

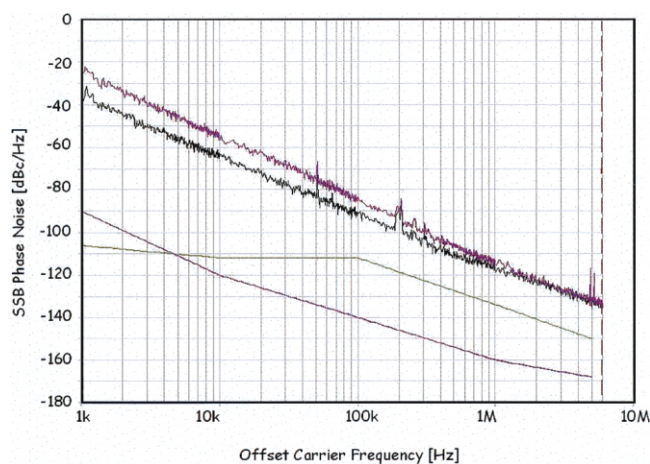


Figure 9 Measured phase noise. -85 – 90 dBc/Hz at 100 kHz and -115 dBc/Hz at 1 MHz. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

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MICROCONTROLLED ELECTROOPTIC SYSTEM FOR ONLINE LIGHT TRANSMISSION CONTROL OF NOVEL ELECTROCHROMIC DEVICES

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ABSTRACT: A new all-plastic electrochromic device configuration is developed and electro-optically tested, and a microcontrolled portable control system is designed for a wide variety of applications. The capability of the electrochromic devices to control the illumination and, eventually, the temperature in receptacles with little windows is checked. © 2006 Wiley Periodicals, Inc. *Microwave Opt Technol Lett* 48: 1572–1574, 2006; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.21725

Key words: electro-optic system; organic electrochromic materials; light transmission; online control

1. INTRODUCTION

The control of light crossing a material can be useful for a great variety of uses, from temperature stabilization of microenviron-

ments to large-volume domestic applications. Some materials are able to carry out this control through different processes: by changing the orientation of their molecules, such as liquid crystals, or by changing their chemical compositions, such as electrochromic (EC) materials under application of either the AC or DC electric field, respectively. Research on electrochromic devices has attracted a great attention during the last years [1–5], supposing an improvement over the liquid crystals in memory effect, isotropic transmittance, low switching voltages, lineal and continuous control of the transmittance, and power consumption.

An EC device is usually formed by a multilayer cover (thickness ~ 1 mm) of a transparent ionic conductor (electrolyte) placed between two layers: one of electrochromic material and the other of a material called counter electrode. The set is inserted between two layers of transparent electrode (usually ITO). Driving voltage, a redox reaction, is produced, thus changing the electrochromic material optical properties.

New EC materials are being tested all over the world in order to reach an optimum performance [6]. A study that focuses its attention both on the materials as well as on the potential applications in actuators for light control of environments is presented. The aim of this work is the implementation of an electro-optic system based on a microcontrolled-driver for online control of versatile EC windows, with previously unknown characteristics. The “new all-plastic” EC device is achieved by using only conducting polymers as EC material, electrolyte, and counter electrode. The main idea in the design is to develop an electronic and scalable portable calibration and control system that can be used with EC devices, regardless of the test place in which they act as transparency regulators.

2. EXPERIMENTAL

Electrochromic devices with a new configuration have been constructed, as shown in Figure 1; the use of a conductor layer to make a contact electrode is avoided. PEDOT acts both as an electrochromic layer as an electrode. PEDOT is coloured in transparent-blue when oxidized and in dark-blue when reduced. In a poly(ethylene terephthalate) foil covered by PEDOT, commercialised by AGFA under the trademark of ORGACON, a tetrahydrofuran solution of a poly(ethylene oxide-lithium triflate) polymer electrolyte is deposited by casting. Afterwards, the solvent is evaporated, at room temperature during 3 h, and a second ORGACON EL-350 foil is glued on top of the polymer electrolyte layer. In this configuration, one of the PEDOT layers acts as electrochromic material and the other layer acts as counter electrode. The construction is totally symmetric, thus the role of the PEDOT layers could be interchangeable. The easy construction of the devices, with only available materials, simplifies from five to three the active layers number, and may derive in many technological advantages. The number of active layers is reduced from the usual five to three.

To evaluate the consumption performance of the EC devices, a potential step chronoamperometric experiment was performed, in which the current through the device is measured during switches from 0 to 3 V. Figure 2 shows five representative cycles (first voltage value is 0 V) of one of the slowest devices, chosen in order to visualize the current injection process more accurately. We observe a charging current that, after a peak, decays quickly to zero (during coloration, with 3 V applied) or to a residual leakage current (during bleaching, with 0 V applied). Current responds within a range of seconds during coloration and bleaching. The stability and reversibility of the EC device was evaluated by performing repetitive double steps.

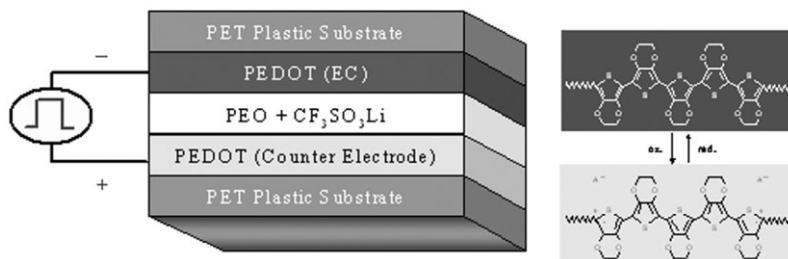


Figure 1 All-plastic EC device configuration used in this work

In order to evaluate the behavior in potential applications of these devices, a complete electrooptical characterization was performed. The optical measurements, not only in the characterization process but also in simulated “real working conditions,” have been proved more efficient to control the device than any other kind [9].

Measurements of spectral transmittance are carried out using a monochromator with a 300–1000-nm range, and a lamp with a stability around 0.6% below 400 nm and 0.2% above 400 nm. The error in the measured wavelength has been quantified for laser emissions as less than 1%. Optical emission spectral features of the lamp are similar to a CIE D65 illuminant, slightly shifted to the red in the optical spectrum.

3. RESULTS AND DISCUSSION

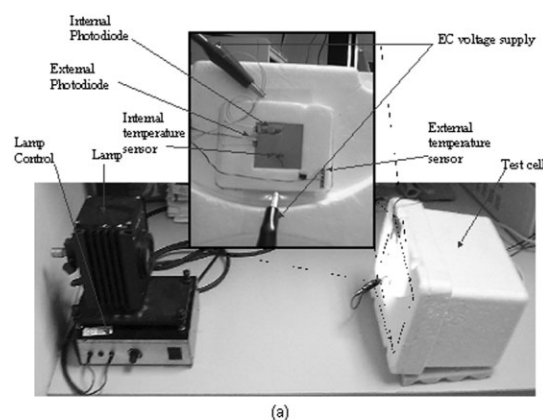
The change in the transmittance is still poor, only an 11% (44.5% to 55.5%). As an average, transmittance in the (400–500-nm) interval is 2.5% higher than that in the (500–700-nm) interval for the colored state. On the contrary, it is 3.3% lower in the bleached state. Thus, the device is mainly blue when it acquires its coloration. Nevertheless, this result is still far for the use in domotic applications, and further research should be needed in the materials and the sticking process to improve it.

The cyclability of the devices is good, since the cycles do not change noticeably even after 1000 cycles: decays of only 1% to 2% in the transmittance range were observed in the transmittance change after these switches.

Switching times are still poor, but enough for typical domotic applications, which usually need only three to four state changes per day. Further improvements, on the contrary, are needed to obtain better transmittance ranges. We can conclude that these devices can be oriented to domotic applications rather than filters for optics, with next research focused on new materials and sticking processes.

A prototype designed to obtain an automatic characterization and automatic control of an EC device has been developed. The system is designed to calibrate and check the capability of these devices to regulate the radiance, and eventually the temperature, inside an enclosure. Any previous knowledge of the device behavior is supposed.

A general view of the system, shown in Figure 3(a), is divided in two main parts. One is the electronic control system, and the other is the test cell itself with the sensors. A test cell (a heat insulator $27 \times 21 \times 19$ cm box) has been developed and manufactured, with a little window as the unique interface with the environment [see the inset in Fig. 3(a)]. This window is completely covered with the all-plastic EC devices tested in this work. Two standard silicon photodiodes are settled inside and outside the box. Two temperature LM335 sensors are located also inside and outside the box. For the tests, a 100-W filament lamp located at different distances from the window acts as radiation source. All



(a)

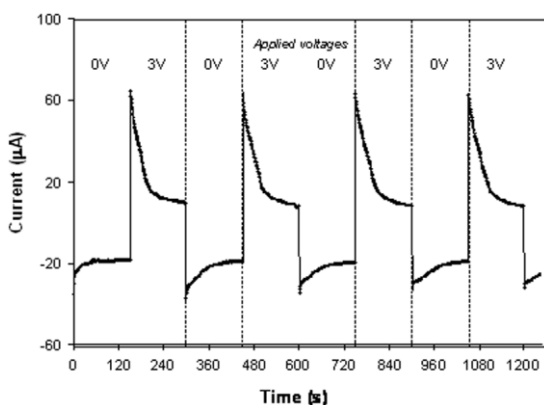
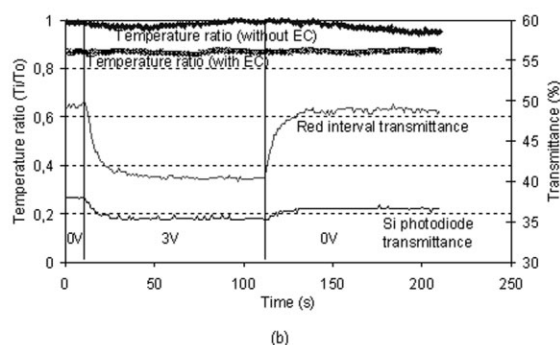


Figure 2 Switching cycles of current through the device



(b)

Figure 3 (a) Experimental setup for the test cell and the EC transmittance control application (inset: detail of the EC window and sensors while working); (b) results given directly by the system

the sensors are controlled by a general-purpose 8-bit 8051 microcontroller, which also controls the user interfaces and the operation of the EC device. The user interface consists on a keyboard and an alphanumeric liquid crystal display (LCD), and an infrared remote control. The scalability of the test cell is independent of the control system.

The control system software performs a program with three main menus:

- optical characterization: acquisition of the response times of the devices, and parameters described in Figure 3, regardless of the kind of EC;
- calibration: possibility of obtaining a look-up table of external and internal reachable illuminations;
- user application: selection of the internal illumination within the possible range achieved in menu b.

The results of the system operation for menu menu a matches those obtained in the preliminary characterization related in Figure 3. As an example, some results obtained with the first menu, directly from the application of the system and for the studied EC materials, are shown in Figure 3(b), while switching the device at constant illumination conditions.

Two main remarks can be derived from the graphs for these devices. The former one, the ability to measure and control the transmittance of the device, is achieved using photodiodes sensitive to the red part of the spectrum and a microcontroller system receiving sensing optical data and providing appropriate actions to manage the whole electrooptical system. The latter, no possibility of controlling the temperature, is achieved with these EC materials as yet, because the light changes in IR spectrum are still far from the operative ranges.

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THE EFFECTS OF PHASE ERRORS ON OPTICAL SSB SYSTEM PERFORMANCE

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ABSTRACT: The authors present a system performance analysis of an optical single sideband system (OSSB) when phase errors occur in the modulating signal driving the dual-arm Mach–Zehnder modulator (MZM). The performance is evaluated in terms of the optical sideband suppression, received subcarrier power, frequency response, and power-penalty measurements. Experiments were carried out and a mathematical model of the OSSB system, incorporating the phase error, was developed. Both the theoretical and experimental results show that, although optical sideband suppression reduces with phase errors, the received subcarrier power can increase as high as 3 dB for positive phase errors. However, for transmission over longer fiber, the frequency response of the OSSB system is not only dependent on the phase error, but also on the phase shift due to chromatic dispersion (CD). The power penalty was found to be dependent on the frequency response of the OSSB system. At any frequency-response null point, the power-penalty slope is reversed as the received subcarrier power is reduced. © 2006 Wiley Periodicals, Inc. *Microwave Opt Technol Lett* 48: 1574–1578, 2006; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.21724

Key words: optical single sideband; subcarrier multiplexing; phase errors; chromatic dispersion

1. INTRODUCTION

Subcarrier multiplexing (SCM) is a viable solution to increase capacity in intensity-modulated direct-detection optical systems where multiple digital or analog signals are multiplexed in the RF domain and transmitted by a single optical carrier [1]. One of the advantages of SCM is the microwave device used in SCM are more stable than their optical counterpart [2]. However, transmission in conventional SCM systems is limited due to the optical sidebands experiencing different amounts of phase shift as a result of fiber chromatic dispersion (CD). This can lead to reduction of the received subcarrier power and degrades carrier-to-noise ratio (CNR) severely [3, 4]. The phase shift due to CD, which varies with subcarrier frequency and fiber length, also limits maximum transmission distance [5].

Optical single sideband (OSSB) can overcome the effects of CD in SCM systems. Smith et al. demonstrated the use of an external dual electrode Mach–Zehnder modulator (MZM) to generate optical SSB [6]. To achieve effective suppression of one of the optical sidebands, the power difference between the modulating signals to both arms and the phase deviation away from the required $\pi/2$ to the lower arm should be minimized. A sensitivity analysis of the MZM was carried out to evaluate the tolerance of optical SSB signal generation due to errors in phase and power levels of the drive signals [7]. It was shown that the OSSB system was tolerant to phase errors and power level errors up to $\pm 5^\circ$ and 3 dB, respectively.

In this paper, the authors present a system performance analysis of an OSSB system when phase errors occur in the modulating