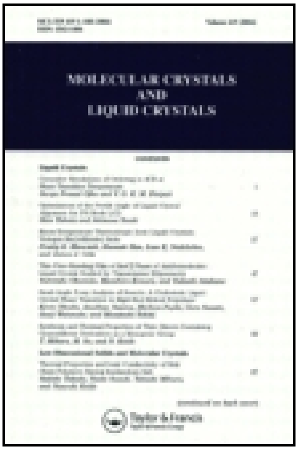

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Design Considerations for Side Polished Fiber Devices with Organic Thin Film Overlays

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Design Considerations for Side Polished Fiber Devices with Organic Thin Film Overlays

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Techniques for determing the critical devices parameters of side polished fiber devices are discussed and illustrated.
Keywords: Side-polished fibers, organic thin films

Recently we reported an investigation of the use of common polymers thin films as the overlay for side polished fiber (SPF) devices .[1] In SPFs a portion (~1 mm in length) of the fiber clad is polished away permitting the light wave to interact with an overlay material placed on the polished area. A variety of overlays have been used with SPFs to make both passive and active SPF devices.[2]

Figure 1 shows the typical transmission spectrum of a side-polished fiber prepared as a "channel dropping" filter. The overlay which was used here is an approximately 9 μm thick film of polystyrene (PS). Polystyrene, like other common polymer hosts, are attractive as overlays because they have the potential to accommodate guest molecules which can add functionality to SPF devices. If dopants with the necessary properties are identified and introduced into one of these hosts then an overlay's optical properties can be modified by the application of light or electric fields. In these cases it is necessary to know critical device parameters such as the SPF-overlay interaction length, L_D, and the filling factor, $\Gamma_{overlay}$, which is the fraction of the light field transmitted through the SPF which actually propagates through the overlay. By using a polymer host overlay made from a solution lightly doped with an absorbing guest, three measurements permit approximate determination of these two waveguide parameters for either a CD or bandpass

(BP) filter. The first measurement directly yields L_D, after which the second and third give $\Gamma_{overlay}$.

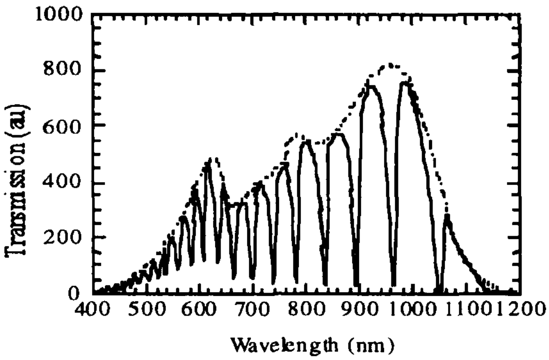

FIGURE 1. Channel Dropping Filter with 9.2 μm thick PS Overlay.

In the first measurement a drop of a liquid superstrate is added to a SPF with an undoped polymer overlay to induce a shift in the resonance spectrum. If the drop is smaller in diameter than L_D the spectral shift is incomplete, thus L_D is approximately equal to the diameter of the smallest water drop which gives a "saturated" shift of the resonance. This measurement is shown in Figure 2 for a 6.52μm undoped overlay.

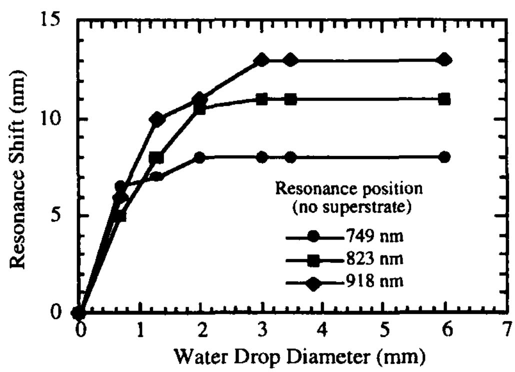

FIGURE 2. CD resonance shift as a function of superstrate coverage.

In the second measurement a standard linear absorption setup is used to determine the absorption spectrum, $\alpha(\lambda)$, or transmission spectrum, $T(\lambda)$, of a doped polymer film with known thickness. This doped film is then used in the *third measurement* as an SPF overlay, and a white light transmission measurement is made. The transmission of the doped film is $T = T_{SPF} \exp(-\alpha\Gamma_{overlay}L_D)$, where T, T_{SPF}, and α are wavelength dependent. T and T_{SPF} are the CD SPF transmission with the doped and undoped film respectively. In the above equation, L_D and α are determined from the first and second measurement respectively, T_{SPF} and T are found from the first and third measurement. Once these four values are known the filling factor $\Gamma_{overlay}$ can be determined from the above equation.

Figure 3 shows the absorption profile of a 9.4 µm PS film doped with 5.32×10^{-3} mol/l of $(H_2Pc)_2(-)$.[3] Pc's are highly conjugated molecular systems, and therefore have the potential for subpicosecond optical responses and large optical nonlinearities. At nonresonant wavelengths such as 830 nm, that is for wavelengths at which light propagates through the fiber in the SPF and only the tail of the light field extends into the overlay, the absorption loss of the SPF-overlay CD filter is proportional to the absorption spectrum of the isolated film, $\alpha(830\ \text{nm})\Gamma_{overlay}L_D = 0.67$. Using a value of $L_D = 1$ mm from Figure 2, and absorption coefficient $\alpha(830\ \text{nm}) = 500\ \text{cm}^{-1}$ (see Figure 3), we infer a value of $\Gamma_{overlay} = 1.3\%$ for the overlay filling factor.

Similar methods applied to a BP filter yielded $L_D = 2$ mm, and $\Gamma_{overlay} = 79\%$.[1] These values are important parameters for device design. For example, the electro-optic effect can produce index changes according to the relation $\Delta n = 1/2\ n^3\gamma E$, where n is the overlay index, γ is the electro-optic coefficient, and E is the applied field. From the results above we know that a BP filter rather than a CD filter must be used, because contrary to a CD filter, in a BP filter most of the transmitted light travels through the overlay, and undergoes the desired phase change. To modulate the phase of a signal as it travels through the SPF BP device by an amount ϕ requires an index shift as given by the relation $\phi = \Delta n 2\pi L_D/\lambda$. A phase shift $\phi = \pi$ (the ideal value for a Mach-Zehnder modulator) at $\lambda = 806$ nm requires an index change of 2×10^{-4}, and therefore a γ of about 85 pm/V, which is a large, but realistic value. Less than ideal modulation can be achieved with materials which have smaller γ values.

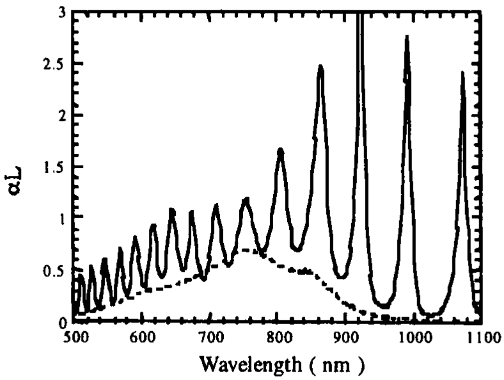

FIGURE 3. CD response of an SPF with a $(H_2Pc)_2$ 9.4 μm doped polystyrene film (solid line). The dotted line shows the absorption of the film.

In summary, common polymer hosts are attractive as overlays because they have the potential to accommodate guest molecules which can add functionality to SPF devices. In these cases it is necessary to know critical device parameters such as the SPF-overlay interaction length, L_D, and the filling factor, $\Gamma_{overlay}$, of the light field within the overlay. By using a polymer host overlay made from a solution lightly doped with an absorbing guest, three measurements permit approximate determination of these two waveguide parameters for either a CD or BP filter. Once these values are known an overlay can be designed which has the required material properties.

Notes and References

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2. See reference section in reference 1
3. Minquan Tian, Tatsuo Wada, Liming Wang, and Hiroyuki Sasabe, Nonlinear Optics **15**, 205-208 (1996).