Laboratory of Physicochemistry of Dielectrics and Magnetics

Liquid Crystals and Polymers Group

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UNIWERSYTET WARSZAWSKI

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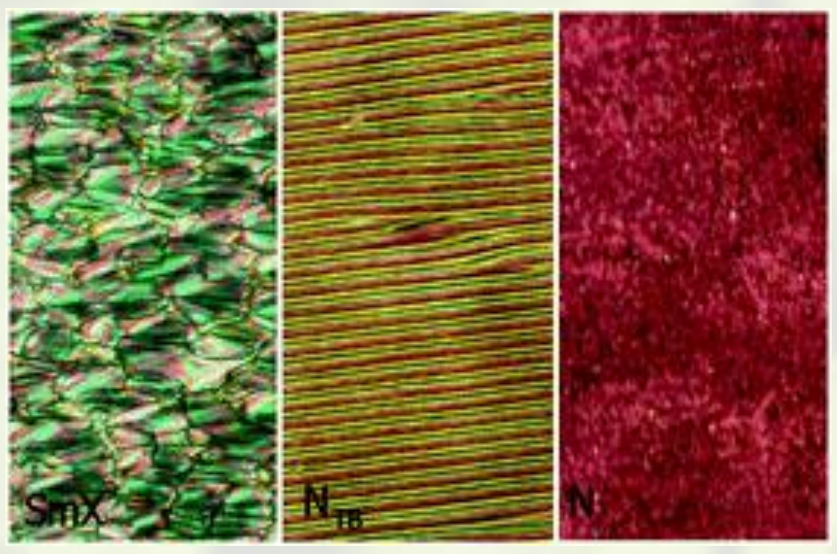
Our research interests:
In general – LIQUID CRYSTALS / POLYMERS

- Spontaneously modulated nematic phases
- LC and crystalline phases with filament and tubular morphologies
- LC elastomers with new functionalities
- Self-assembling of inorganic nanoparticles
- Mesogens with non-conventional molecular geometry
- Metallomesogens
- Rapid alignment of block copolymers

Research methods used:

- *X-ray diffraction and small angle x-ray scattering*
- *AFM imaging*
- *Optical polarizing microscopy*
- *Differential Scanning Calorimetry*
- *ToF measurements of charge mobility*
- *Electron spin resonance*
- *Laser zone annealing*
- *Flow-coating, Spin-coating*
- *Plasma etching*
- *Spectral refletance*
- *Circular dichroism*



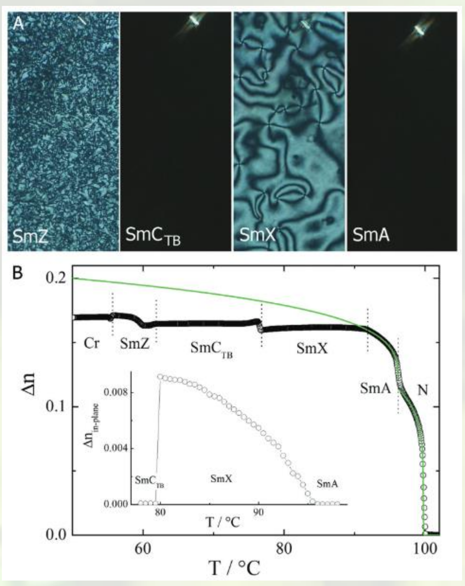
International collaboration:

Tokyo Institute of Technology,
Academy of Sciences of Czech Republic
University of Maribor
Middle Tennessee State University
Lawrence Berkeley National Laboratory
Brookhaven National Laboratory
University of Aberdeen
RIKEN

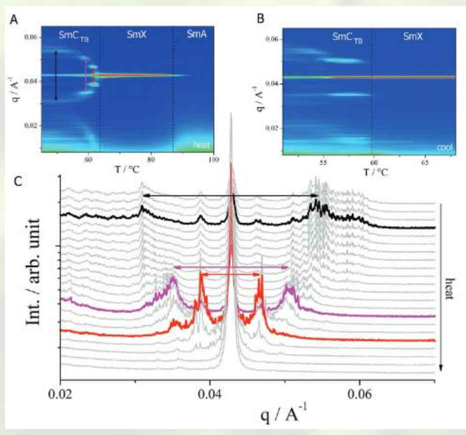
Photonic Bandgap in Achiral Liquid Crystals—A Twist on a Twist

D. Pociecha, Vaupotič N., Majewska M., Cruickshank E, Walker R., Storey J.M.D., Imrie C.T., Wang C. and Gorecka E.
Adv. Mater. 2021, 33, 2103288

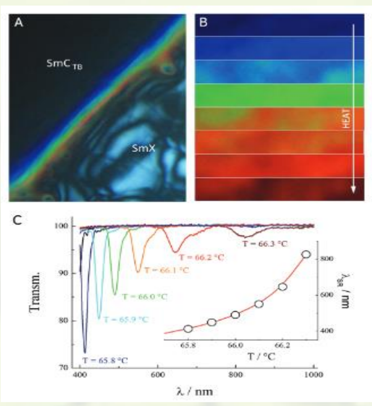
Achiral mesogenic molecules are shown to be able to spontaneously assemble into liquid crystalline smectic phases having either simple or double-helical structures. At the transition between these phases, the double-helical structure unwinds. As a consequence, in some temperature range, the pitch of the helix becomes comparable to the wavelength of visible light and the selective reflection of light in the visible range is observed. The photonic bandgap phenomenon is reported for achiral liquid crystals.



A) Optical textures of the CB6O.14 homologue observed between crossed polarizers in a 3 μm thick cell with a homeotropic anchoring. B) Temperature dependence of the optical birefringence for green light (λ= 532 nm) for CB6O.14, measured in a planar cell (3 μm thick). The green line is a fit to the critical dependence in the N and SmA phases, with the critical exponents β equal to 0.17 and 0.27, respectively. The inset: the in-plane birefringence of the SmX phase, determined in a cell with homeotropic anchoring.



A,B) Temperature evolution of the resonant X-ray scattering signals for the CB6O.12 homologue observed on heating (A) and cooling (B). C) Scattered intensity versus wavevector (q) measured in a heating run across the SmX–SmCTB phase transition.

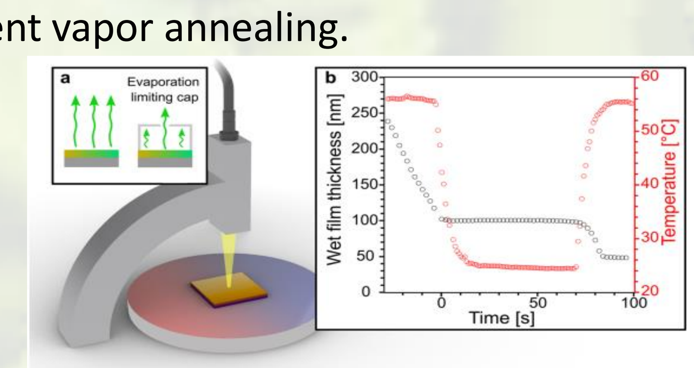


A) Optical texture of CB6O.12 taken in a 3 μm thick cell with a homeotropic anchoring at the transition from the SmCTB to the SmX phase. The rainbow colors due to a selective reflection appear simulta-neously because of a small temperature gradient in the sample. B) A sequence of optical textures taken as a function of temperature at the SmCTB–SmX phase transition for CB6O-9. C) Transmission spectra taken from a 20 μm size spot in the SmCTB phase of CB6O-9 as a function of temperature. The inset: position of the selective reflection band (λSR) versus temperature (T).

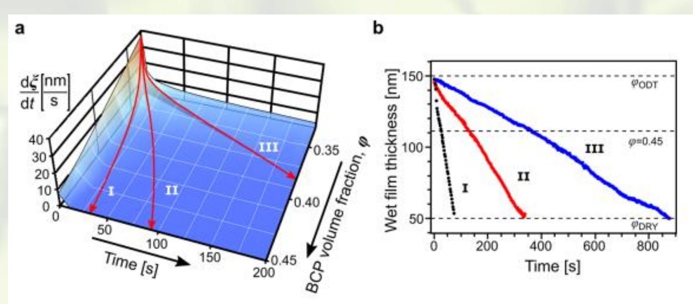
Pathway-Dependent Grain Coarsening of Block Copolymer Patterns under Controlled Solvent Evaporation

Leniart A. A., Pula P., Style R. W. and Majewski P. W.
ACS Macro Lett. 2022, 11, 121–126

Solvent evaporation annealing (SEA) is a straightforward, single-step casting and annealing method of block copolymers (BCP) processing yielding large-grained morphologies in a very short time. Here, we present a quantitative analysis of BCP graincoarsening in thin films under controlled evaporation of the solvent. Our study is aimed at understanding time and BCP concentration influence on the rate of the lateral growth of BCP grains. By systematically investigating the coarsening kinetics at various BCP concentrations, we observed a steeply decreasing exponential dependence of the kinetics power-law time exponent on polymer concentration. We used this dependence to formulate a mathematical model of BCP ordering under nonstationary conditions and a 2D, time- and concentrationdependent coarsening rate diagram, which can be used as an aid in engineering the BCP processing pathway in SEA and also in other directed self-assembly methods that utilize BCP–solvent interactions such as solvent vapor annealing.



Schematics of the controlled solvent evaporation experiment. (a) A nonvolatile solvent evaporates from a wet BCP film under a convection-restricting cap while white-light reflectometry is used to monitor the thickness of the film. (b) Substrate temperature (red circles) is used to control the rate of solvent removal and temporarily stabilize the thickness of the wet film and investigate grain-coarsening under constant BCP concentration (black circles).

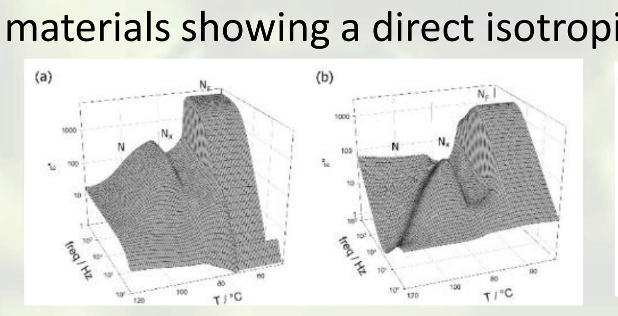


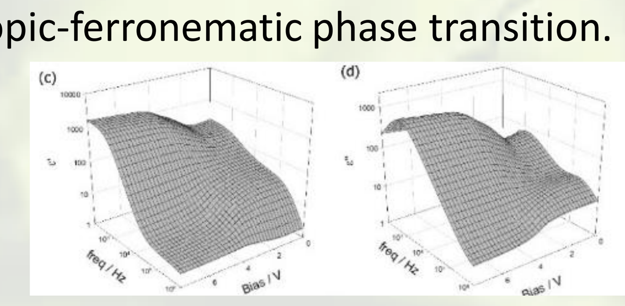
(a) BCP grain coarsening rate in solvent evaporation annealing performed over distinct trajectories. (b) The trajectories correspond to the wet film drying profiles recorded in constant-rate solvent evaporation experiments (I: 1.32; II: 0.45; and III: 0.11 nm/s). Time progress is measured from the moment when the system reaches ODT (ϕBCP = 0.33, d = 150 nm).

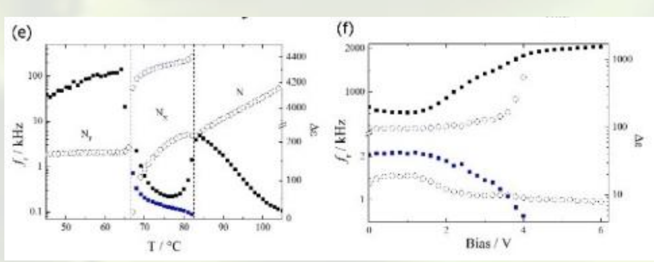
Multiple Polar and Non-polar Nematic Phases

Brown S., Cruickshank E., Storey J.M.D., Imrie C.T., Pociecha D., Majewska M., Makal A. and Gorecka E.
ChemPhysChem 2021, 22, 2506–251

Liquid-crystal materials exhibiting up to three nematic phases are reported. Dielectric response measurements show that while the lower temperaturę nematic phase has ferroelectric order and the highest temperature nematic phase is apolar, the intermediate phase has local antiferroelectri corder. The modification of the molecular structure by increasing the number of lateral fluorine substituents leads to one of the materials showing a direct isotropic-ferronematic phase transition.







Dielectric dispersion for compound 4 measured in 20-μm-thick cel with homeotropic anchoring: (a) real and (b) imaginary part of dielectric susceptibility vs. Temperature and frequency; (c) real and (d) imaginary part of dielectric susceptibility vs. bias voltage and frequency in the Nx phase (T=70°C). Relaxation frequency (open circles) and dielectric mode strength (solid squares) evaluated from above data by fitting to Cole-Cole formula: (e) vs. temperatureand (f) vs. bias voltage in Nx phase.

Publications in 2021

1) Żywociński, A., Bernatowicz, P., Pociecha, D., Górecka, E., & Gregorowicz, J. (2021). Investigation of the aggregation behaviour of the anionic surfactant sodium dodecyl sulfate in ionic liquids 1-allyl-3-methylimidazolium chloride and 1-Ethyl-3-methylimidazolium diethyl phosphate. *Journal of Molecular Liquids*, *343*, 117610.
2) Brown, S., Cruickshank, E., Storey, J. M., Imrie, C. T., Pociecha, D., Majewska, M., ... & Gorecka, E. (2021). Multiple Polar and Non-polar Nematic Phases. *ChemPhysChem*, *22*(24), 2506-2510.
3) Pociecha, D., Vaupotič, N., Majewska, M., Cruickshank, E., Walker, R., Storey, J. M., ... & Gorecka, E. (2021). Photonic bandgap in achiral liquid crystals—a twist on a twist. *Advanced Materials*, *33*(39), 2103288.
4) Kwon, O., Cai, X., Qu, W., Liu, F., Szydłowska, J., Gorecka, E., ... & Tschierske, C. (2021). Charge Transportation and Chirality in Liquid Crystalline Helical Network Phases of Achiral BTBT-Derived Polycatenar Molecules. *Advanced Functional Materials*, *31*(28), 2102271.
5) Park, W., Yang, M., Park, H., Wolska, J. M., Ahn, H., Shin, T. J., ... & Yoon, D. K. (2021). Directing Polymorphism in the Helical Nanofilament Phase. *Chemistry–A European Journal*, *27*(24), 7108-7113.
6) Walker, R., Pociecha, D., Storey, J. M., Gorecka, E., & Imrie, C. T. (2021). Remarkable smectic phase behaviour in odd-membered liquid crystal dimers: the CT6O. m series. *Journal of Materials Chemistry C*, *9*(15), 5167-5173.
7) Bagiński, M., Pedrazo-Tardajos, A., Altantzis, T., Tupikowska, M., Vetter, A., Tomczyk, E., ... & Lewandowski, W. (2021). Understanding and Controlling the Crystallization Process in Reconfigurable Plasmonic Superlattices. *ACS nano*, *15*(3), 4916-4926.
8) Walker, R., Majewska, M., Pociecha, D., Makal, A., Storey, J. M., Gorecka, E., & Imrie, C. T. (2021). Twist-bend nematic glasses: the synthesis and characterisation of pyrene-based nonsymmetric dimers. *ChemPhysChem*, *22*(5), 461-470.
9) Parzyszek, S., Pociecha, D., Wolska, J. M., & Lewandowski, W. (2021). Thermomechanically controlled fluorescence anisotropy in thin films of InP/ZnS quantum dots. *Nanoscale Advances*, *3*(18), 5387-5392.
10) Podoliak, N., Cigl, M., Hamplová, V., Pociecha, D., & Novotná, V. (2021). Multichiral liquid crystals based on terphenyl core laterally substituted by chlorine atom. *Journal of Molecular Liquids*, *336*, 116267.
11) Bubnov, A., Cigl, M., Penkov, D., Otruba, M., Pociecha, D., Chen, H. H., & Hamplová, V. (2021). Design and Self-Assembling Behaviour of Calamitic Reactive Mesogens with Lateral Methyl and Methoxy Substituents and Vinyl Terminal Group. *Polymers*, *13*(13), 2156.
12) Novotna, V., Stulov, S., Pociecha, D., Hamplová, V., Fekete, L., & Cigl, M. (2021). Mesogens with four-benzene molecular core and two lactate units in the chiral chain. *Liquid Crystals*, *48*(15), 2097-2105.
13) Novotná, V., Stulov, S., Hamplová, V., Cigl, M., & Pociecha, D. (2021). The cholesteric and TGB phases under the applied electric field. *Liquid Crystals*, *48*(9), 1283-1294.
14) Leniart, A. A., Pula, P., Style, R. W., & Majewski, P. W. (2021). Pathway-Dependent Grain Coarsening of Block Copolymer Patterns under Controlled Solvent Evaporation. *ACS Macro Letters*, *11*, 121-126.
15) Majewski, P. W., Michelson, A., Cordeiro, M. A., Tian, C., Ma, C., Kisslinger, K., ... & Gang, O. (2021). Resilient three-dimensional ordered architectures assembled from
16) Wolska, J. M., Błażejewska, A., Tupikowska, M., Pociecha, D., & Górecka, E. (2021). Gold nanoparticles grafted with chemically incompatible ligands. *RSC Advances*, *11*(16), 9568-9571.
17) Grabovac, T., Gorecka, E., Pociecha, D., & Vaupotič, N. (2021). Modeling of the Resonant X-ray Response of a Chiral Cubic Phase. *Crystals*, *11*(2), 214.
18) Boychuk, A., Shibaev, V., Cigl, M., Pomeisl, K., Hamplová, V., Pociecha, D., ... & Bobrovsky, A. (2021). Photo-orientation Processes in Liquid Crystalline Polymethacrylates with Side Azobenzene Groups Having Lateral Methyl Substituents. *Macromolecules*, *54*(22), 10499-10509.
19) Kapuściński, S., Szczytko, J., Pociecha, D., Jasiński, M., & Kaszyński, P. (2021). Discs, dumbbells and superdiscs: molecular and supermolecular architecture dependent magnetic behavior of mesogenic Blatter radical derivatives. *Materials Chemistry Frontiers*, *5*(17), 6512-6521.