Center on Advanced Materials for Photonics and Lasers
Chemical Engineering, University of Rochester

AMPL

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Motivation and Goals:

- **Leverage UR's strengths and reputation in *advanced materials*, *optics and photonics***
- **Promote *multidisciplinary research*: ChE, Optics, Chemistry, and LLE**
- **Boost US competitiveness and accomplish *DoD missions.***

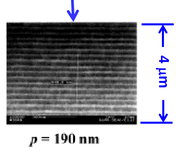
Why Polarization Control?

- **Communications, imaging, information displays, medical needs, high energy density physics**
- **Reducing lasing threshold while elevating power output by beam combination**
- **Laser materials processing, fluorescence polarization and second-harmonic-generation imaging, holography, interferometry**

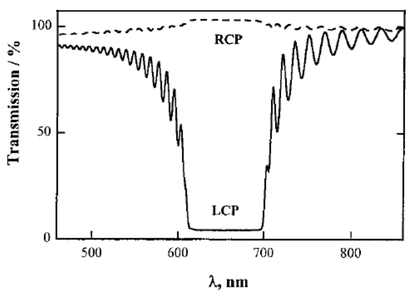
Glassy Liquid Crystals (GLCs): A Signature Research Program at UR

- **Rod-like moieties as building blocks for nematic and cholesteric liquid crystals**
- **Passive devices for polarization control, beam shaping, and polarization smoothing underlying laser-based devices**
- **Active devices for generation of circularly polarized lasers using cholesteric LC devices**
- **Models for passive and active devices to accomplish polarization of powerful lasers**

incident light



helical stack

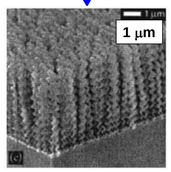


- **Light propagation normal to helical stack**
- **Solid density without voids and defects**
- **Square tops**
- **|LCP–RCP| ≈ 100 %**
- **Perfect circular polarization**

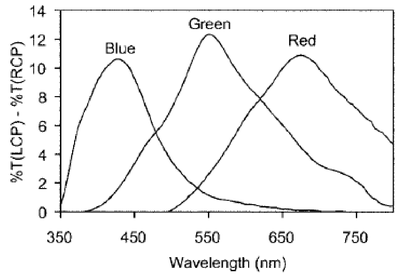
Chen et al., *Adv. Mater*. **2000**, *12*, 1283.

Conventional GLAD-Fabricated Helical Coils Exhibit Circular Polarization Inferior to GLC Helical Stacks

incident light



helical coils

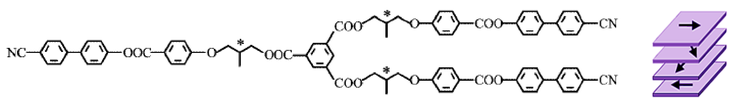


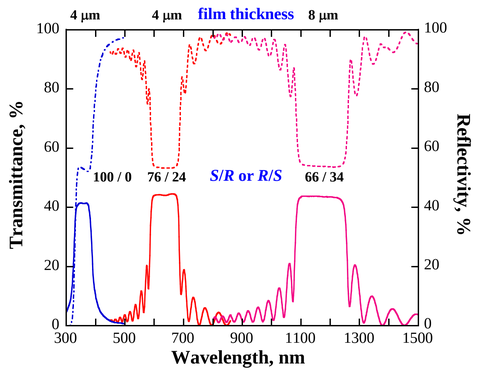
- **Light propagation along helical coils**
- **Round tops, broad spectra**
- **|LCP–RCP| < 13 %**

Brett et al., *Applied Optics* **2004**, *43*, 3632

Robust GLC Materials for Fine Control of Polarized Absorption, Reflection, and Transmission

- **Mixtures of enantiomeric Ch-GLCs enabling tunable stopband from 360 nm through visible to infrared**
- **Bandwidth monotonically increasing from 60 nm without encountering immiscibility problem**
- **Circular dichroism representing the differential absorption of left- vs. right-handed polarized incidents**





- **T_g 73 °C; T_c 295 °C**
- **Chen *et al., Chem. Mater.* 2008, *20*, 5859**
- **Chen et al., *Ind. Eng. Chem. Res*. 2018, *58*, 4470**
- **Chen et al., U.S. Patent 2013, No. 8,562,863 B2**

Cholesteric glassy liquid crystals provide versatile high-quality circularly polarized light as a new platform for night-vision technologies in support of national security.

Mesomorphic Ceramics: Inspired by GLCs for Polarization Control of Lasers

- ***Mesomorphic Ceramics*: inorganic nanostructured solids with sintered liquid crystalline superstructures**
- **Analogous to GLCs with uniaxial orientation or helical stacking of rod-like building blocks**
- **Passive devices: robust polarizers and waveplates for industrial or high power (up to 100 kW)**
- **Active devices: high power laser gain media**

Foundations for Materials Processing

Experimental

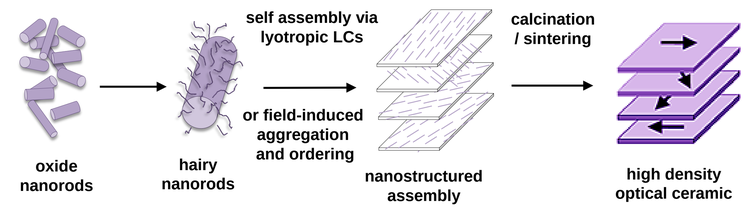
- **Nanorods forming lyotropic liquid crystals in isotropic solvents;** Dierking, I.; Al-Zangana, S. *Nanomaterials* **2017**, *7*, 305.
- **Hairy nanoparticles revealing their brush dynamics and colloidal phase behavior;** Kim, J.U.; Matsen, M. W. *Macromol.* **2008**, *41*, 4435.

Theory / Computation

- **Nanoparticles capable of forming lyotropic and thermotropic liquid crystals :** Mederos, L.; Velasco, E.; Martınez-Raton, Y. *J. Phys.: Condens. Matter* **2014, *26*,** 463101.
- **Elastic assemblies of hairy nanoparticles and shear alignment and relaxation dynamics of colloidal rods;** Tchoul, M. N.; Fillery, S. P.; Koerner, H.; Drummy, L. F.; Oyerokun, F. T.; Mirau, P. A.; Durstock, M. F.; Vaia, R. A. *Chem. Mater.* **2010**, *22*, 1749.

Novel Ceramics Processing via Self- and Field-Induced Nanoparticle Assembly

- **Transition from Molecular to Nanometer Scale**



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