Optical propagation loss measurements in electro optical host - guest waveguides

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ABSTRACT

Thin organic waveguiding layers are applied more and more frequently as optical components in novel optoelectronic devices. For development of such devices it is important to know the optical properties of the used waveguides. One of the most important parameters is optical propagation loss in the waveguide. In this paper we present optical propagation loss measurements in planar electro optical waveguides using travelling fiber method. Using this method attenuation coefficient α at 633 nm as a function of chromophore concentration for the first two guiding modes in the slab waveguide was determined.

EXPERIMENTAL

For measuring optical propagation losses we used the travelling fiber method . The prism coupling technique was applied for coupling light into planar optical waveguides .

The principal scheme of this method is displayed in **Figure 1**. The incident beam is coupled through a high refractive index prism into a planar waveguide. The light can be coupled at incidence angles that correspond to mode resonance angles in the waveguide. As optical mode propagates in the thin film part of the intensity is scattered at the waveguide – air boundary. This scattered light is collected using a multimode optical fiber. If we assume that surface roughness and waveguide inhomogeneity is maintained throughout the film and that the scattered light intensity is proportional to the light intensity in the waveguide core, then the propagation losses can be estimated. Full scheme of the experimental setup is shown in **Figure 2**. The prism coupling is performed on a goniometric stage. We used a He-Ne laser as light source. Using a computer controlled motorized one axis stage the fiber can be moved along light propagation path and the scattered light can be collected. The scattered light intensity is registered using the PC.

Planar NLO host/guest polymer **PMMA+DMABI** waveguides, were spin-coated from a chloroform solution onto glass substrates. Guest concentrations were varied and waveguides doped at 7.5 %, 10%, 12.5% and 15% were prepared. The waveguide thickness was kept constant at approximately 2 µm.

The scattered light intensity as a function of propagation length x is approximated using an exponential function

$$I = A \cdot e^{-\alpha' \cdot x}$$

where *A* is the light intensity in counts at x=0, *α'* characterizes the exponential decay. If propagation length is displayed in mm, then the attenuation coefficient α in dB/cm can be expressed as

$$\alpha = 10 Log_{10}(e) \cdot \alpha'$$

where *e* is the Euler's number.

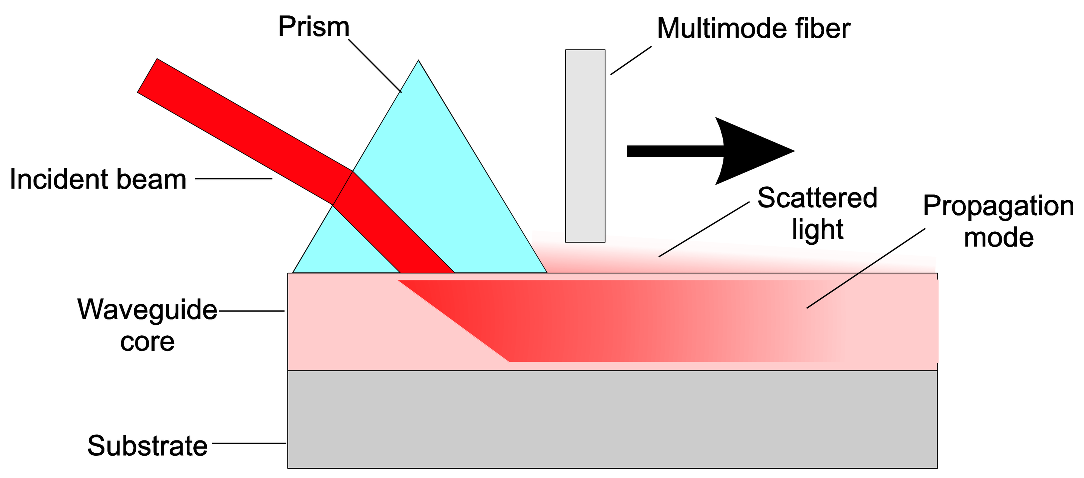

Figure 1. *The principal scheme of light propagation loss measurement by travelling fiber method, the light coupling into the waveguide is performed by the prism coupling technique.*

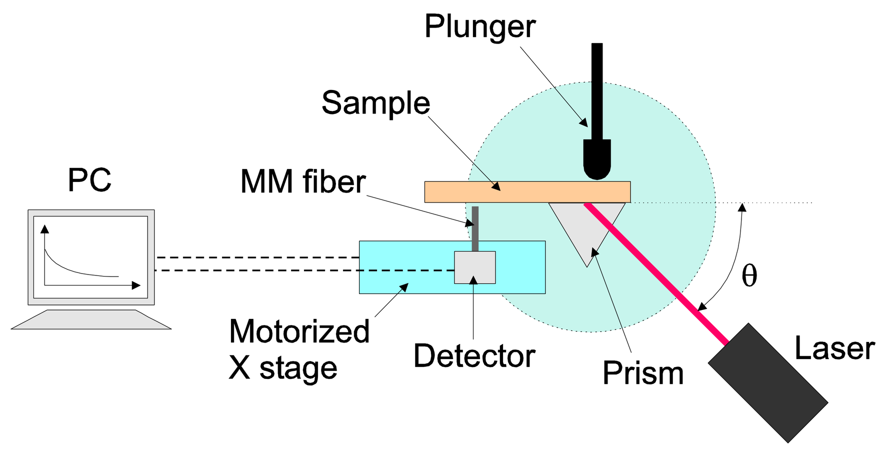

Figure 2. *Experimental setup for measuring light propagation losses in planar waveguides.*

RESULTS AND DISCUSSIONS

The measured scattered light intensity as a function of light propagation distance is shown in **Figure 3**. It can be seen that light intensity decays exponentially as the light propagates through the waveguide. The experimental data do not lie smoothly on the approximation curve and some bumps can be noticed. These are caused by additional scattering elements in the sample such as dust or crystalic phase. The scattering objects are formed during the sample preparation, but should be avoided for good optical propagation loss measurement. The approximation of the experimental data shown in Figure 3 yields that the optical propagation loss for this particular measurement is 9.6 dB/cm.

The measured attenuation coefficient α dependence on the chromophore concentration in the matrix is shown in **Figure 4**. The loss measurements were performed for the first two TE modes of the slab waveguide. We were not able to couple the second TE mode in the waveguides with guest concentration of 7.5 wt%. Since the used laser light wavelength 633 nm is close to the absorption maxima, the measured attenuation coefficients are quite high. From the graph it can also be seen that measured attenuation coefficient values at higher guest concentrations are higher than expected (indicated by lines). This is due to the fact that at higher chromophore concentrations they tend to form crystalic aggregates which reduce the optical quality of the film. Due to this the last point of the first TE mode is no taken into account when determining attenuation coefficient dependence on chromophore concentration.

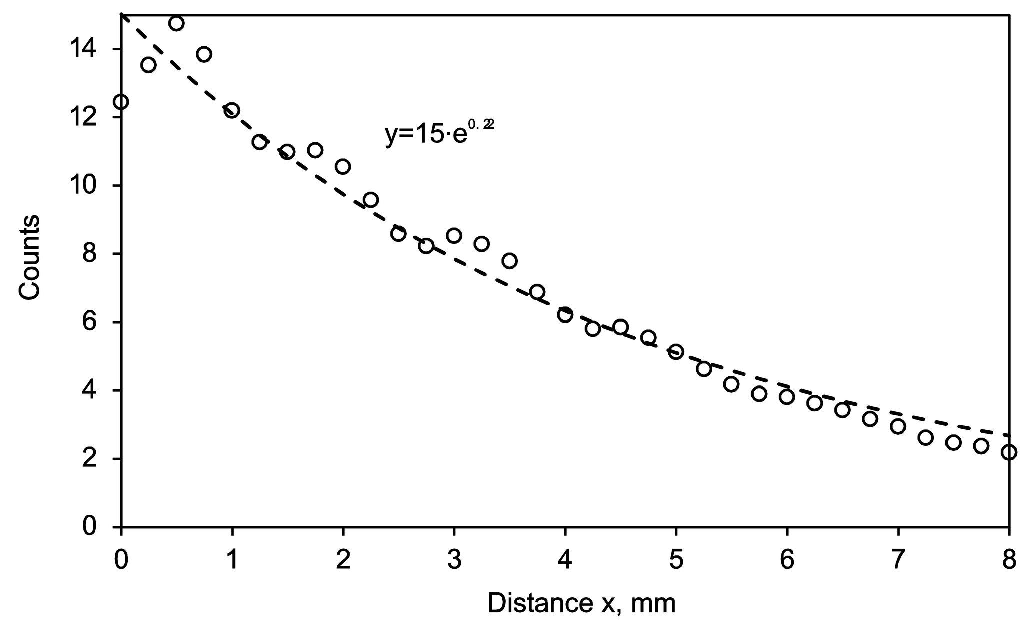

Figure 3. *Scattered light intensity as a function of light propagation length x*

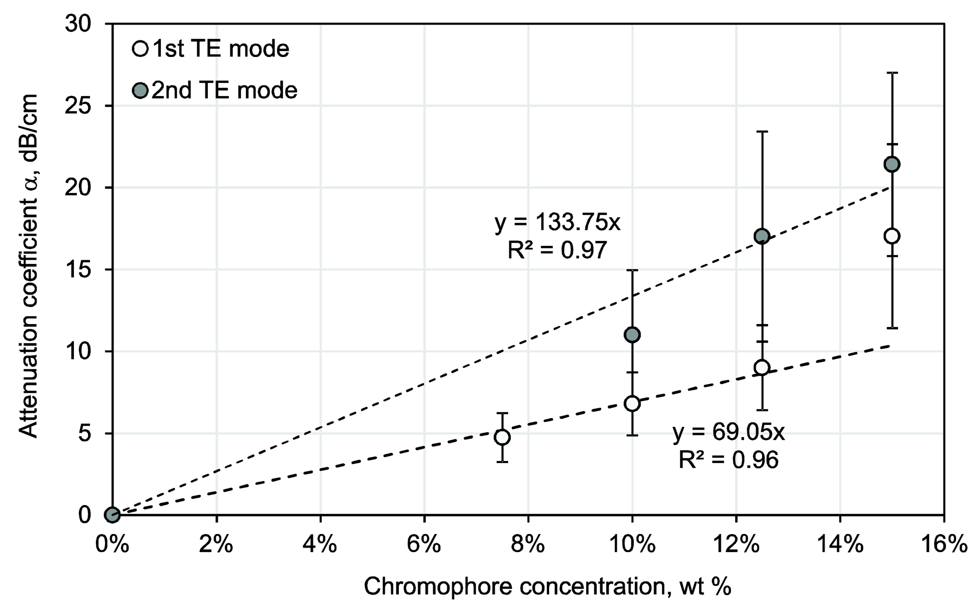

Figure 4. *Attenuation coefficient α at 633 nm wavelength as a function of chromophore (DMABI) concentration in host (PMMA)*

CONCLUSIONS

We have applied the travelling fiber method for measuring light propagation losses at 633 nm of thin organic waveguiding layers and determined the attenuation coefficient α dependence on the NLO active DMABI chromophore concentration in the PMMA matrix. It is found that α grows linearly as the chromophore concentration is increased. Linear growth can be noticed with DMABI concentration up to approximately 12.5 wt%. If the concentration is increased above the mentioned value the propagation losses grow rapidly due to formation of crystalic aggregates which increase the losses due to light scattering. So for low chromophore concentrations the attenuation coefficient is mainly determined by the light absorption, but above the critical value – by the light scattering from crystalic aggregates.

The measured propagation losses are quite high mainly due to the fact that the measurement was performed spectrally close to absorption peak which is at 490 nm. In order to satisfy the material application requirements α < 1 dB/cm, the NLO chromophore concentration at 633 nm should be approximately 1.5 wt% which for DMABI doped PMMA thin films gives the refractive index 1.496. From this value the appropriate waveguide thickness can be found. Theoretically the waveguide thickness that would satisfy the single mode conditions in such a configuration should be around 1.3 µm.

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