Solution-Processable Electronic and Photonic Structures

Functional Organic and Organic/Inorganic Hybrid Materials

Stingelin Lab @ Georgia Tech

Our current research interests encompass the broad field of functional organic materials for organic electronics; multifunctional inorganic/organic hybrids for smart, advanced optical systems; and mixed conductors for bioelectronics. Establishing interrelationships between performance, processing and materials' structure are thereby a central topic. Our group's multi-disciplinary efforts in the Materials Science field have been exploited to build collaborations across departments and faculties at Georgia Tech, on national level, and internationally.

Check out our lab's publications, scan this QR code:
Email: natalie.stingelin@mse.gatech.edu
Web: stingelin-lab.gatech.edu/
@StingelinGroup

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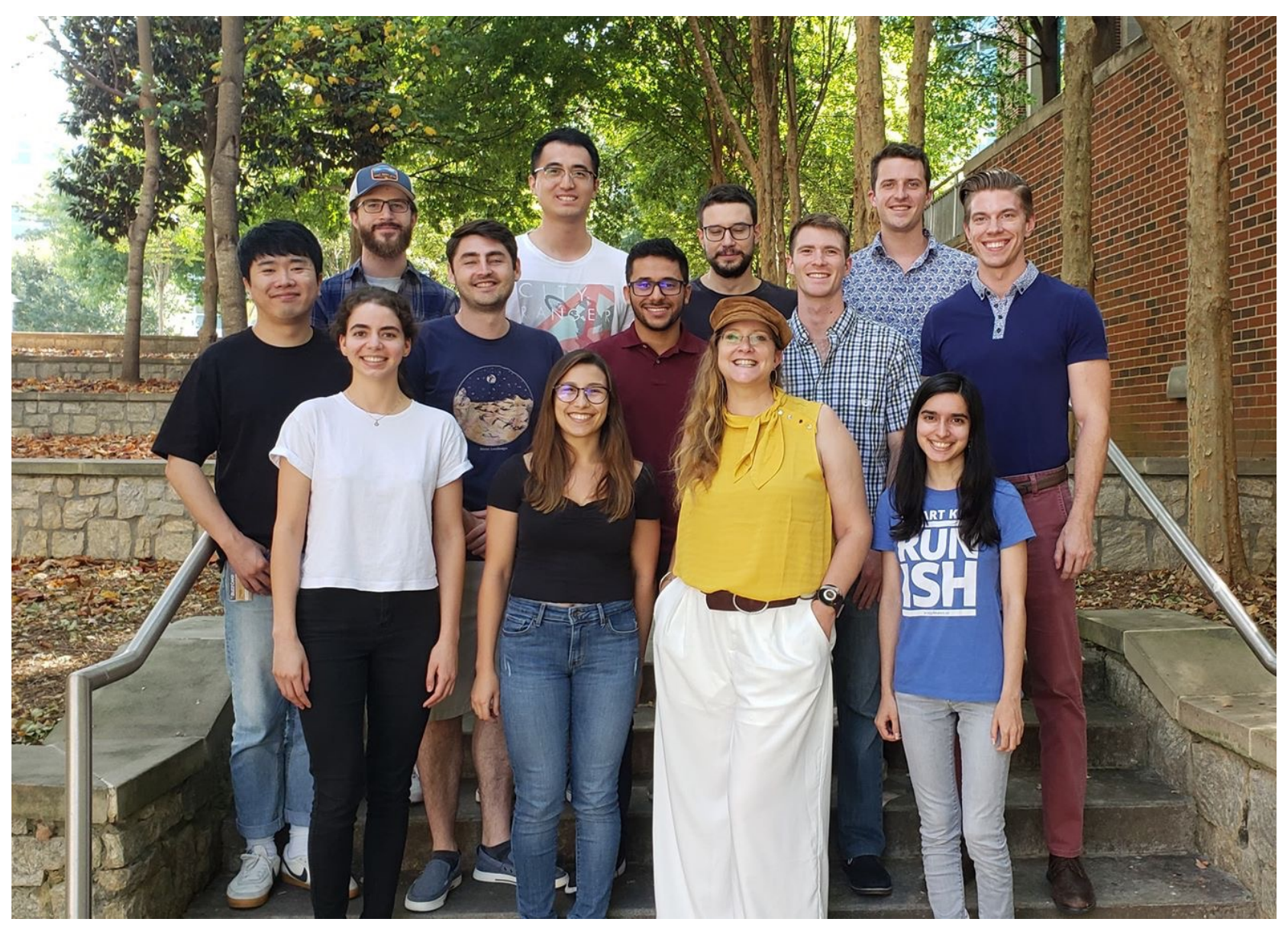


Materials for sustainable and renewable technologies

Biomaterials for sustainable packaging (with Meredith Lab)

Sustainable packaging is enabled by crosslinking cellulose derivatives with citric acid to control moisture sensitivity by altering the permeability and hydrophilicity of the films.

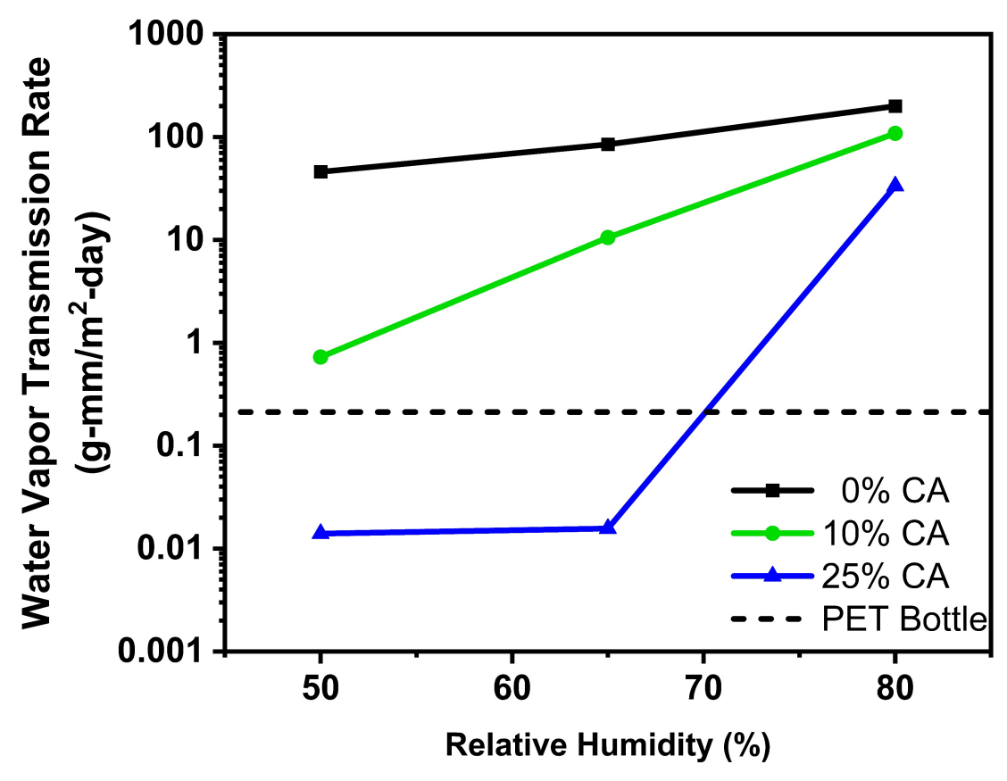


Figure 1: Water vapor transmission rate of carboxymethyl cellulose films crosslinked with citric acid.

Transparent IR mirrors and thermal switches for heat management (with Yee Lab)

IR mirrors made of hybrid materials can reflect the sun's radiation and potentially cool a building. Thermal switches can dynamically control the amount of heat flow.

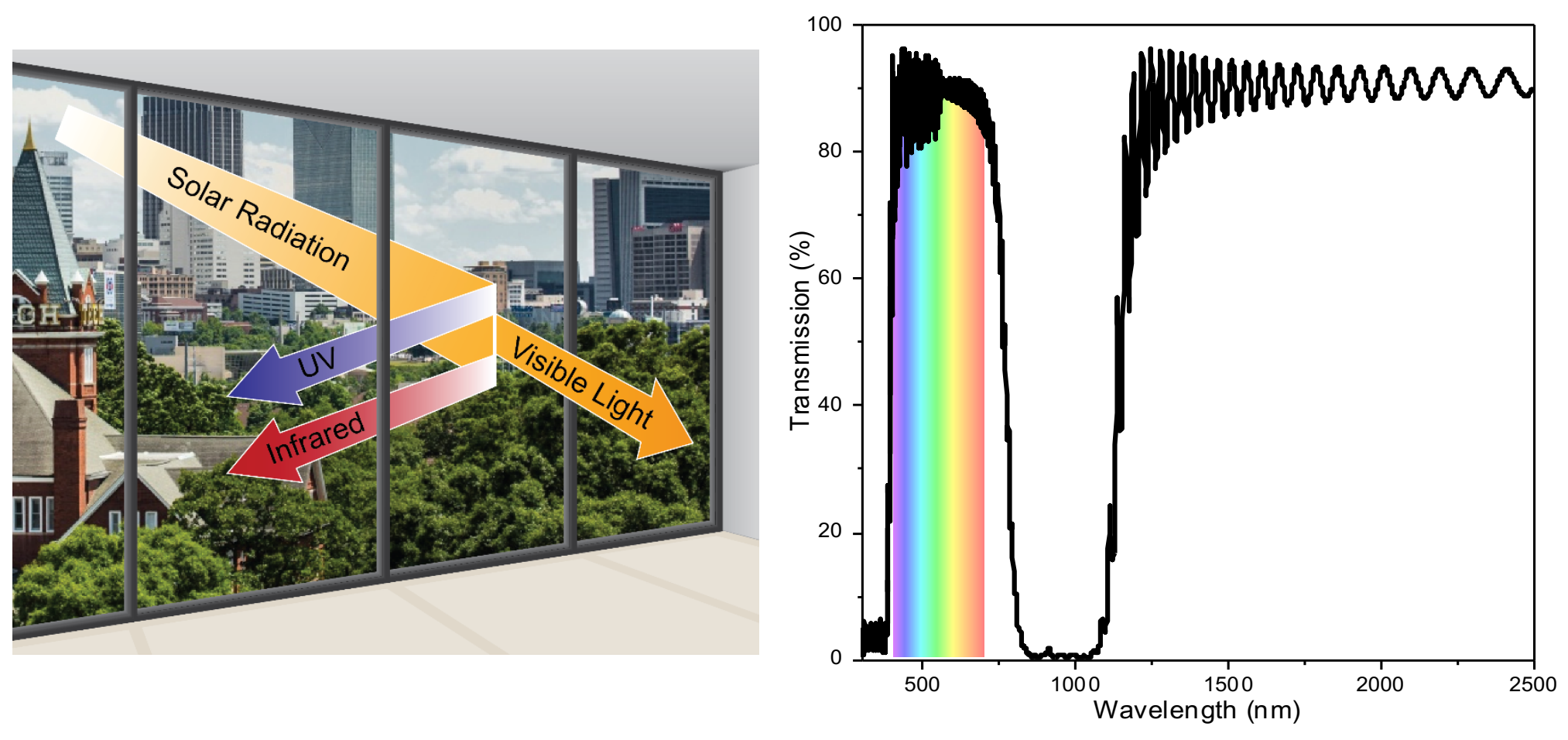


Figure 2: Window coatings based on Distributed Bragg Reflectors (DBR's) with stopband tunable to infrared, while transmitting visible wavelengths.

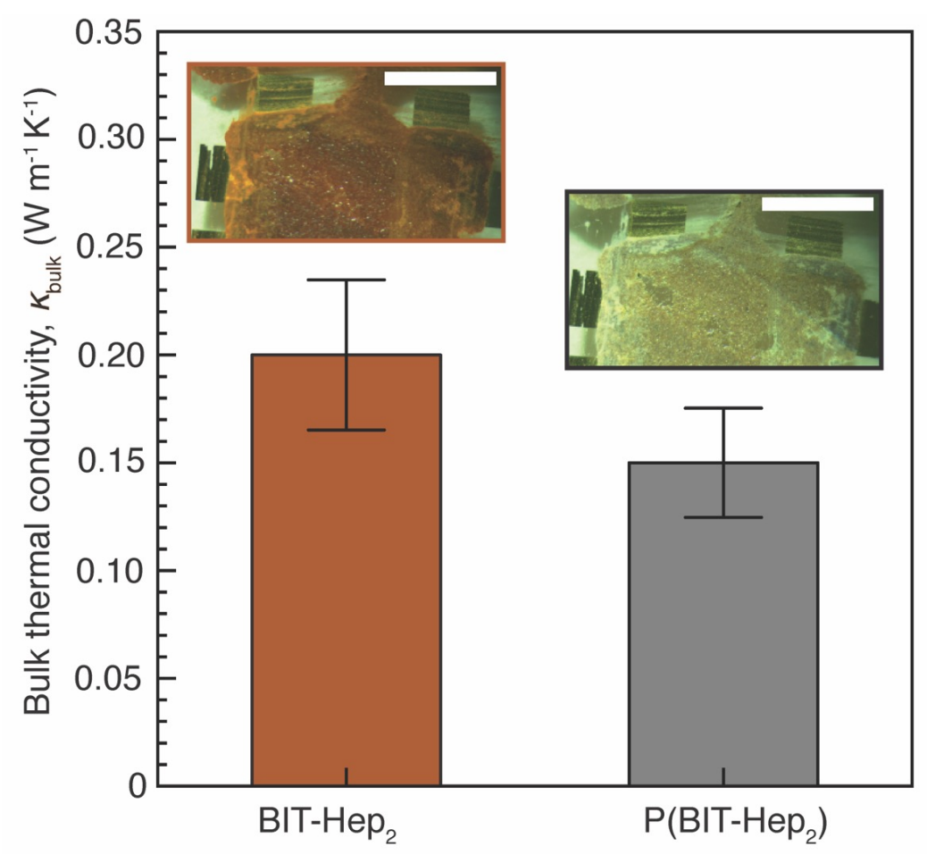


Figure 3: Reversible polymerization results in a change in thermal conductivity

Structure-property relationship of semiconductors and blends

Organic semiconductor devices (e.g., OPVs, OFETs, thermoelectrics) rely on a unique property set derived from specific material and its combinations. However, structure-property relationship of such semiconductor materials and their blends, e.g., with respect to transport properties, are not well understood. Here, we focus on different polymers and their blends in order to gain deeper insights into them.

Blending PBTTT with ionic liquids alters photophysical properties

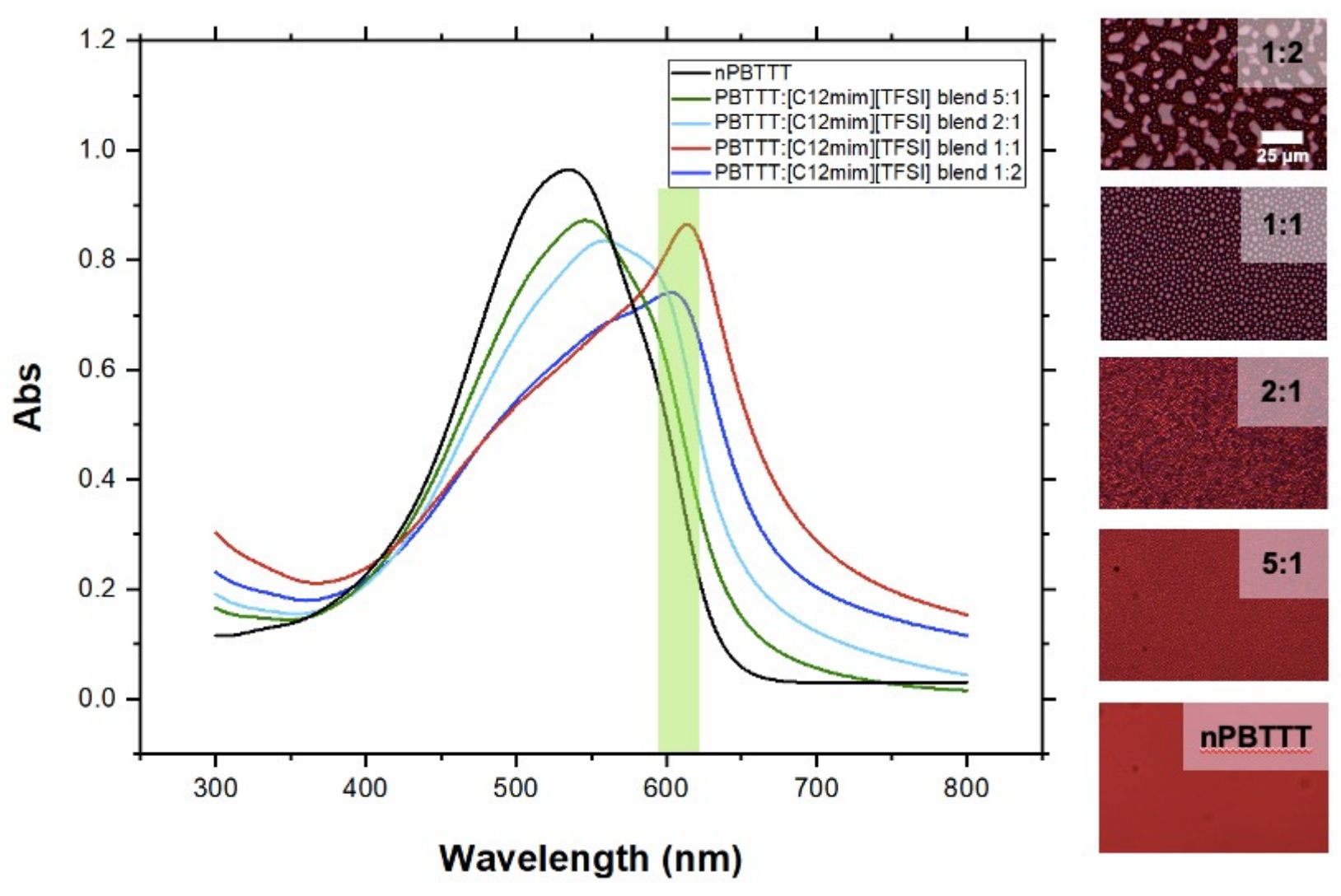


Figure 4: Controlling local order of conjugated polymers allows for the adjustment of optoelectronic properties. Here, we can see that as ionic liquid (IL) content increases, phase separation increases. The more phase-separated samples tend to have high 0-0 vibronic transitions.

Processing induced liquid-crystalline phases

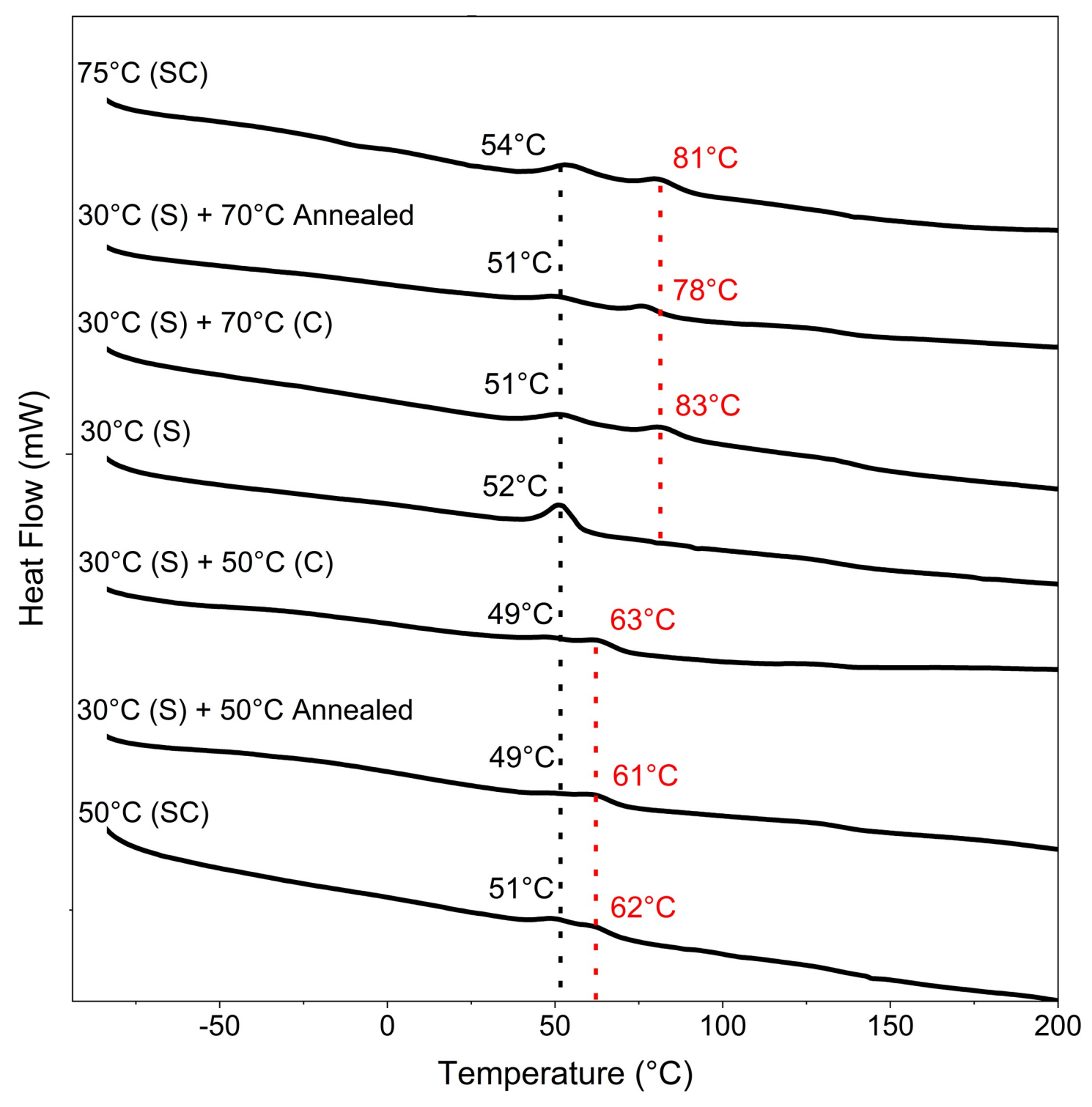


Figure 5: Processing PBTTT under pressure and sufficiently high temperatures induces increased order of liquid crystalline phase indicated by a unique enthalpic recovery at 61 °C and secondary endothermic peaks at 82°C.

High electrical conductivity of polymer:dopant blend near eutectic

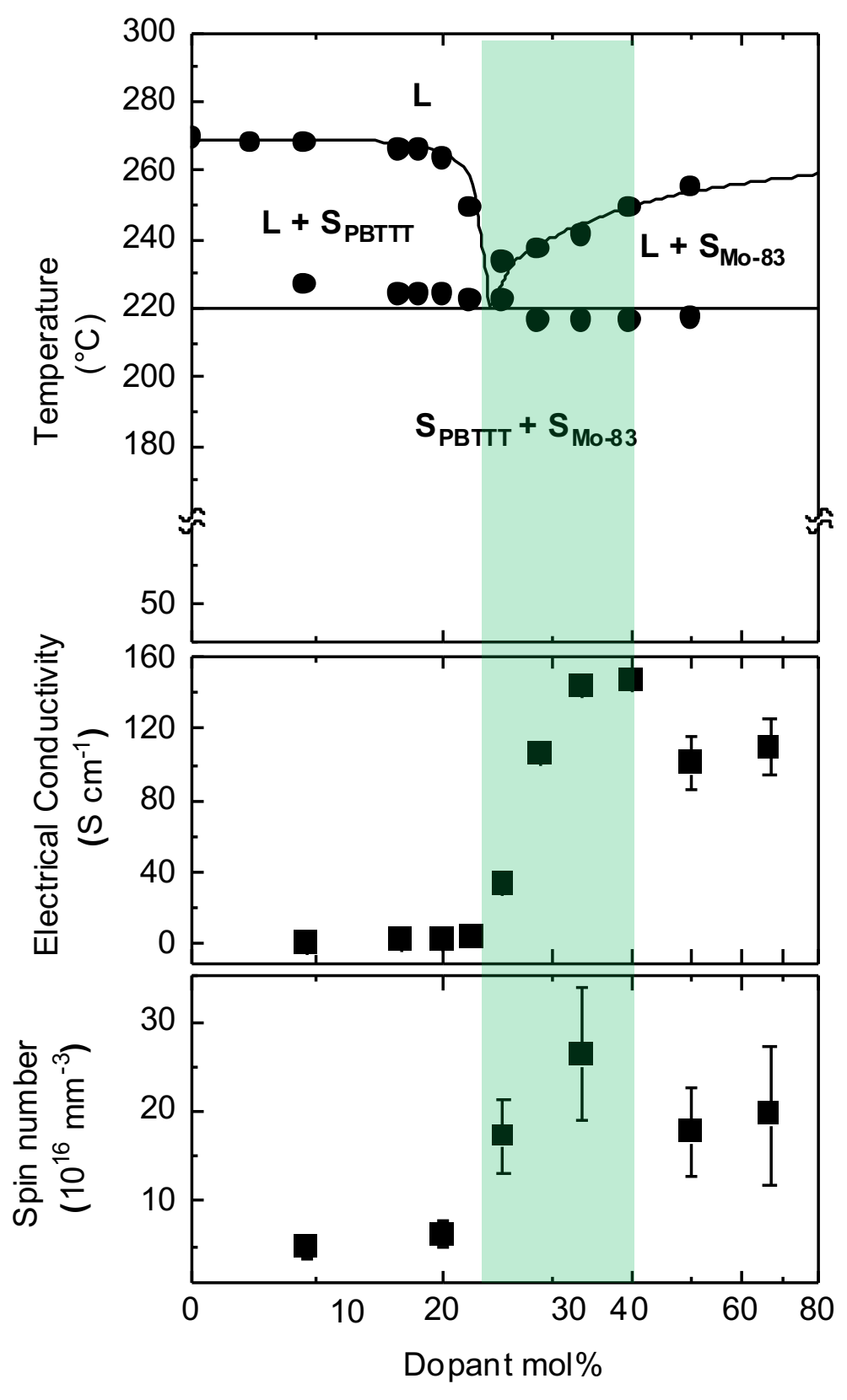


Figure 6: Phase diagram of PBTTT:Mo-83 system and corresponding electrical conductivities. Highlighted region indictates the vitrified samples.

Liquid-crystalline and birefringent materials

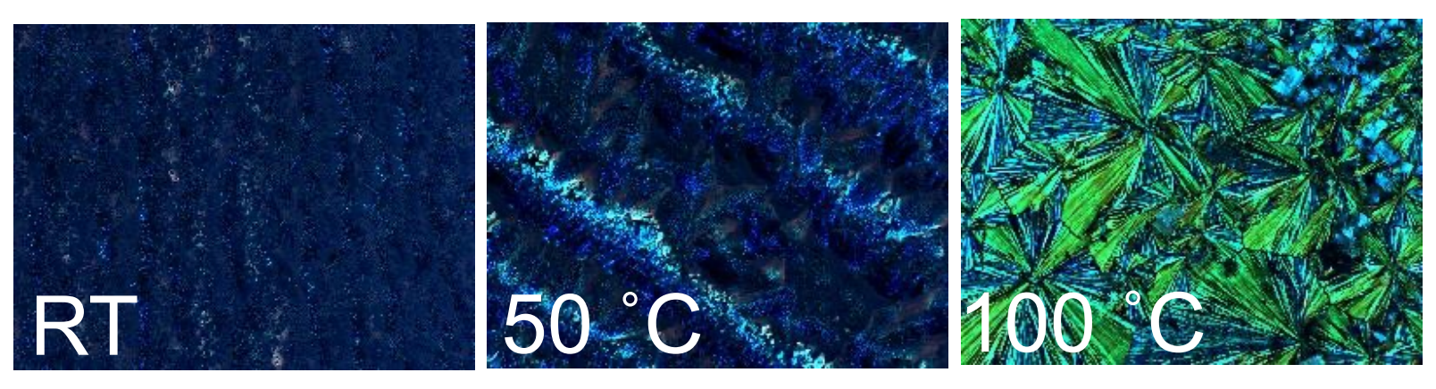
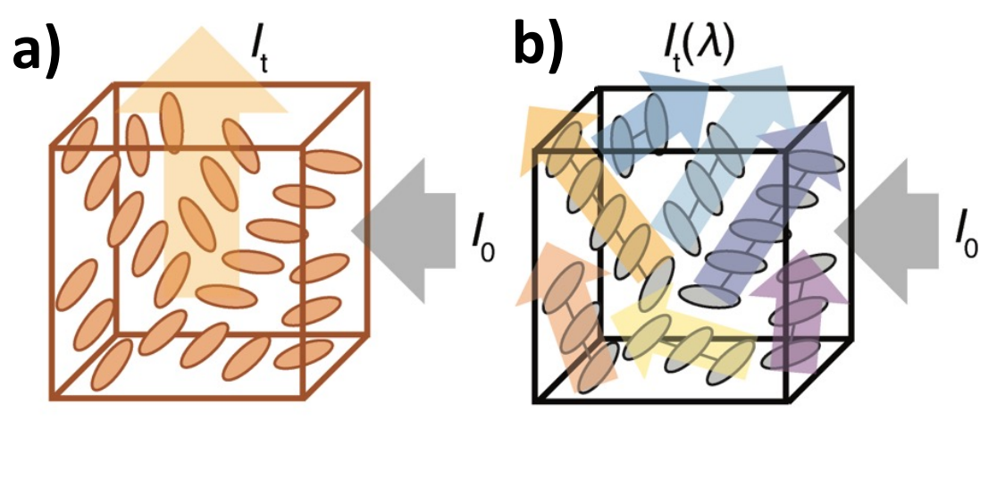


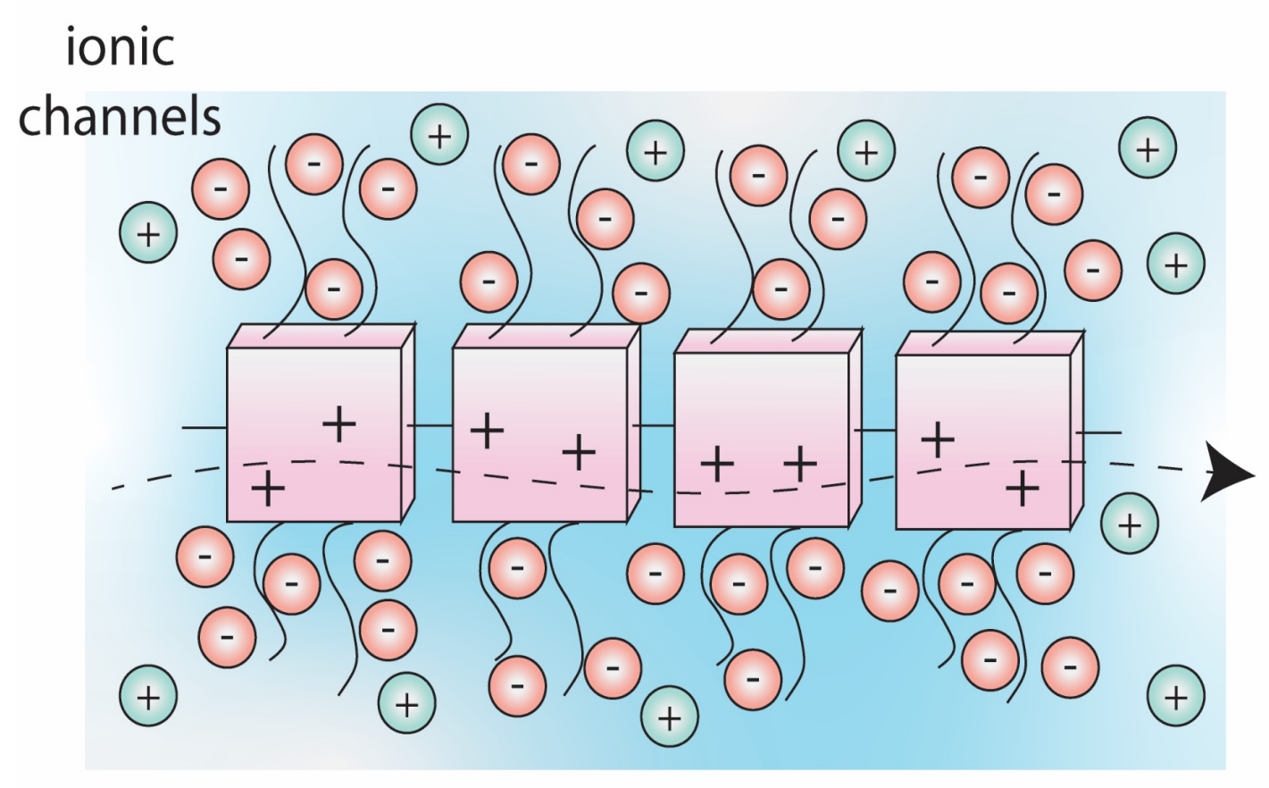
Figure 7: ITIC small molecule is a non-fullerene acceptor that undergoes distinct phase transitions when blended and subject to temperature

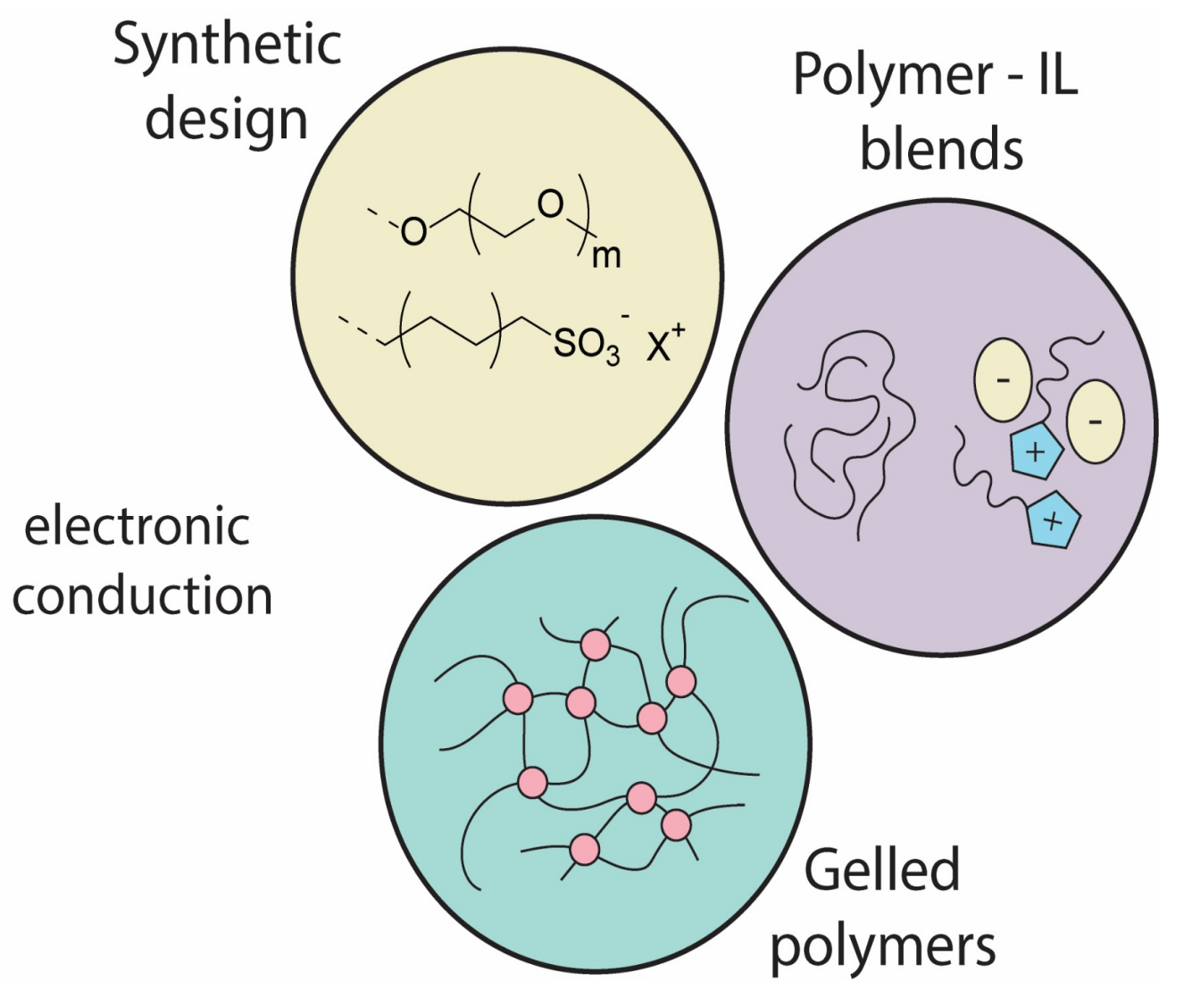
Figure 8: Birefringent organic materials exhibit orientation-dependent indices of refraction. A) This diagram illustrates a monomer that is not birefringent. B) The polymer with the same repeat unit is birefringent due to the orientation of the polymer chains.



Inorganic-organic hybrid materials

Mixed conduction materials exhibit simultaneous electronic and ionic conductivity, enabling direct interfacing between electronics and electrochemical systems. Potential applications for mixed conduction include batteries, synthetic neural and cardiomyocyte tissue scaffolds, and biosensors, amongst others.





Reversible swelling of semiconducting copolymer with hydrophilic sidechains (with Reynolds Lab)

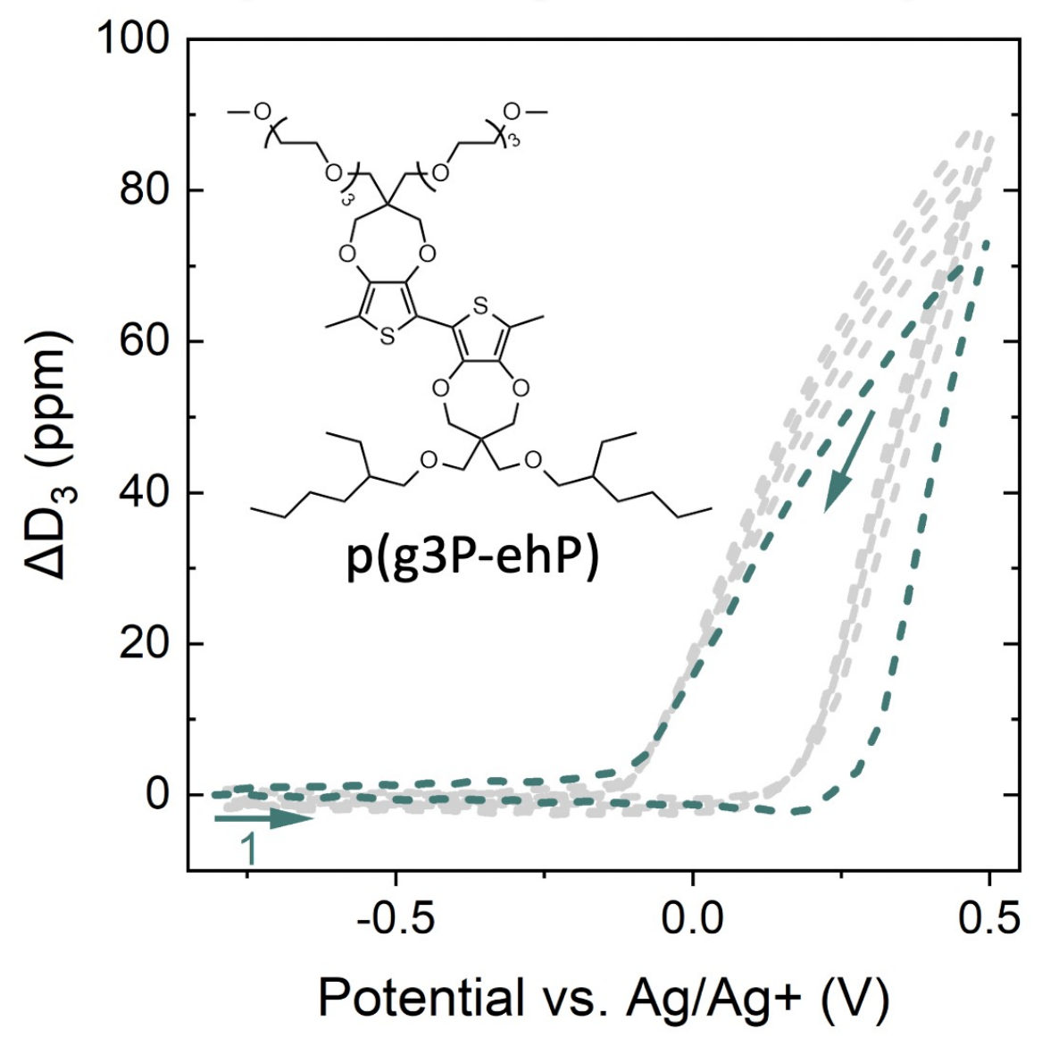


Figure 9: Neutral ProDOT copolymer with 'amphiphilic' aliphatic and oligoether sidechains swells and de-swells reversibly, as shown by electrochemical quartz crystal microbalance with dissipation monitoring

Mechanical properties of hybrid gels

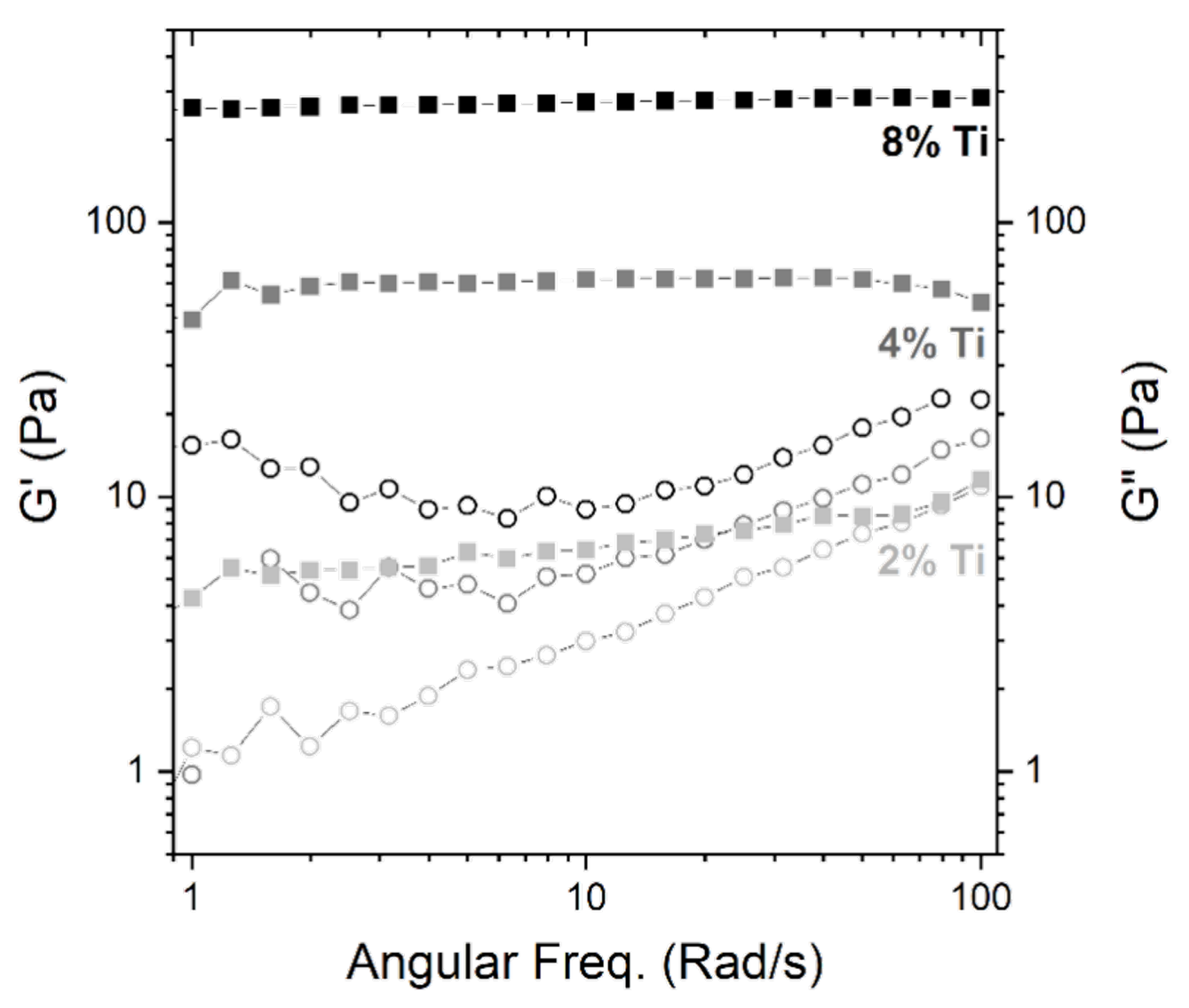


Figure 10: Increasing titanium oxide hydrate content in inorganic:organic hybrids with poly(vinyl alcohol) results in higher storage and loss moduli, associated with a higher density of crosslinks.

All-organic, solution-processable microcavities (with Silva Lab)

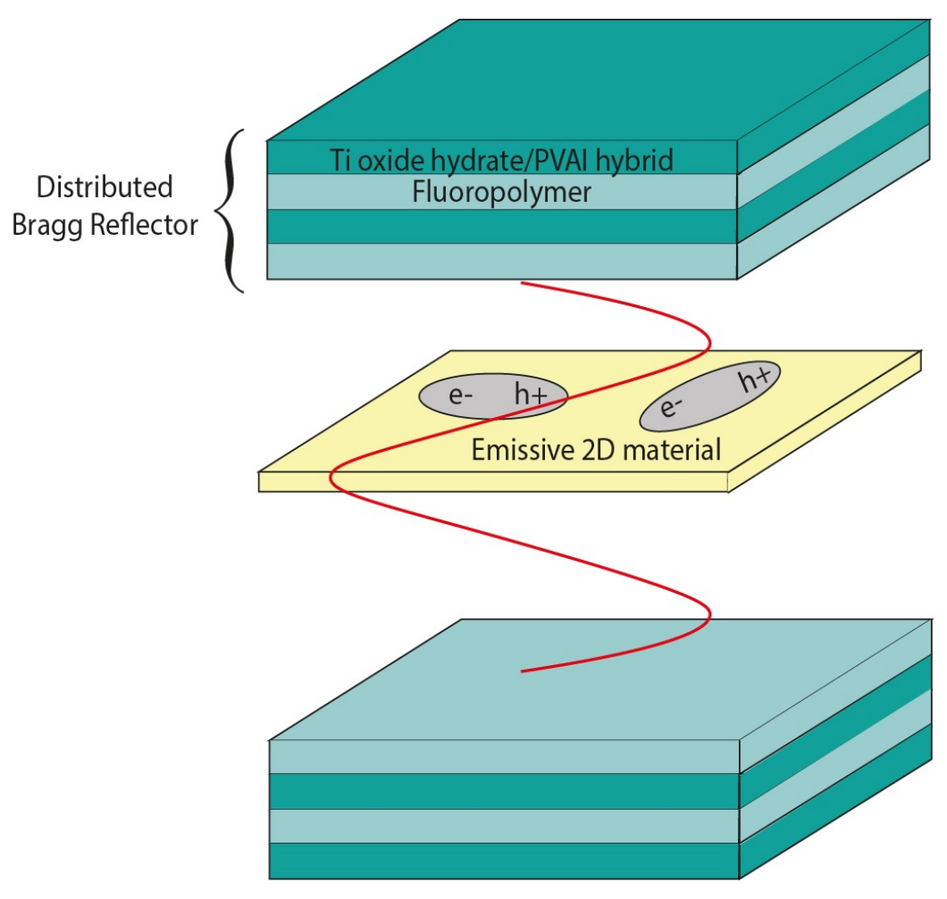


Figure 11: Structure of a solution-processed microcavity.

Capacitive sensors for UV detection

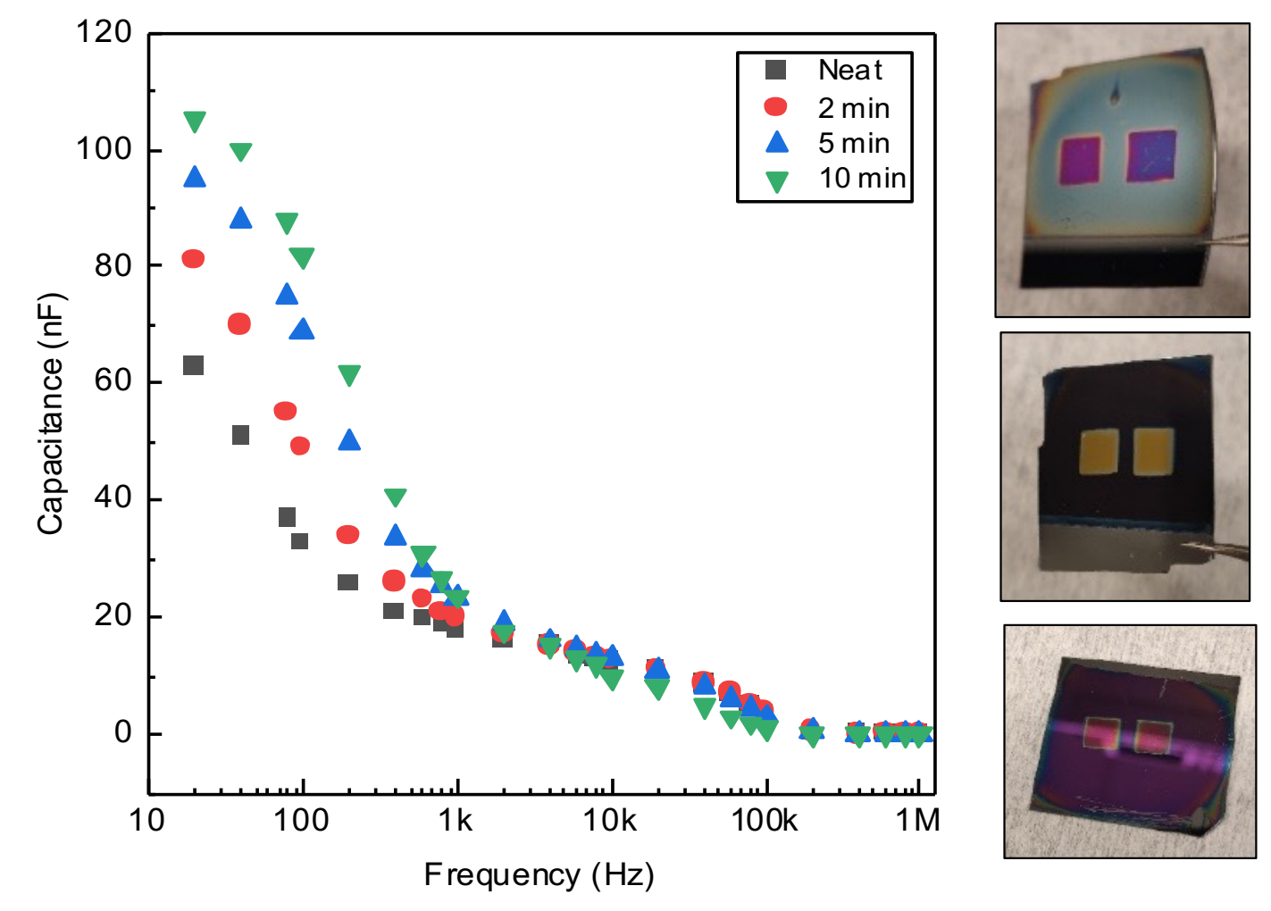


Figure 12: Flexible capacitive UV sensors based on biodegradable Polyvinyl alcohol is enabled by manipulating the hydrated titanium oxide concentrations to change the capacitance when exposed to UV doses.

Local ordering of semiconducting polymers

Local ordering affects electrostatic, Coulombic, and general photophysical processes in semiconducting polymers. Thus, understanding the impact of local ordering in these materials is crucial to optimizing them.

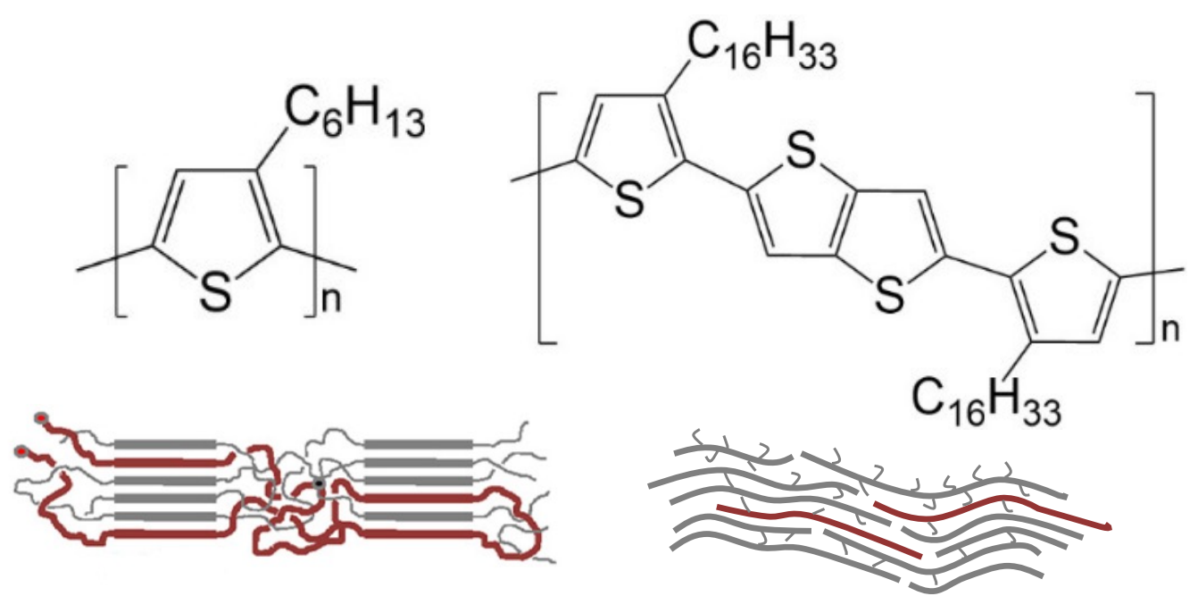
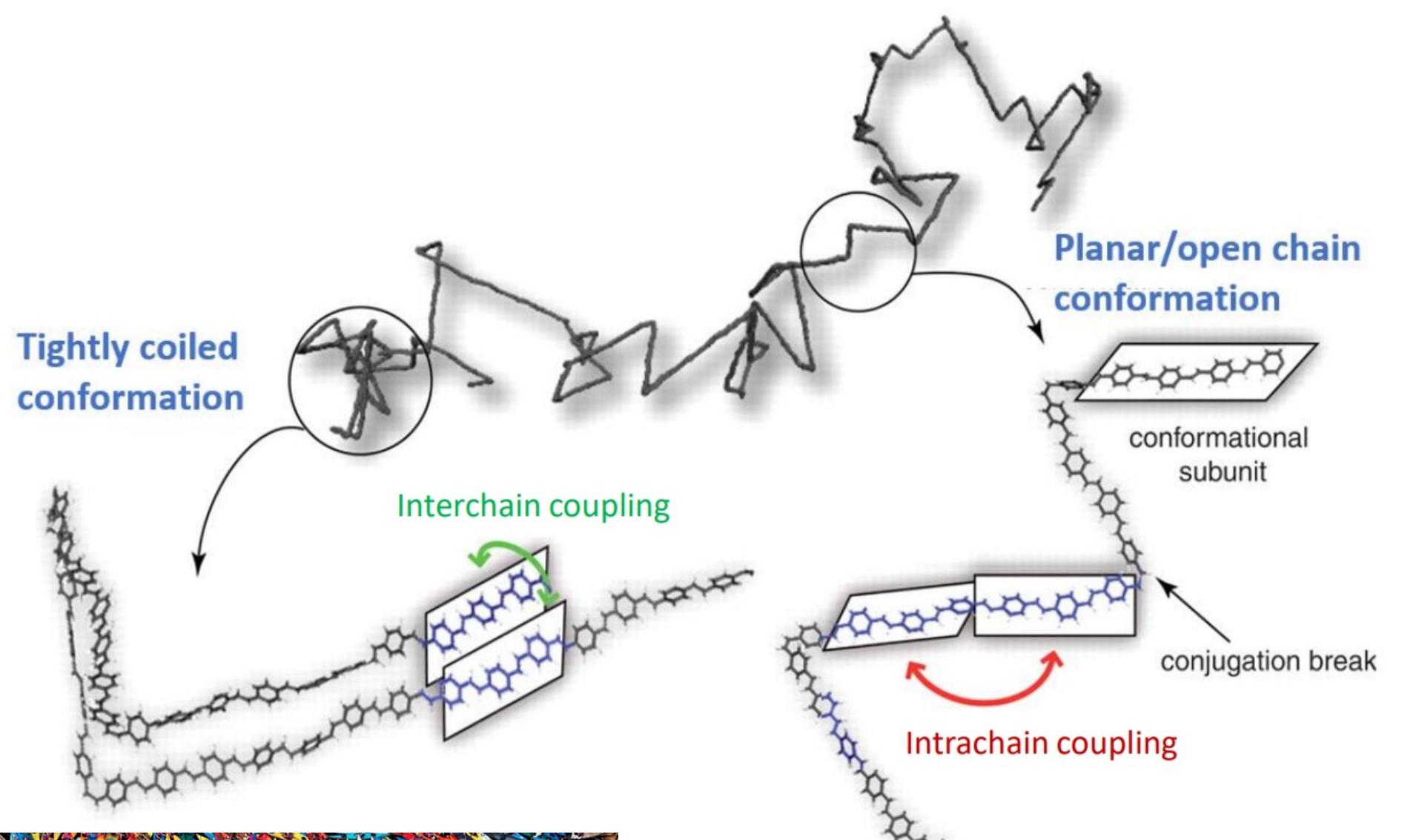


Figure 13: Chemical structure and schematics of P3HT (left) and PBTTT (right).



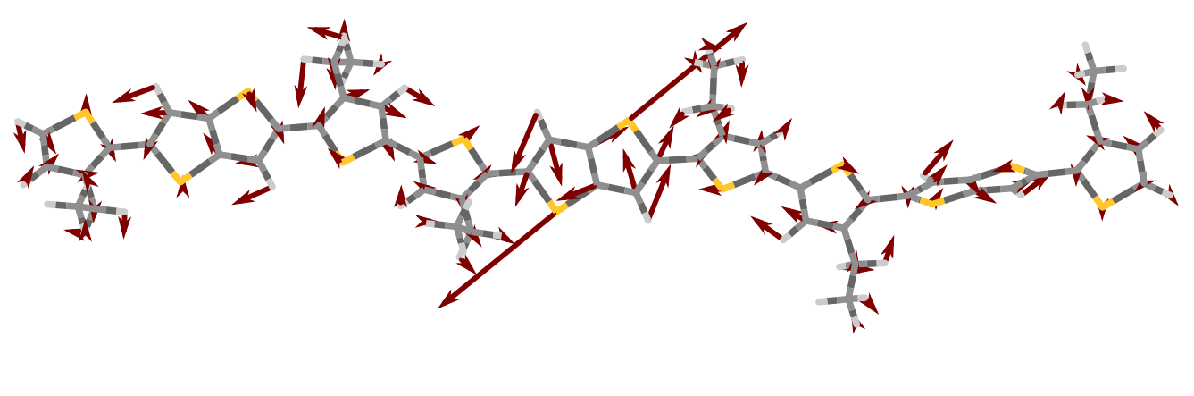


Figure 14: Vector graph of one vibrational pattern of BTTT oligomer.

Figure 15: Kayaks can be thought of as rigid repeat units. Here, we see local order due to the rigid "backbone" of the kayak (*National Geographics*).