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Optical properties of electrophoretically manipulated ZnO nanowire suspensions and their high application potential in Smart Window devices

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We demonstrate the counterintuitive increase in optical scattering efficiency during negentropic orientational transition in dilute ZnO nanowire suspensions!!!

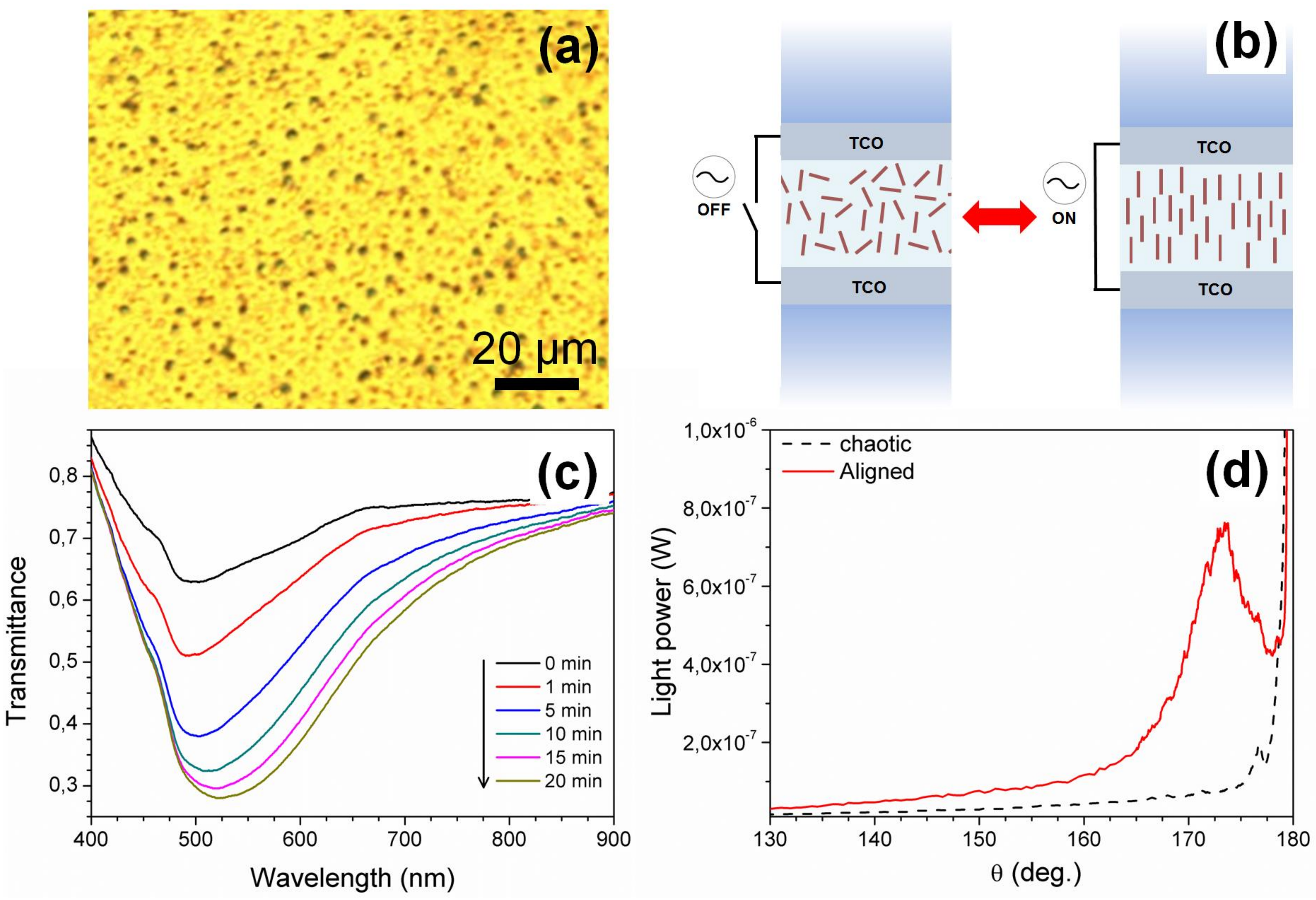

Fig. 1 Optical microscopy image for aligned ZnO NWs in PDMS (0.05 vol%) (a); schematic representation of electrophoretic ZnO NW alignment (b); decrease of transmittance of 150 µm thick sample cells with 0.05 vol% (c) of ZnO NW suspensions in PDMS in an applied electric field (1 V/µm). The graph (d) demonstrates the angular distribution of intensity of scattered light in chaotic and in the aligned state.

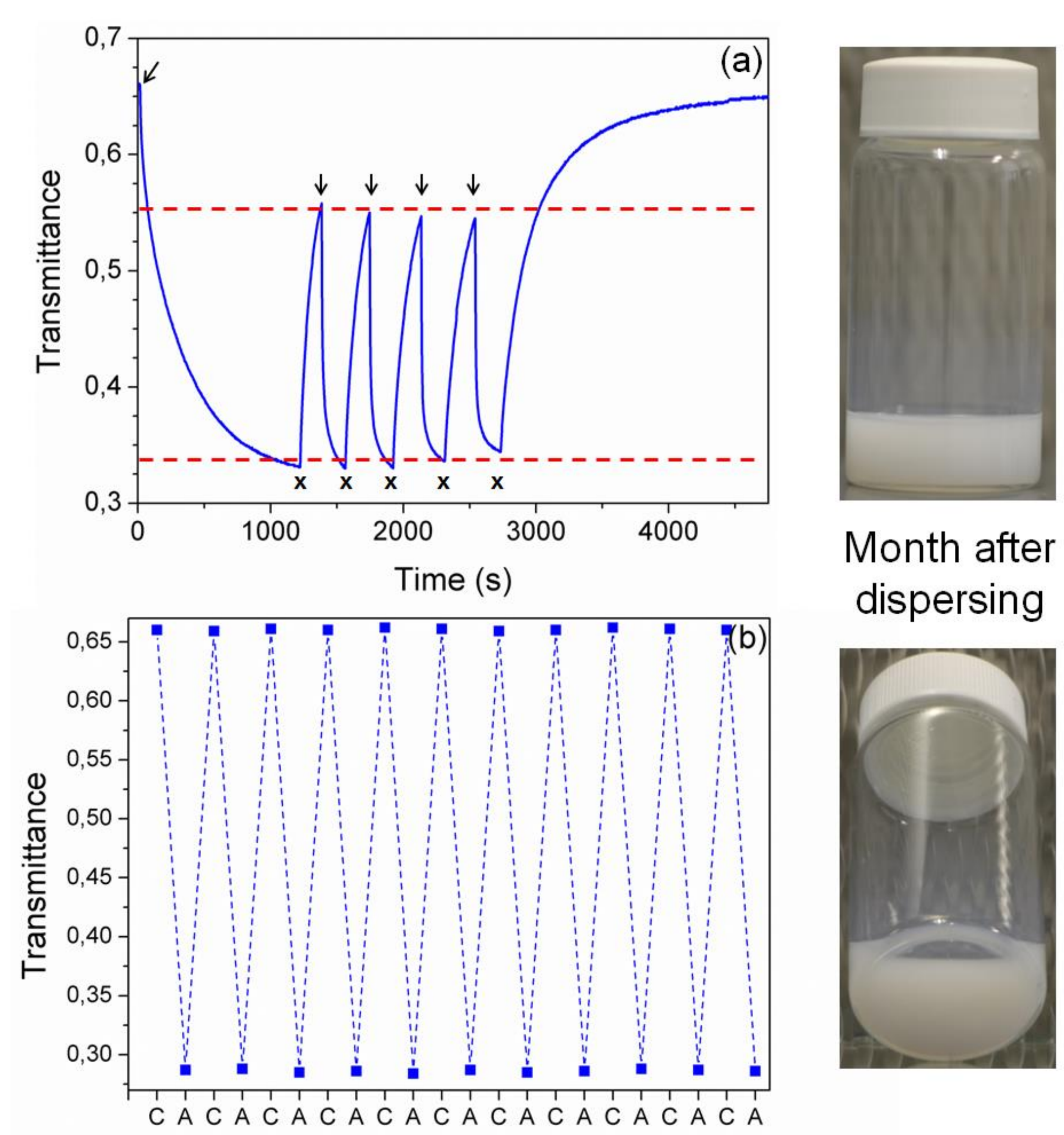

Fig. 3 Electro-optical performance of a 150 µm thick sample with 0.05 vol% of ZnO NWs in PDMS during several "on-off" cycles in AC electric field (1 V/µm). Graph (b) demonstrates constant optical contrast, indicators "C" and "A" on x-axis on graph (b) refer to chaotic and aligned states of ZnO NWs in PDMS. Stability of the same ZnO NW suspension in PDMS over longer time periods is demonstrated on photographs of a glass vial containing the suspension 1 month after preparation.

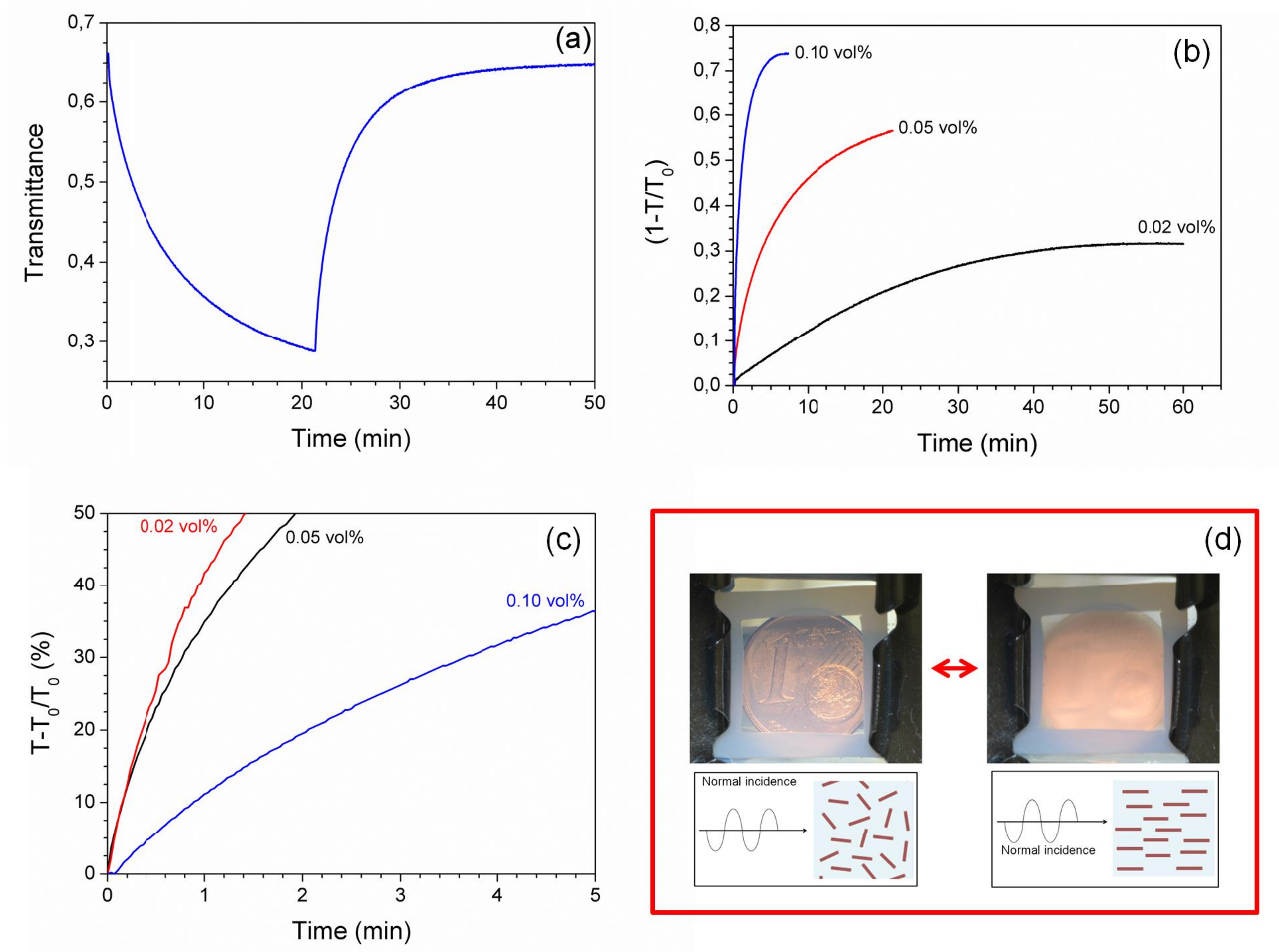

Fig. 2 (a) The decrease and recovery of transmittance observed in a 150 µm thick sample with 0.05 vol% of ZnO NWs in PDMS at 550 nm wavelength during an "on" and "off" cycle (AC, 1 V/µm), (b) the kinetics of alignment under an applied AC field (1 V/µm), represented as change in transmittance of different suspensions; (c) reorientation kinetics, represented as change in transmittance of suspensions with different ZnO NW concentrations; and (d) fixed focus photographs presenting the visual appearance of a sample containing 0.05 vol% of ZnO NWs before (left photo) and after (right photo) applying the electric field.

Conclusions: Stable suspensions of ≤0.1 vol% ZnO NWs in PDMS were prepared by a multistep solvent exchange, ultrasonication and high shear mixing process. The obtained materials exhibited unexpected optical properties: the scattering efficiency increased significantly as negentropic orientational transition from chaotically oriented state to partially ordered (aligned) state was induced with longer axis of nanowires parallel to the direction of incident light, despite the fact that the geometrical cross-section of the particles decreases during such transition. The cause for such effect may be the abnormally low scattering cross section in chaotic state that is exhibited by the fraction of nanowires having suitable effective geometrical cross-section. The reported electro-optical property of dilute ZnO NW suspensions has a substantial potential to be used in smart window applications. At relatively small concentrations of ZnO NWs (0.05 vol%), a significantly large ($\Delta T = 40\%$) and reversible change of transmittance was observed in the prepared electro-optical devices.

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References: Andris Šutka, Martin Timusk, Martin Järvekülg, Ardi Loot, Urmas Joost, Rynno Lohmus and Kristjan Saal, RSC Adv., 2015, Accepted Manuscript DOI: 10.1039/C5RA22448A