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Temperature Dependence of Long Term Modulation Applied to Electro-optic Polymer Waveguide

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Abstract: *We evaluated the long-term stability of EO-polymer based Mach-Zehnder modulator at 25℃, 50℃ and 70℃. We confirmed the existence of phase-drift and derived the activation-energy to be equal to 0.52 eV.*

Introduction

Electro-optic (EO) polymers have attracted renewed interest as practical material platform for realistic devices. One of the major issues of these materials is long-term behavior and stability. There have been reports on the Vπ relaxation and DC-drift for organic[1,2] as well as inorganic materials[3-5]. However, important factors, which are necessary for long-term extrapolation, such as Arrhenius curves, activation energies, have not been sufficiently studied.

In this talk, we report for first time, to the author's knowledge, the temperature dependence of the drift of EO polymer based Mach-Zehnder modulator (MZM) and discuss on the feasibility of this material system with respect to commercially available lithium niobate (LN) based MZM.

Design

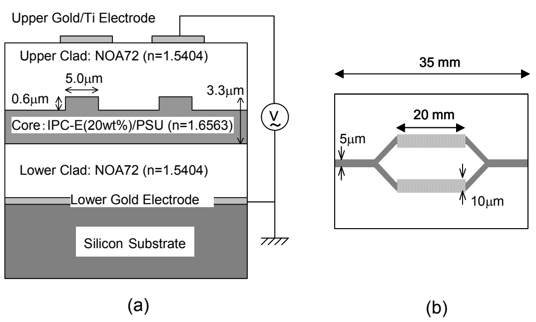

Figure 1: (a) Cross-section of the waveguide at the two arms of the MZM and (b) the planer structure of the device.

As shown in Fig. 1 (a), the modulator consists of a silicon substrate, a bottom electrode, a lower clad layer, a core layer with a rib-structure etched on top of it, an upper clad layer and, finally, the top electrodes. We used chromophores called IPC-E[6]. The IPC-E was dispersed in the host material polysulfone (PSU) such that 20wt% loading density of IPC-E was mixed in PSU. We fabricated the devices using a standard semiconductor process scheme, which has been reported in our past works[7,8]. The planer structure of the device is show in Fig. 2 (b). The coupling loss and the refractive index difference, Δn, for the 0.6μm rib height and 5.0μm channel width is 3.3dB/side and 0.26% (ns=1.6409, nc=1.6451) for the TM-mode, respectively, which is calculated from the refractive indices shown in Fig. 1 (a).

Experiment and Discussion

A commercial laser at 1552nm wavelength provided a continuous wave generation which was launched into a polarization maintaining fiber and connected to a calibrated half-wave plate (HWP). The HWP allowed us to select the TM-mode which was launched into the MZM. The multifunction data acquisition (DAQ) card installed to the personal computer generated a triangular wave form with 10Hz frequency, and the voltage output from the DAQ card was amplified to ±20V without DC bias by high speed bipolar amplifier for driving the MZM. The optical output from MZM was monitored using a power-meter. Both the driving signal and optical response were stored into the personal computer simultaneously using the DAQ card, and subsequently the optical power versus applied voltage was plotted to produce the MZM output.

As shown in Fig.2, the response of our MZM for t=0 and t=80 hrs at T = 25°C, is illustrated in order to define the phase-drift, $\Delta\phi(t, T)$.

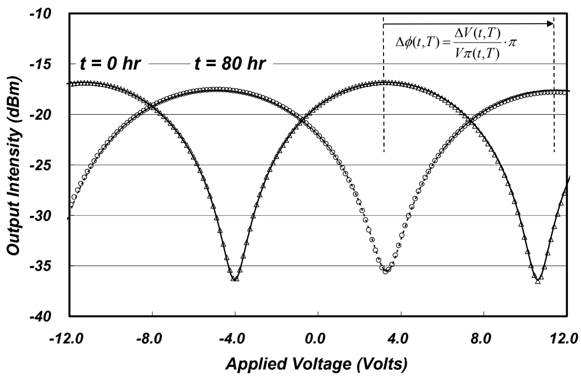

Figure 2: Typical response curves of our MZM at t=0 and t=80 hours at T=25°C

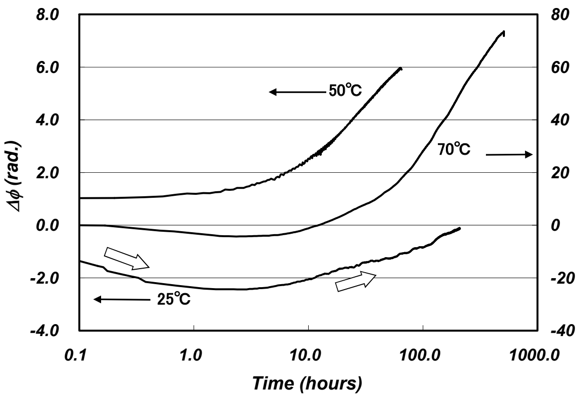

Figure 3: $\Delta\phi(t, T)$ characteristics for T is 25°C, 50°C and 70°C data respectively

As shown in Fig.3, we present the behavior of the phase-drift dependence on the operation temperatures, 25°C, 50°C and 70°C. It is interesting to see that at room temperature, T=25°C, the drift shifts toward negative side and then reverses for the first hundred hours which is similar to LN devices[4]. This effect is also visible in higher temperature T=70°C. It is, therefore, speculated that the cause of this behavior in polymers might be similar to that in LN's. The details of this phenomenon will be discussed in our talk.

Fig. 4 shows the Arrhenius curves obtained using the results in Fig. 3. The characteristics show a linear property which allow us to deduce the activation energy, Ea=0.52 eV. This value is similar to LN which is approximately 1 eV[4]. Therefore, we believe that with optimization realistic device similar to LN-based modulator can be achieve using DC-compensation circuit.

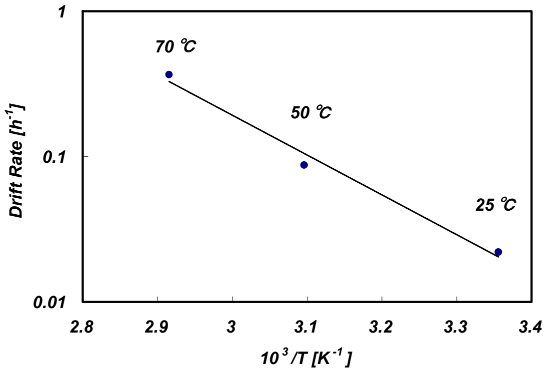

Figure 4: Arrhenius plot of phase-drift rate.

Summary

We have evaluated the phase drift of EO polymer device and found that it is comparable to LN-based MZMs. Although, further repeatability test is necessary, by directly measuring the phase-drift at 25°C, 50°C and 70°C, we deduced the activation-energy to be equal to 0.52 eV. This degree of performance is expected to be sufficient for realistic applications using EO polymer devices combined with commercially available DC-compensation circuits.

Reference

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