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Passive and active light scattering obstacles

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Abstracts

Simulation of vision pathologies and adverse viewing conditions in laboratory conditions requires optical phantoms with different level of light scattering. Such obstacles are designed as passive or active elements applying several technologies. We used for studies two kinds of solid state smart materials with electrically controllable light scattering – electrooptic PLZT ceramics, polymer dispersed liquid crystals PDLC and obstacles with fixed light scattering – composite of polymer methylmethacrilat PMM together with grinded glass microparticles. Report analyzes optical characteristics of such obstacles – attenuation, scattering, depolarization of different wavelength light at various scattering levels and changes of visual performance applying obstacles in vision science studies.

Key words

light scattering, light polarization, polymer dispersed liquid crystals, birefringence, visual perception

Summary

Simulation of vision pathologies and adverse viewing conditions in laboratory conditions requires optical phantoms with different level of light scattering. Such obstacles can be designed as passive or active elements applying several technologies. We have used for such purposes two kinds of solid state smart materials with electrically controllable light scattering – electrooptic PLZT ceramics,¹ polymer dispersed liquid crystals PDLC² and obstacles with fixed light scattering - composite of polymer methylmethacrilat PMM together with grinded glass microparticles.

PLZT ceramics (composition similar to piezoelectric PZT - lead zirconate titanate, however in our case additionally modified by

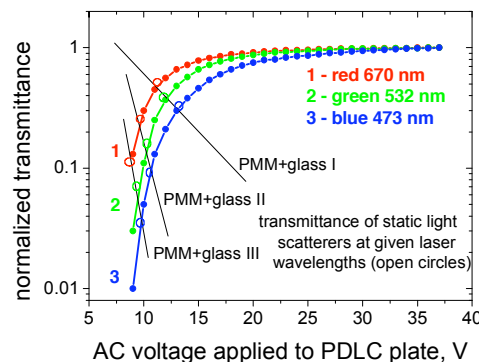
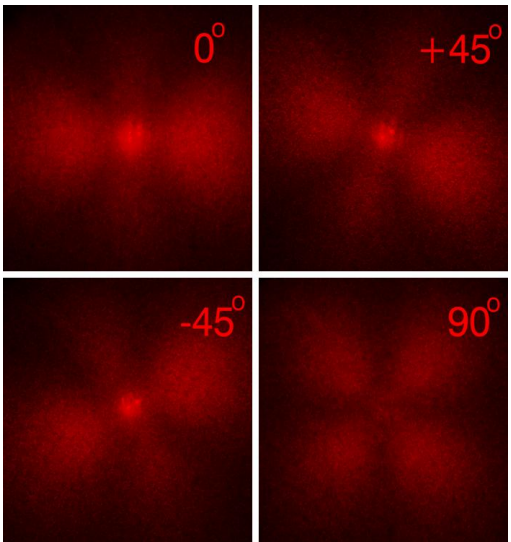


Fig.2. Transmittance of PLDC cell with AC voltage applied at three RGB laser wavelengths 670 nm (upper curve), 532 nm (middle) and 473 nm (lower curve).

lanthanum), is a transparent in visible bulk ferroelectric polycrystalline material. Different scattering levels were generated by changing the voltage applied to the ceramics. In absence of electric field applied in our devices ceramic compositions stay uniform and nonpolar. When an electrical field is applied to transparent electrodes deposited on the opposite sites of the 1.5 mm thick PLZT plate, a reversible nucleation of submicron size dielectrically polar and thus also birefringent regions are induced, thus producing local variations of the refractive index in ceramics. That produces an amount of forward straylight that increases with voltage.

PLDC cells used in experiments (Fig.1) as eye obstacles consist of two glass plates with transparent ITO electrodes forming a 10 microns gap of a composite polymer (PN393 *MerckKgaA*) with dispersed liquid crystal (BL035 *MerckKgaA*) droplets of micrometers size. Values of the refractive index were – for polymer $n = 1.473$ (at 589nm) and for birefringent liquid crystal $n_o = 1.528$ and n_e same as for polymer. Applying the AC voltage aligns directors of liquid crystal droplets along the direction of the electric field E in the layer - light passing the cell does not meet refractive index variations, and no scattering takes place. At absence



of an external influence droplets are randomly oriented causing local optical non-homogeneities and light scattering. As the birefringence is much higher as compared with PLZT ceramics the thickness of the scattering layer for similar scattering degrees is within a micrometer range. Thus the voltage U needed maximally to align liquid crystal droplet directors along the transmitted light beam does not override 30-40 V. In such PDLC plate Mie light scattering takes place opposite to PLZT ceramics that due to smaller size of light scattering birefringent domains can be characterized with Rayleigh scattering. However also for Mie scattering in PDLC the noticeable wavelength dependence is observed. Figure 2 shows the attenuation of the collimated directly transmitted light beams at three wavelengths (red, green and blue) of the RGB laser.

Fig.4. Indicatrices of the scattered light by PDLC light scattering obstacles analyzing it with a rotating polarizer. Orientation of analyzer corresponding to the polarization plane of the initial 633 nm laser beam is shown at the right upper part of images.

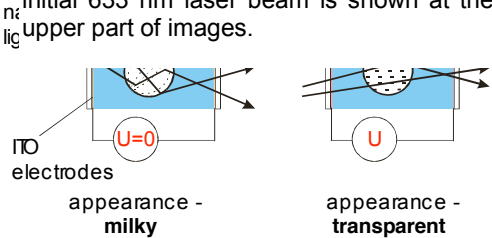


Fig.1. Polymer disperse liquid crystal cell in two states – light scattering Off state and transparent On state.

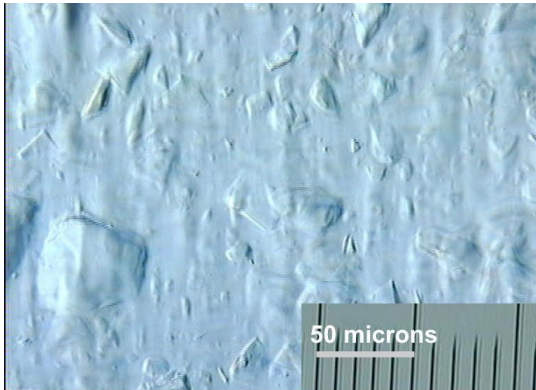


Fig.3. Interference contrast microscopy of glass particles in PMMA matrix.

Another way to obtain graded step-by-step light scattering is using of composite – matrix of less refractive glue monomer of methacrilate MMA (refractive index $n = 1.45$) mixed together with dispersed small glass particles ($n = 1.5$). A gap between two glass plates of thickness 0.06-0.5 microns are filled with such mixture (glass powder concentration 100-200 mg/ml) thus obtaining pairs of obstacles with fixed but graded degrees of the light scattering. A picture of an interference contrast microscopy is depicted in Fig.3. Also for such scattering obstacles scattered light is

strongly wavelength dependent in visible spectral range (Fig.2).

Besides intensity and spectral dependencies the scattered light produced by such obstacles reveals also noticeable polarization dependencies. Figure 4 shows polarimetry analysis of the scattered by PDLC cell linear polarized 633 nm laser light applying the rotating analyzer. Obtained pictures allow to analyze polarimetry of the scattered light for angles much larger as those determining normal visual acuity. However previously Bueno at all.^{3,4} have analyzed light scattering in human eyes and have revealed similarity of changes of the depolarization degree produced by such scatterers (PLZT ceramics) comparing it with the depolarization degree of the scattered light in elder cataract eye patients at smaller angles - below 1 arc degree.

All kind of such light scattering obstacles have been used for determination of various visual performance characteristics. Visual acuity looking through such obstacles with graded scattering drops down from standard 20/20 to zero for black-white and black-red, black-green and black-blue stimuli (for black-blue the most drastic between all listed optotypes). Scattering obstacles are used in vision research also for studies of colour contrast sensitivity, stimuli recognition search time and diminishing of objective optical characteristics of the model eye in presence of scattering. Studies of visual performance of observers without any vision pathologies however using obstacles capable to induce different degrees of light scattering allow to simulate a decrease of visual functions for cataract persons⁵ and also decrease of recognition of colour stimuli in adverse weather conditions.

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