May 2019

Bottom-Up Shape Engineering of Organic Molecular Single-Crystals

Griffin Reed
Western Washinton University

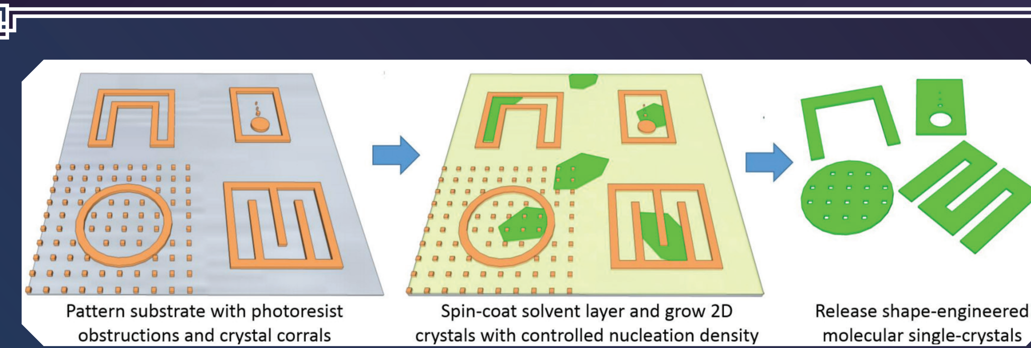
SHAPE ENGINEERING OF ORGANIC MOLECULAR SINGLE-CRYSTALS

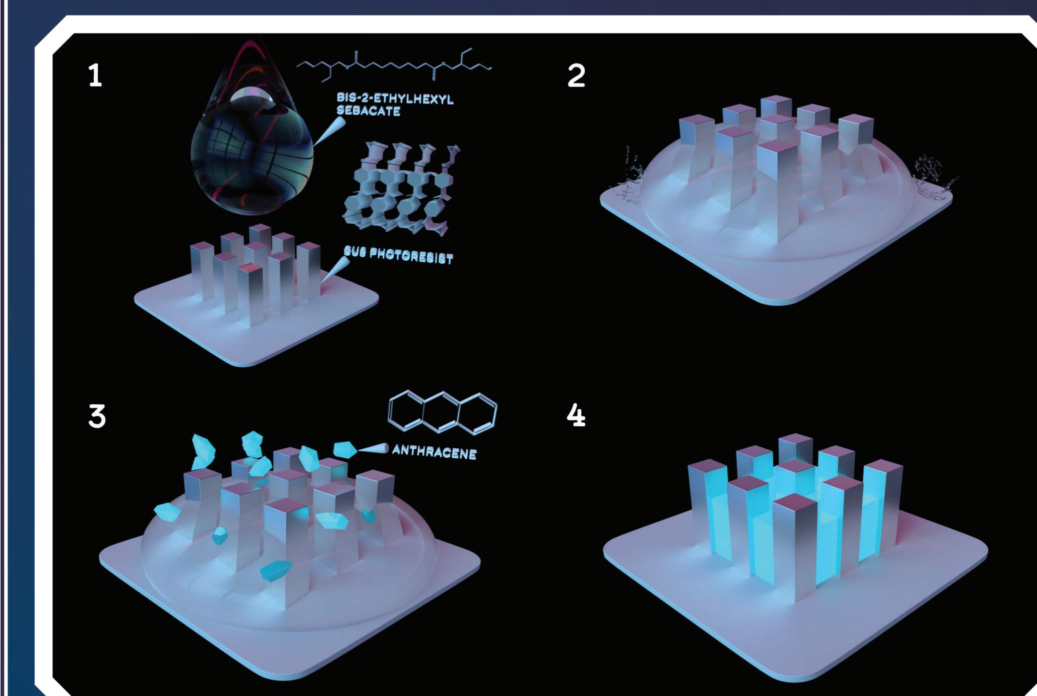
Griffin Reed, Haley Doran, Matthew Littleton, David Patrick
Department of Chemistry, Western Washington University, Bellingham, WA

Key Ideas

- Nanoscale machining methods for inorganic crystalline semiconductor materials have enabled countless modern technologies, from microelectromechanical systems to integrated circuits
- Patterning methods for single-crystal molecular materials, such as organic molecular crystals, have matured in the past two decades but are still being developed
- Traditional nanofabrication methods for inorganic crystals are not compatible with molecular crystals due to the weak intermolecular bonding forces in molecular crystals

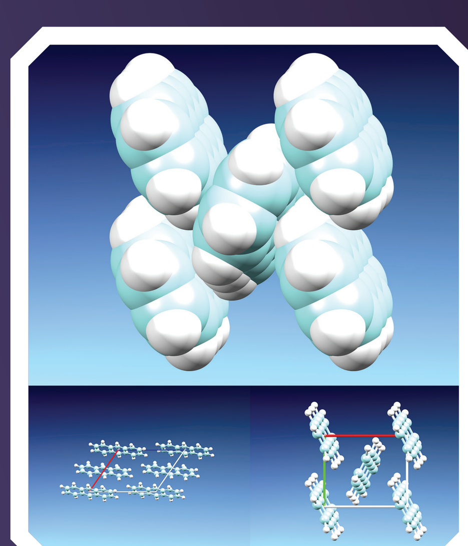
Internal and External Patterning via Photolithography





- Control over both the bounding perimeter shape and the internal microstructure of single crystals can be achieved by pairing a traditional photolithography pattern with an organic-vapor-liquid-solid (OVLS) deposition method
- Traditional methods for patterning inorganic materials using photolithography typically utilize harsh chemicals or treatments (e.g. wet etching) that are not compatible with organic molecular crystals due to the weak bonding in OMCs[2]
- We exploit the plasticity of organic molecular crystals in order to force the crystals to adopt specific shapes and sizes within the photolithographic pattern

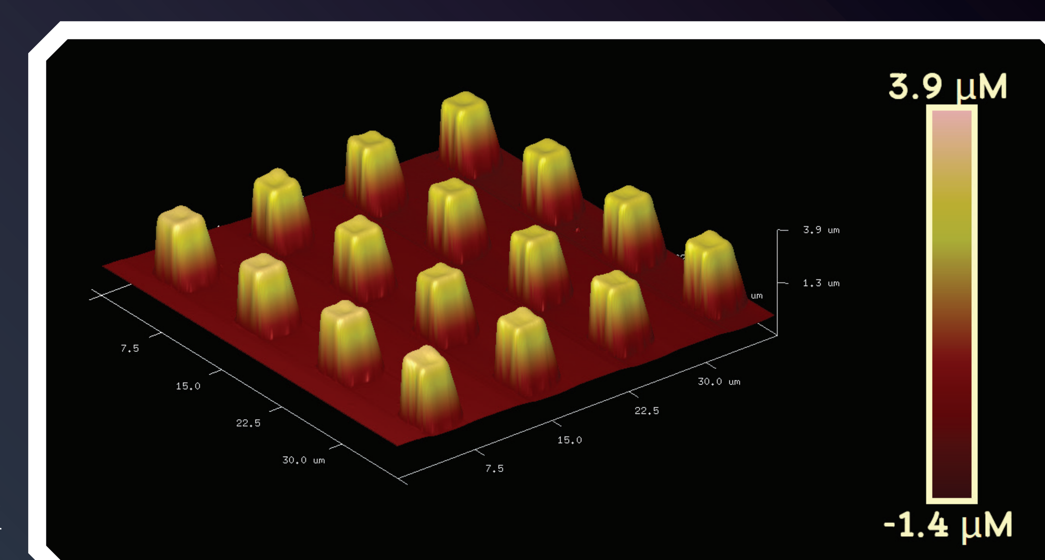
Molecular Crystals

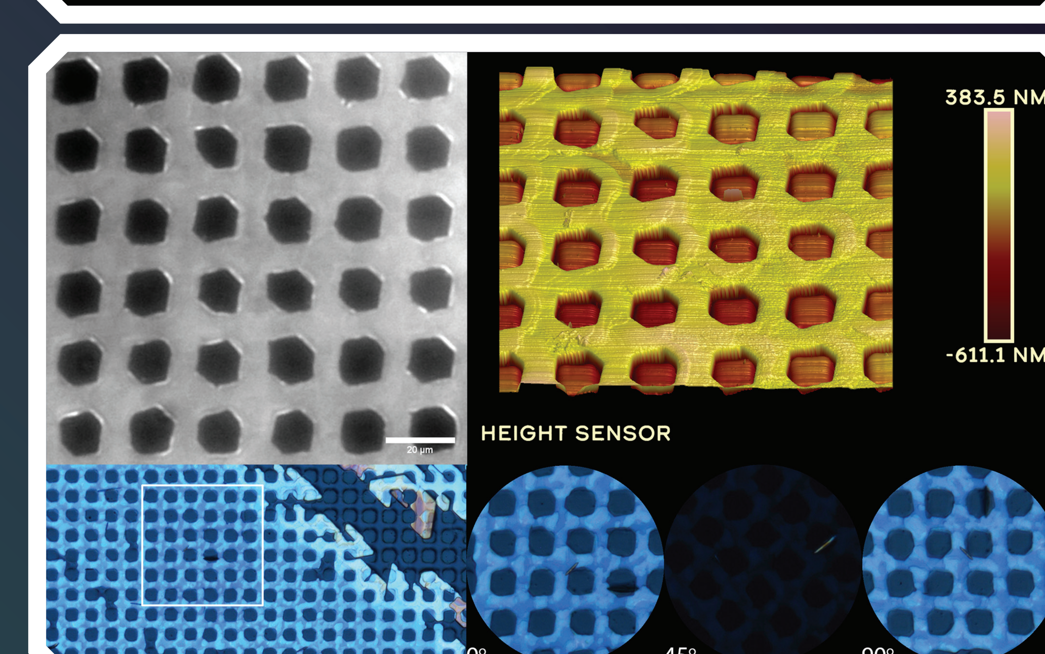


- Molecular crystals have markedly different physical properties than covalent or ionic crystals
- Molecular crystals are bound together by intermolecular forces rather than ionic or covalent bonds
- These weak intermolecular forces can impart mechanical flexibility onto these crystals (a feature that allows for fabrication of flexible electronic devices such as bendable displays and roll-up solar panels)[1]
- Weak bonding allows for low deposition temperature and vacuum-free setup, reducing cost and environmental impact

Photonic, Phononic, and Plasmonic Crystals

- In our experiments, we have fabricated near-nanoscale perforated architectures (2-25 micron holes), which correspond to infrared bands
- These types of patterns can be found in nature; "structural color", such as the ever-changing skin of a chameleon, the blue wings of a butterfly, or the iridescent flecks on a peacock feather arise from nanoscale periodic patterns
- These patterns can create what is known as a "photonic bandgap", where certain wavelengths of light are allowed to or are forbidden from propagating through the structure
- This phenomenon can be exploited for many interesting photonic and optoelectronic applications, and other types of wavelike quasiparticle such as phonons, plasmons, and exciton-polaritons can be manipulated by the same sort of technique (allowing for control over properties such as thermal conductivity)[3]

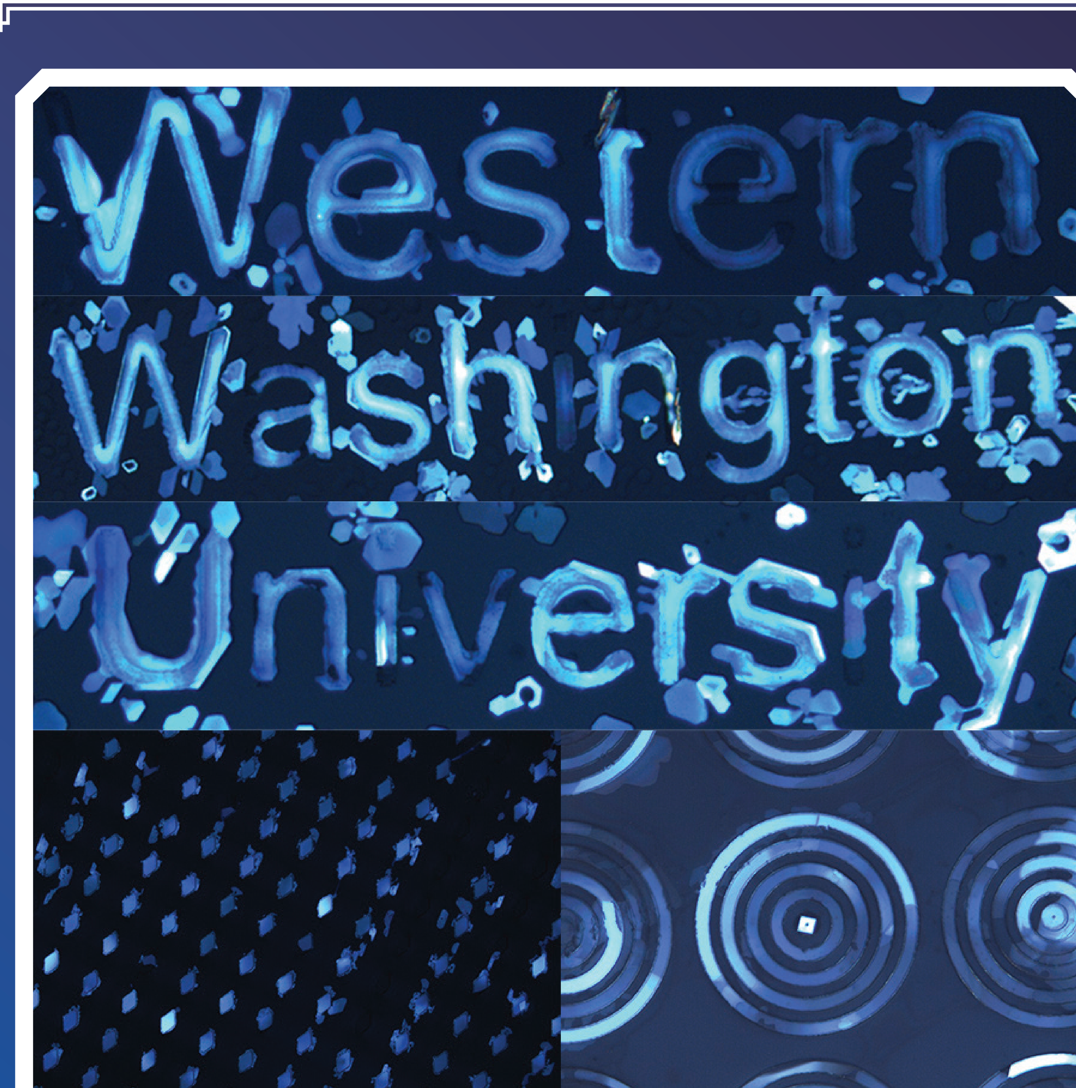


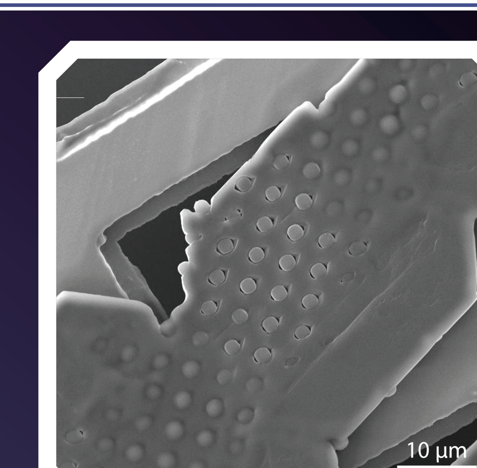


Deposition Scheme

- Glass tube is placed between two glass slides
- Monomer to be deposited is placed on the bottom slide, while a liquid-layer-coated slide is placed atop the glass tube with the liquid layer facing down
- Upon heating, monomers will sublime and diffuse from the bottom slide and dissolve into the liquid layer on the top slide
- Jar with inert gas can be placed over the system for an air-free environment

Shape Control and Crystal Transfer for Optoelectronics Applications

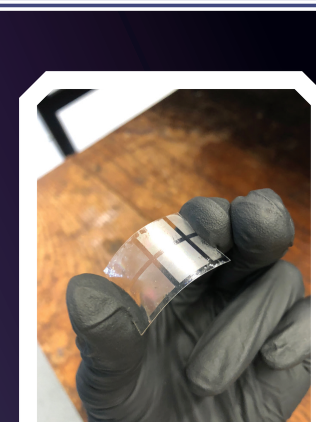




- Control over the specific shape, size, and positioning of individual semiconductor crystals is critical for organic electronics applications such as OFET, OLET, and OLED arrays
- OLED arrays for display applications require that a large number (~8.8 million for 4K) of microscale organic stacks be deposited into precise positions on a device with a specific size and shape
- For both pixel and transistor arrays, every single element of the multimillion element system needs to be reliable[4]

Future Work

- Device fabrication, including OFETs and OLEDs on flexible substrates
- Control over molecular packing in pharmaceuticals
- Characterization of photonic band structure
- Nanoscale patterning for visible light and phonon control



Acknowledgments

Special thanks to Dr. Patrick for his guidance and knowledge, to Matt Littleton and Haley Doran for their strong worth ethic, and to Daniel Korus, Kayla Koch and Ayesha Nadeem for their artistic input on this poster.

References

[1] Chem. Soc. Rev., 2019, 48, 1492-1530
[2] JACS, 2018, 140 (22), 6984-6990
[3] Jpn. J. Appl. Phys., 2018, 57, 080101
[4] Light: Science & Applications, 2018, 7, 17168