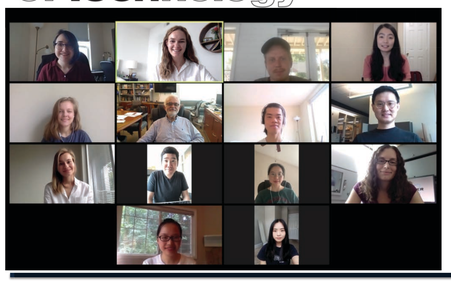
Surface Engineering and Molecular Assemblies Group

Georgia Institute of Technology



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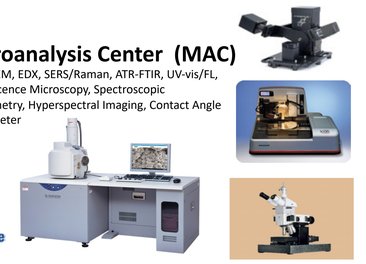
Support: ARO, NSF, AFOSR, DOE, NIH, DTRA, SMART, Oak Ridge National Laboratory, NASA, Novartis, Alcon, Kimberly-Clark, Aditya Birla Carbon, Max Planck Institute of Colloids and Interface

Microanalysis Center (MAC)

AFM, SEM, EDX, SERS/Raman, ATR-FTIR, UV-vis/FL, Fluorescence Microscopy, Spectroscopic Ellipsometry, Hyperspectral Imaging, Contact Angle Goniometer

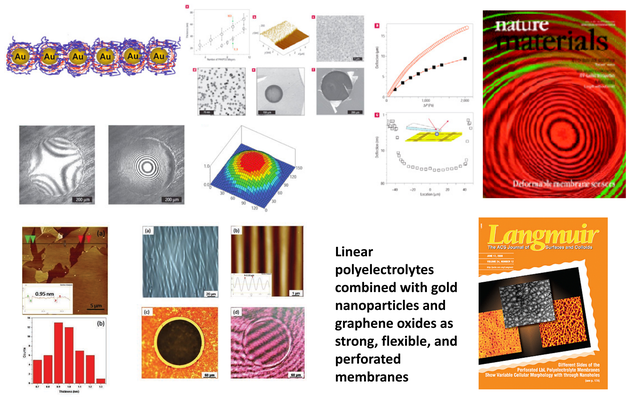


Surface & Interfacial Assemblies

Engineering self-assembled and hybrid nanomaterials at organic-inorganic interfaces

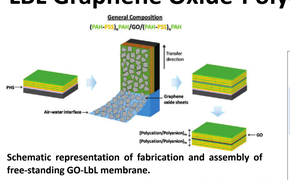
- Multilayered freely standing nanomaterials: polyelectrolytes, nanoparticles, nanowires
- Molecular films from multifunctional molecules: stars, brushes, and hyperbranched
- Assembly of polyelectrolyte-graphene oxide films

Layer-by-layer Assembly

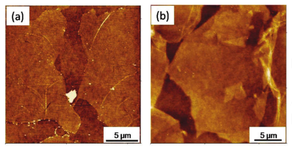


Linear polyelectrolytes combined with gold nanoparticles and graphene oxides as strong, flexible, and perforated membranes

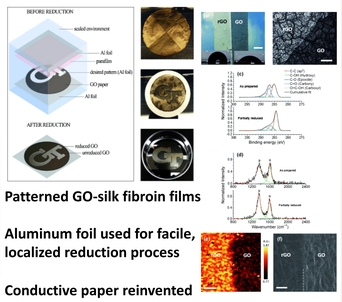
LBL Graphene Oxide-Polyelectrolyte Nanomembranes and GO-Silk Biopaper



Schematic representation of fabrication and assembly of free-standing GO-LbL membrane.



Morphology of GO-LbL membranes with (a) $(PAH/PSS)_5$ PAH-GO and (b) $(PAH/PSS)_5$ PAH-GO-PAH $(PSS/PAH)_5$ composition.

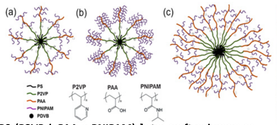


Patterned GO-silk fibroin films

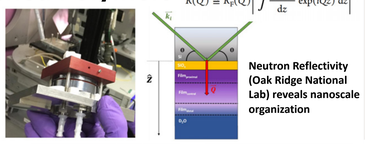
Aluminum foil used for facile, localized reduction process

Conductive paper reinvented

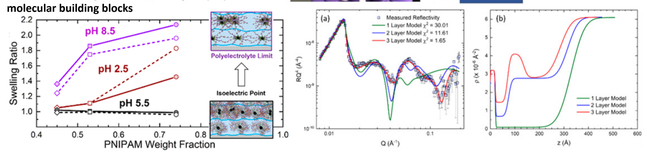
Responsive, Hierarchical Organization from Multifunctional Branched Polymers



$[PS_n(P2VP\text{-}b\text{-}PAA\text{-}g\text{-}PNIPAM)_m]$ star-graft polymers as molecular building blocks



Neutron Reflectivity (Oak Ridge National Lab) reveals nanoscale organization



Advanced characterization and modelling approach is used to study tunable internal structures and compartmentalized swelling at interfaces

Major publications

Xiong, R., Yu, S. Kang, S., Adstedt, K. M., Nepal, D., Bunning, T.J., Tsukruk, V.V., *Adv. Mater.* **2020**, 32, 1905600.

Erwin, A. J.; Korolovych, V. F.; Iatridi, Z.; Tsitsilianis, C.; Ankner, J. F.; Tsukruk, V. V. *Macromolecules* **2018**, *51*, 4800.

Xiong, R.; Kim, H. S.; Zhang, S.; Kim, S.; Korolovych, V. F.; Ma, R.; Yingling, Y. G.; Lu, C.; Tsukruk, V. V. *ACS Nano* **2017**, *11* (12), 12008–12019.

Erwin, A. J.; Xu, W.; He, H.; Matyjaszewski, K.; Tsukruk, V. V. *Langmuir* **2017**, *33* (13), 3187–3199.

Korolovych, V. F.; Ledin, P. A.; Stryutsky, A.; Shevchenko, V. V.; Sobko, O.; Xu, W.; Bulavin, L. A.; Tsukruk, V. V. *Macromolecules* **2016**, *49* (22), 8697–8710.

Hu, K. S.; Tolentino, L. S.; Kulkarni, D. D.; Ye, C. H.; Kumar, S.; Tsukruk, V. V., *Angewandte Chemie-International Edition*, **2013**, *52*, 13784.

Collaborations:
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M. Boyce, MIT
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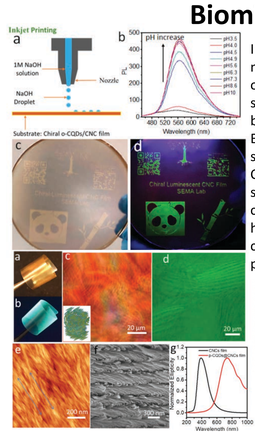
C. Tsitsilianis, U. Patras
A. Muller, U. Bayreuth
T. Bunning, AFRL
J. Ankner, ORNL
A. Fedorov, Georgia Tech
V. Shevchenko, IMNAS

Sensing and Optical Systems

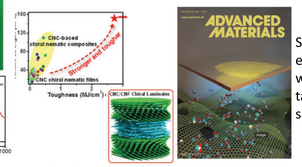
Design of systems that are highly sensitive to the physical and optical environment

- Biomimetic vibrational and strain sensors: structured polymer-based systems
- Optical gas and fluid trace detection: Raman enhancement using open porous structure
- Electrochemical responsiveness: Tunable nanoparticle-polymer systems
- Tunable fluorescence films: Light responsive QD-polymer films for patterning

Biomimetic Sensors



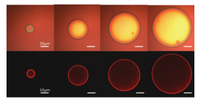
Increased mechanics in optical sensors using bio-based, Bouligand structures. Capable of sensing pH changes, humidity, and chemical presence.



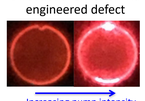
Self-powered electronic skin with bio tactile sensitivity

Sensing and Optical Systems

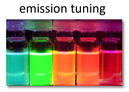
Tunable modes via QD disk size



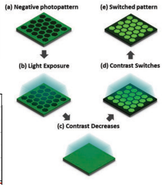
Directional emission via engineered defect



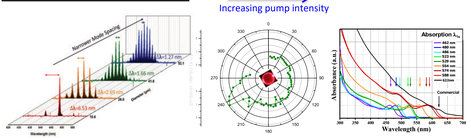
Quantum confined emission tuning



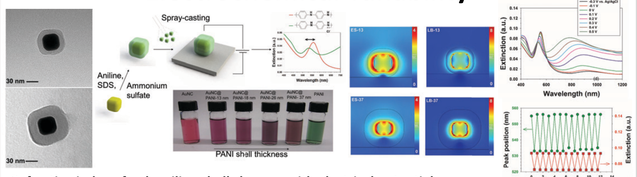
Optically controllable QD-polymer photopatterns



Increasing pump intensity



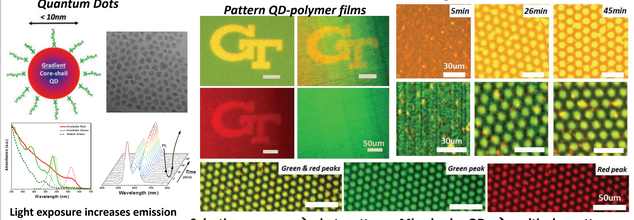
Electrochemical Tunability



Refractive index pf polyaniline shell changes with electrical potential

Optical resonances of gold nanocubes (coated with polyaniline shell) can be reversibly tuned

Fluorescence Tunability



Light exposure increases emission

Selective exposure → photopatterns; Mixed color QDs → multicolor patterns

Major publications

R. Xiong, S. Yu, M.J. Smith, J. Zhou, M. Krecker, L. Zhang, D. Nepal, T. J. Bunning, V. V. Tsukruk, *ACS Nano*, **2019**, 13, 9074-9081.

C. H. Lin, Q. Zeng, E. Lafalce, M. J. Smith, S. T. Malak, J. Jung, Y. J. Yoon, Z. Lin, Z. V. Vardeny, V. V. Tsukruk, *Adv. Opt. Mater,* **2017**,

Zhou, J.; Jeon, J.-W.; F. Ponder, J.; A. Geldmeier, J.; A. Mahmoud, M.; El-Sayed, M.; R. Reynolds, J.; V. Tsukruk, V. *J. Mater. Chem. C* **2017**, *5* (47), 12571–12584.

Smith, M. J.; Malak, S. T.; Jung, J.; Yoon, Y. J.; Lin, C. H.; Kim, S.; Lee, K. M.; Ma, R.; White, T. J.; Bunning, T. J.; Lin, Z.; Tsukruk, V. V. *ACS Appl. Mater. Interfaces* **2017**, *9* (20), 17435–17448.

Jeon, J.-W. Ledin, P. A., Geldmeir J. A., Ponder, J. F., Mahmoud, M. A., El-Sayed, M., Reynolds, J. R. Tsukruk, V. V. *Chem. Mater.* **2016,** 2868–2881.

Chyasnavichyus, M.; Young, S.L.; & V.V. Tsukruk, *Langmuir,* **2014,** *30,* 10566.

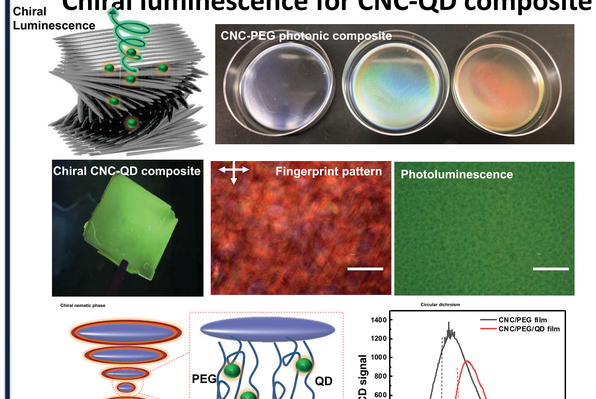
Collaborations:
M. Stone, AFRL
Barth, U. Vienna
S. Coombs, BGU
H. Blackman, U. Bonn
T. König, U. Bayreuth
Valy Vardeny, U Utah
N. Thomas, Rice
T. Kottos, Wesleyan U.
A. Abouraddy, UCF
J. Reynolds, GT
M. El-Sayed, GT

Biocompatible Composites

Fabrication and testing of isotropic and anisotropic polymer films and shells

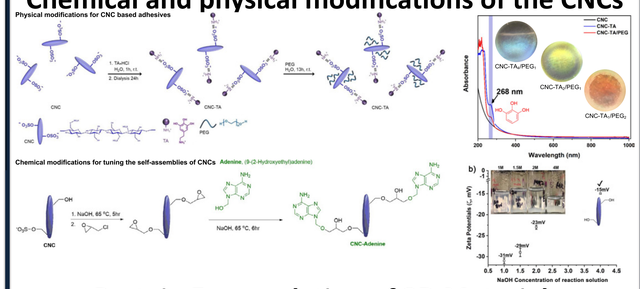
- Combinations of CNCs and carbon quantum dots for photoluminescence
- Surface modification of CNCs for tunable self-assembly
- Encapsulation of cells to form protected cell environment for biosensing

Chiral luminescence for CNC-QD composite

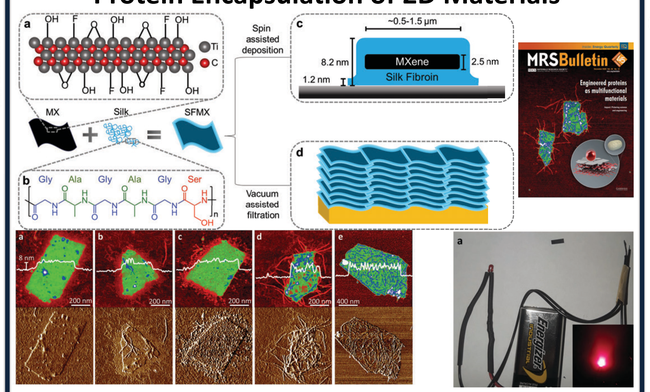


The combination with cellulose nanocrystal (CNCs) chiral photonic structure and inorganic quantum dot (QD) with achiral morphology provides well-designed chiral photoluminescence with strong circular dichroism (CD) peaks without destroying initial chiral nematic phase of CNCs.

Chemical and physical modifications of the CNCs



Protein Encapsulation of 2D Materials



Major publications

R. Xiong, J. Luan, S. Kang, C. Ye, S. Singamaneni, V.V. Tsukruk, *Chem. Soc, Rev.* **2020**, 49, 3, 983-1031.

V. Cherpak, V.F. Korolovych, R. Geryak, T. Turiv, D. Nepal, J. Kelly, TJ> Bunning, O.D. Laverntovich, W.T. Heller, V.V. Tsukruk, *Nano Letters* ***2018****, 11, 6770-6777.*

Ye, C.; Malak, S.T.; Hu, K.; Wu, W.; Tsukruk, V.V., *ACS Nano,* **2015,** 9, 10887-10895

Krecker, M. C., Bukharina, D., Hatter, C. B., Gogotsi, Y., Tsukruk, V. V. *Adv. Funct. Mater.* **2020,** 30, 2004554

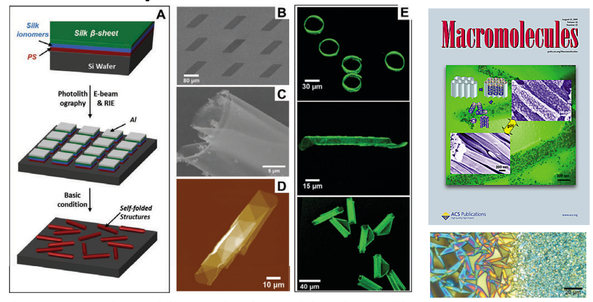
Collaborations:
D. Nepal, AFRL
Y. Gogotsi, Drexel
T. Bunning, AFRL
Y. Gogotsi, Drexel

Responsive Materials & Hybrid Structures

Biological and responsive macromolecular materials as prospective building blocks

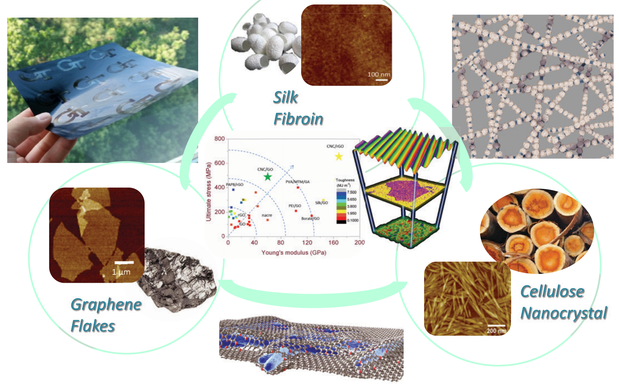
- Self-folding silk origami: patterned silk films, self-folded microtubes, tunable morphology
- Hybrid materials: silk fibroin-graphene oxide films with enhanced mechanical properties
- Magnetic Assemblies: Nanorod assemblies with magnetically tunable spacing

Responsive Patterned Nanofilms

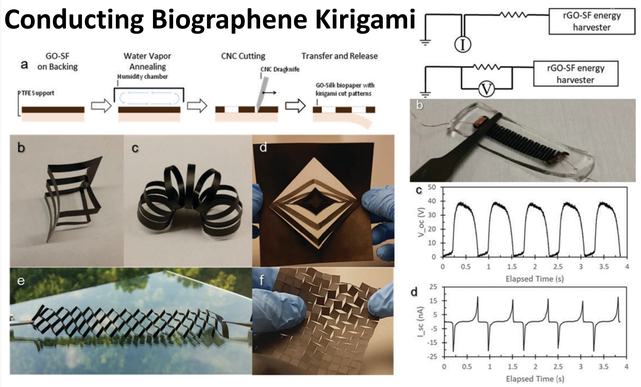


Micro /nanoscale multilayered polymer/biopolymer films

Ultra Robust Bio/Nano Hybrid Composites



Conducting Biographene Kirigami



Major publications

Ma, R.,Tsukruk, V. V. *Adv. Funct. Mater.* **2017.**

Xiong, R.; Kim, H. S.; Zhang, S.; Kim, S.; Korolovych, V. F.; Ma, R.; Yingling, Y. G.; Lu, C.; Tsukruk, V. V. *ACS Nano* **2017**, *11* (12), 12008–12019.

Xiong, R.; Hu, K.; Zhang, S.; Lu, C.; Tsukruk, V. V. *ACS Nano* **2016**, *10* (7), 6702–6715.

Grant, A. M., Kim, H. S., Dupnock, T. L., Hu, K., Yingling, Y. G., Tsukruk, V. V., Adv. Func. Mater., **2016**.

Ye, C., Tsukruk, V.V., *Science* **2015**, *347,* 130.

Ye, C.; Nikolov, S.V.; Calabrese, R.; Dindar, A.; Alexeev, A.; Kippelen, B.; Kaplan, D.L.; Tsukruk, V.V., **2015**, *Angew. Chem. Int. Ed. Engl.* **2015,** 54, 8490–849.

Ma, R., Wu, C., Wang, Z. L., Tsukruk, V. V. *ACS Nano,* **2018**, 12, 9714-9720.

Collaborations:
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R. Vaia, AFRL
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D. Kaplan, Tufts U.
V. Shevcheno, NASU
J. Ankner, ORNL