High performances photochromic polyurethanes for phase and amplitude optical elements

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Abstract: Tunable and rewritable phase and amplitude optical elements are developed by exploiting the light-switching properties of Photochromic Polyurethanes based on thiophene and thiazole derivatives.

OCIS codes: (160.4670) Optical materials; (160.5335) Photosensitive materials; (250.2080) Polymer active devices

1. Introduction

Materials which change their optical properties by a light stimulus are highly desirable to develop optical elements. Photochromic materials offer a good option since they undergo a reversible change in color by irradiation. The color switching is only one of the properties that change upon photoreaction, and modulation of refractive index, vibrational spectra (IR and Raman) or fluorescence also occur [1]. Color modulation, which can be seen as a change in transparency, and the refractive index modulation are exploited to develop both amplitude and phase optical elements, to be used in different technological areas (figure 1) [2].

We have demonstrated photochromic Computer Generated Holograms (CGHs) for optical testing [3], to measure the quality of aspheric and free-form optical elements and a fully adaptable point diffraction interferometer [4].

Concerning the phase elements, photochromic materials can be used in the NIR region and optical waveguides with complex architectures, phase masks and phase gratings can be obtained.

The main advantage for all these elements is the writing procedure which consists simply in a light exposure without any chemical post-process, making the process fast and reliable. Moreover, as the light-triggered modulation is reversible, the written pattern can be erased and photochromic layers can be reused.

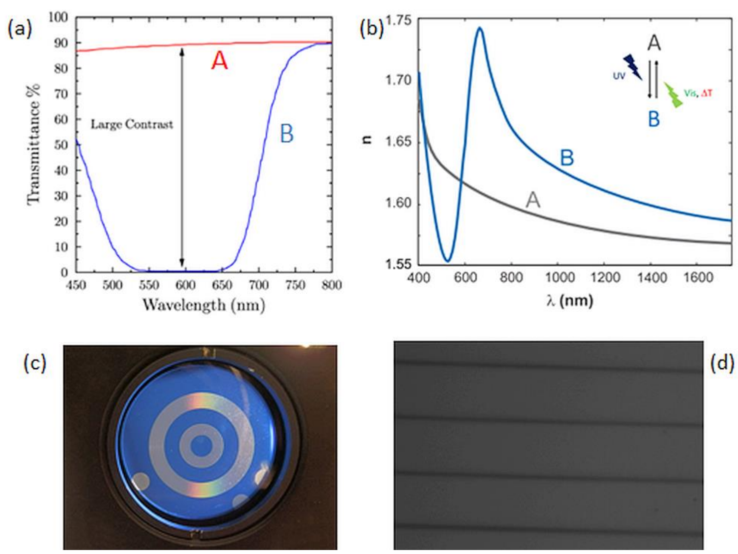

Fig. 1. (a) Modulation of the transparency in the visible and (b) of the refractive index in the vis-NIR in a photochromic film. (c) Example of photochromic CGH and (d) optical waveguides.

2. Photochromic Polyurethanes

A key issue for the reliable production of such rewritable elements is the not-trivial combination of a good optical quality with a large modulation of the target property, which is directly related to the concentration of the photochromic units in the substrate. An interesting approach is the design and synthesis of backbone photochromic polymers, that maximize the content of photochromic units preventing the formation of scattering sites. Moreover, the use of dithienylethene as photochromic units provides a good overall photochromic behavior, in terms of response sensitivity, contrast and fatigue resistance.

In this framework, we show results obtained with high performance photochromic polyurethanes as active substrates. The basic components of these polymers are a photochromic dialcohol and an aliphatic diisocianate (H12MDI) which react *in situ* to afford the photochromic coating onto a glass substrate. We demonstrate that acting on the process parameters and the structure of the photochromic dye (see figure 2) mechanical, optical and photochromic properties can be optimized. Furthermore, two or more different photochromic structures can be co-polymerized to develop multiplexed CGHs for simultaneous multi-wavelength interferometry.

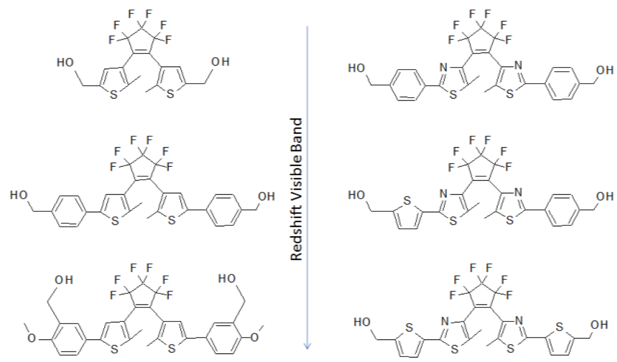

Fig. 2. Chemical structure of the photochromic monomers in the uncolored state to produce the polyurethane coatings. On the left: thiophene derivative; on the right: thiazole derivative. Within the two homologous series of photochromic materials, the arrow represents the red-shift of the absorption band of the colored state.

An Optical Density up to 1 for each micron of film thickness has been achieved by increasing the content of photochromic moiety, obtaining contrast values in the range 10^2 – 10^3. The refractive index modulation (Δn) is proportional to the content of photochromic unit in the polymer and values > 10^{-2} are measured at 1.5 μm wavelength. Besides classical ellipsometric techniques, the phase patterns have been also characterized by means of digital holography at 1.5 μm, in order to measure the effective Δn and its profile, hence determining the light transfer function. This is useful especially in the case of optical waveguides, where the geometry affects the light propagation.

3. References

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