Research Highlights
Electronic Materials and Devices (EMD)

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Investigator	Department	Expertise
Steven Koester	ECE (co-leader)	*2D materials, transistors, sensors*
Bharat Jalan	CEMS (co-leader)	*Complex oxides, molecular beam epitaxy*
Chris Leighton	CEMS	*Electronic/magnetic properties, material growth*
Paul Crowell	Physics	*Magnetism, transport, ultra-fast spectroscopy*
Steve Campbell	ECE	*Thin-film photovoltaics, 2D materials*
Eray Aydil	CEMS	*Thin-film photovoltaics, 2D materials*
Uwe Kortshagen	ME	*Nanomaterial devices and synthesis*







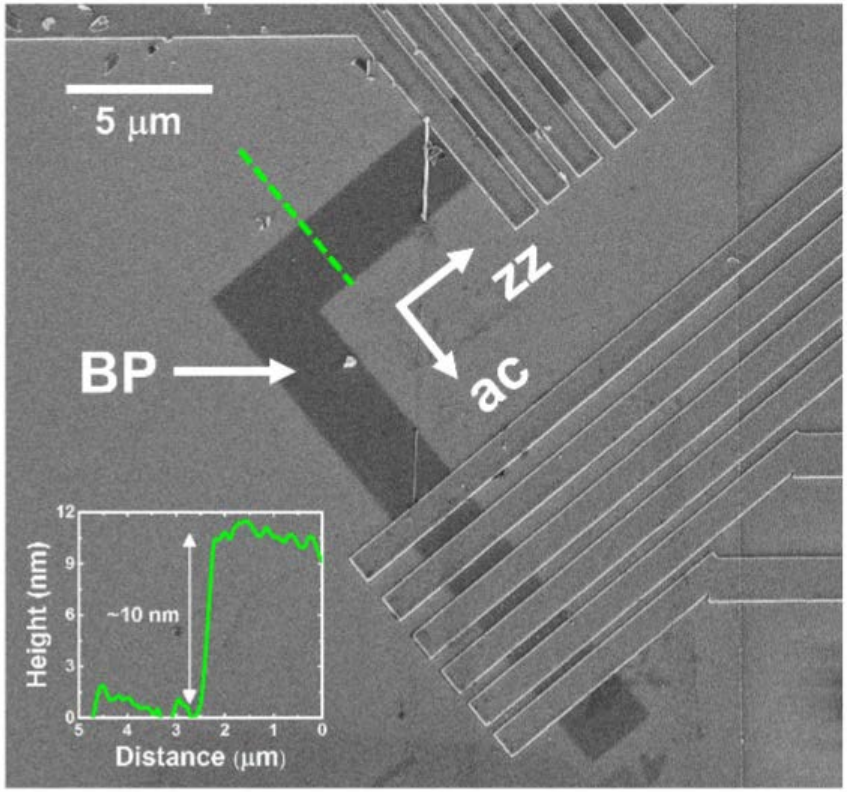
Faculty from 4 different departments. Diverse and complementary range of expertise.

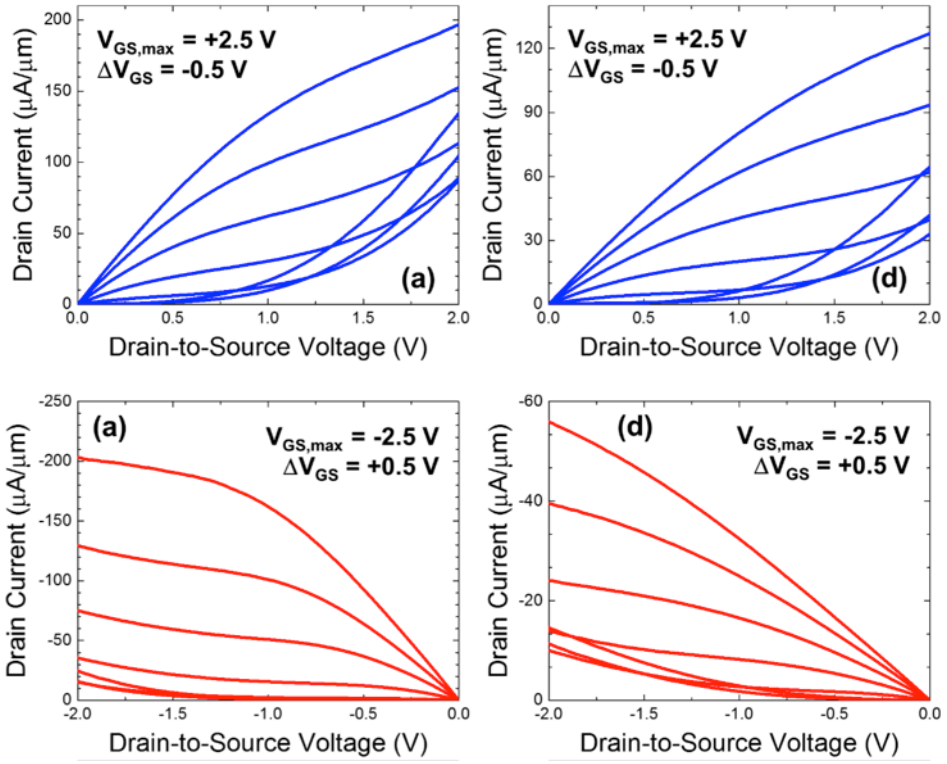
Synthesis, structural and chemical characterization of materials relevant for a wide range of electronic, optical and magnetic devices. Particular emphasis is placed on the understanding of the fundamentals of electronic structure and transport in electronic and magnetic materials, in addition to the materials science, physics and chemistry of the interfaces and nanostructures that play a vital role in device operation.

Anisotropic Transport in Black Phosphorus

- Evaluated transport anisotropy in 2D black phosphorus (phosphorene):

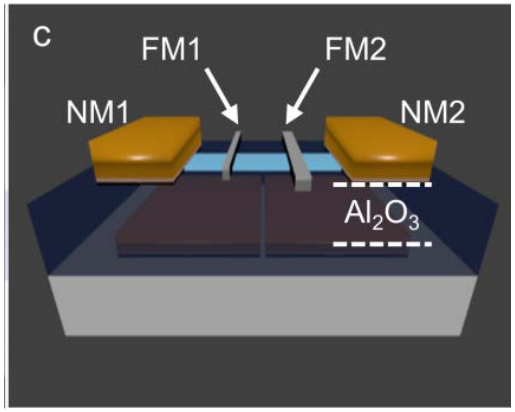
N. Haratipour, et al., *IEEE Elect. Dev. Lett*. **38**, 685 (2017).



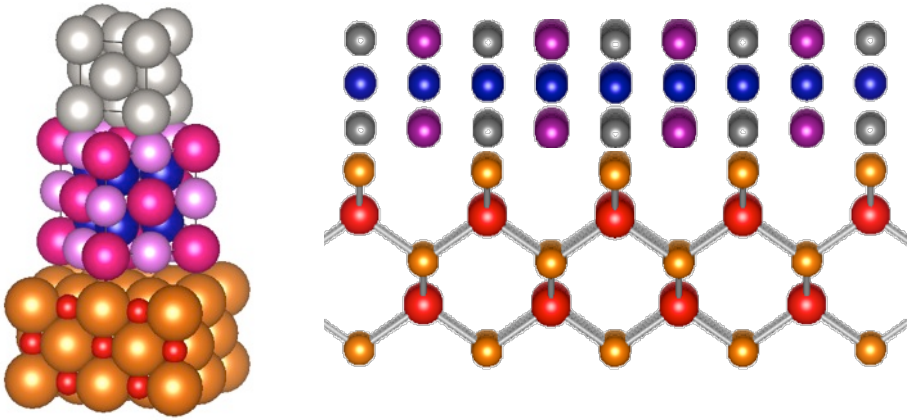


- n-MOSFETS (p-MOSFETs) show 2x (4x) performance enhancement when oriented along the armchair vs. zigzag crystal orientation. Highest performance for BP nFETs to date.
- Potential applications for high-performance flexible and printed electronics.

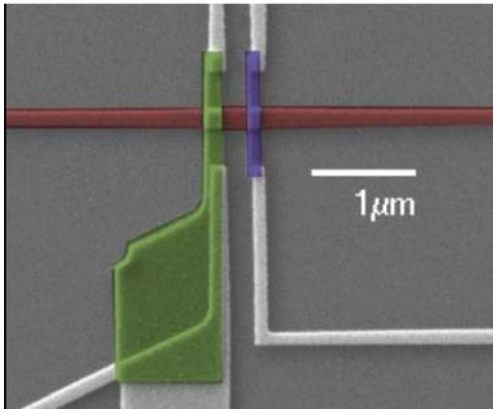
Physics of Spintronic Devices



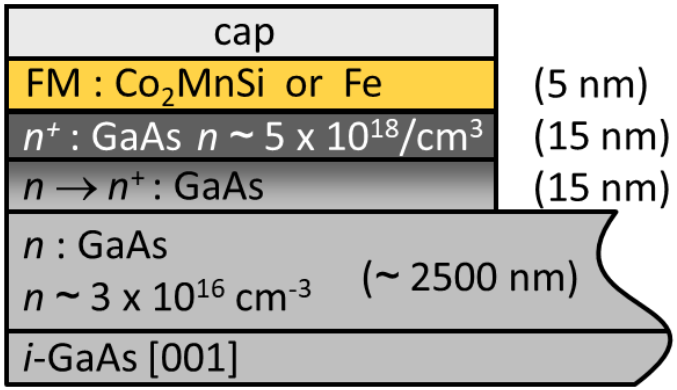
Graphene spin valves (w/ Koester)



Heusler-alloy based epitaxial heterostructures



Metallic spin valves (w/Leighton)

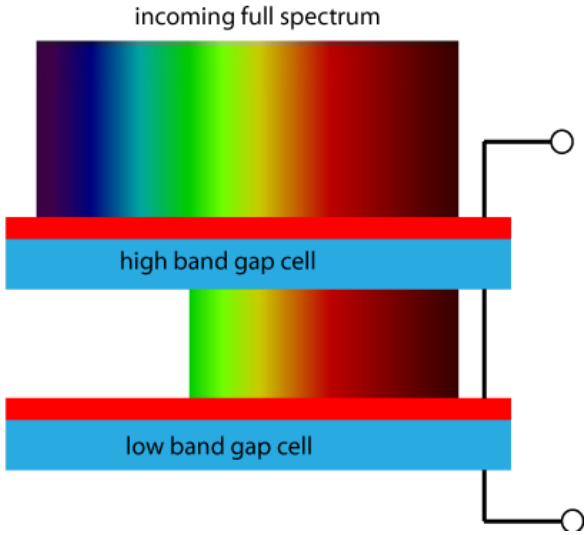


III-V semiconductor spintronic devices

- Spintronic devices based on integration of ferromagnetic metals with semiconductors, graphene, and normal metals.
- Magnetotransport, microwave, and optical measurements.

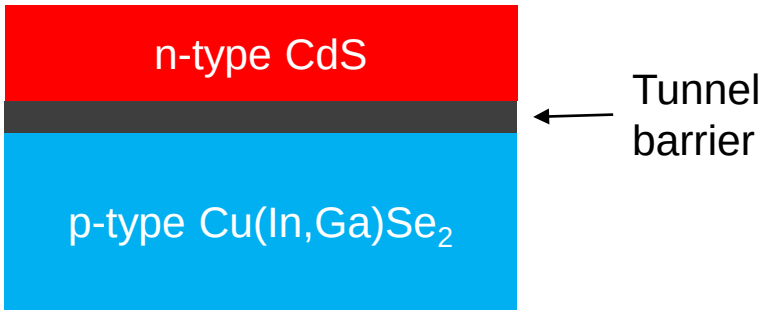
Tandem CIGS Solar Cells

- Investigating multi-junction thin-film solar cells for high-efficiency, low-cost photovoltaics:



- Only multijunction photovoltaics can allow solar cell efficiency to improve
- But, the temperature required for the top cell leads to inter diffusion of the bottom cell layers, killing the device

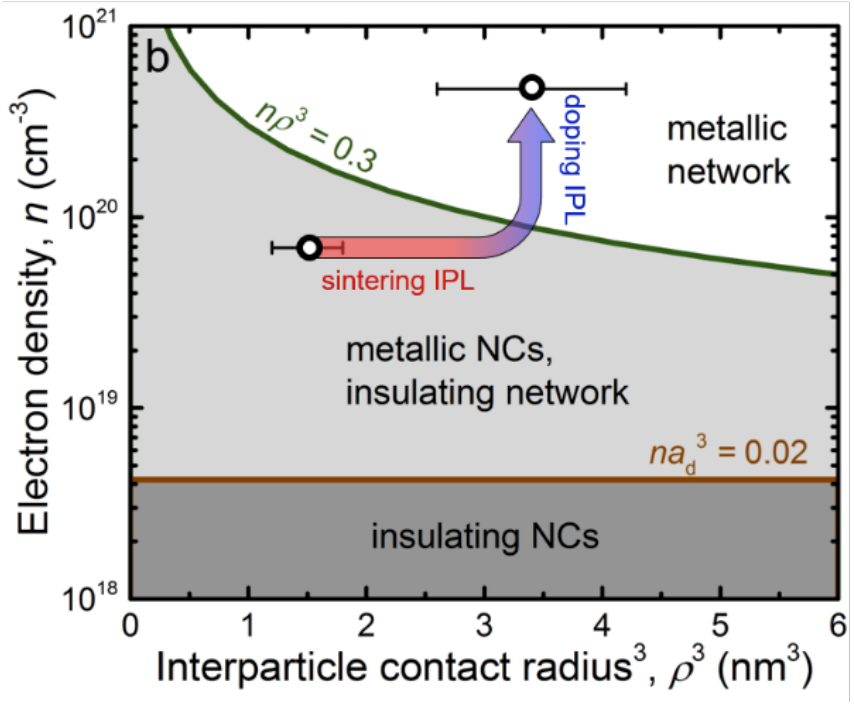
- Potential solution: diffusion barrier
  - Thin enough for electrical tunneling but still block Cd diffusion at 500 ^{o}C
  - UMN: depositing ultrathin Si_3N_4 on CIGS
  - Phi: sputter profiling with TOF-SIMS

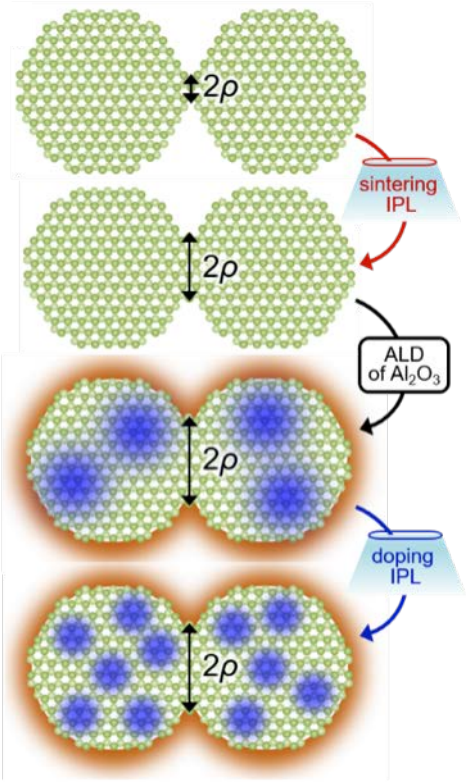


Campbell

Insulator-Metal Transition in ZnO Nanocrystal Networks via Intense Pulsed Light Annealing

- The insulator-metal transition (IMT) in semiconductor nanocrystal networks (NCs) is predicted to occur at $n\rho^3 \approx 0.3$ (where n is the carrier density and ρ is the interparticle contact radius:





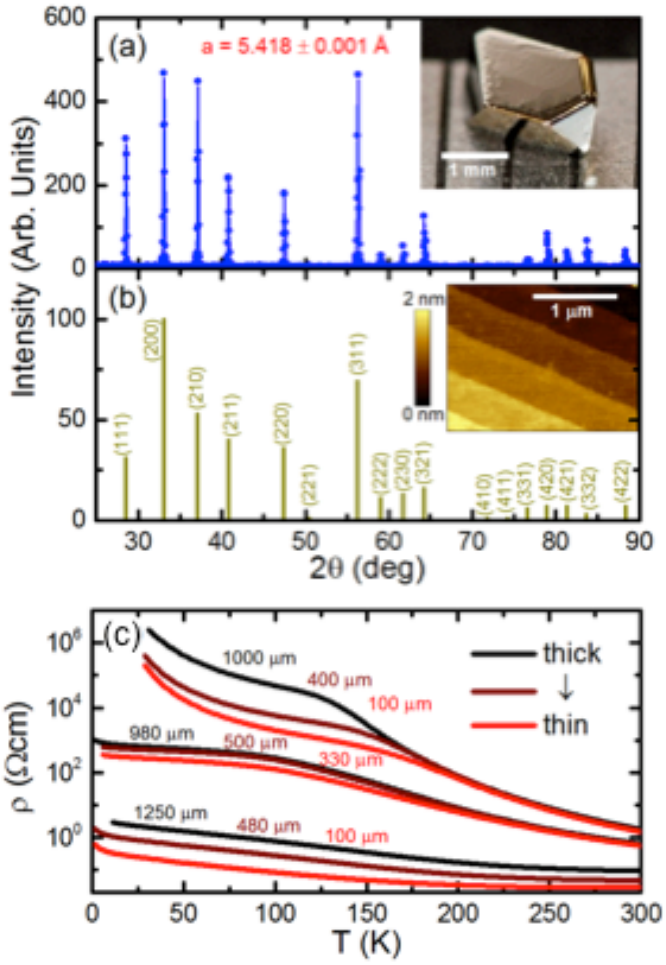
- Used intense pulsed light (IPL) annealing to tune n and ρ independently in networks of plasma-synthesized ZnO NCs. Increased $n\rho^3$ to at least 3x the predicted critical value → conductivity scaling consistent with arrival of IMT region.

Kortshagen / Aydil

Pyrite FeS_2: A Potential Low-Cost Earth-Abundant Photovoltaic Material

- Studying doping and electronic transport in single crystals of FeS_2 grown in our lab: Zhang et al., submitted, Phys. Rev. Mater. (2017), Walter et al., Voigt, et al., in preparation (2017)

- Inability to control doping in FeS_2, and low open circuit voltages, have limited its potential as a potentially low-cost light absorber in solar cells → surface conduction a possible contributing factor.
- Characterized structure and composition using techniques such as TOF-SIMS in collaboration with IPRIME partner Physical Electronics.
- Found strong evidence for surface conduction in these crystals, with surprisingly diverse surface behavior. Also acquired critical evidence for S vacancies as the dominant source of bulk n-type doping, a significant advance.



Leighton / Aydil