Welcome to NU-MSE!

and

the VPD Group!!

We are looking for –

A Few

Proud

Wo/men

Shape, form, pattern, architecture..

Transcend disciplines, phenomena, length-scales..

The “inner space”:

Plenty of room for manipulation..

The “outer space”:

No room for manipulation!

Carbon Supported Pt Catalyst

M20 Nebula (galaxies) !!
**Atomic & Nanoscale Phenomena in Materials:**  
*Electronics, Energy, Health and Advanced Tools/Techniques*

**Vinayak P. Dravid**  
Abraham Harris Chaired Professor, Materials Science & Engineering - McCormick  
Professor of Entrepreneurship (Courtesy), Kellogg School of Management  
Founding Director, NUANCE Center  
Founding Director, SHyNE Resource  
(Foundry Director: Q-FAB: TBA)  
Co-founder International Institute for Nanotechnology (IIN)  
Founding Director, Global McCormick

Active Member: CCNE, NSEC/IIN, MRSEC, PS-OC, CLP, CAMI, RHLCCC, EFRC..

E-mail: v-dravid@northwestern.edu  
Ph.: (847) 467-1363, Office: 1133 Cook Hall

**Program Assistant:** Ms. Amy Morgan, Ph.: (847) 491-7795  
amy.morgan@northwestern.edu

**Student Labs:**  
1141-1149 and 1163 Cook Hall (Hard)  
B0060 Silverman Hall (Soft)  
http://www.northwestern.edu/vpdgroup  
http://www.nuance.northwestern.edu

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**Dravid Group**  
Seeing & Sensing the Invisible

- **Elected Fellowships:**  
  - AAAS, APS, ACerS, MSA, MRS, RMS
  - Recent/Major Awards:
    - MSA Burton, MAS Heinrich Medals  
    - US-Japan Fulrath Award  
    - Chinese Academy Lee Huen Award  
    - Indian Academy – MRS-I & ASM-IIM  
    - UK – Royal Microscopy Soc. Fellow

- **Global Leadership in EM**  
- **Regional and National Center of Excellence**  
- **Integrated Research, Education & Outreach**

- ✔️ 480+ publications  
- ✔️ 24+ patents & IDs  
- ✔️ Hirsch H-Index >99+  
  - One of the highest at NU
Dravid Group: Research Pyramid

1985 - Present

Interfacial and Defect Phenomena

2001 - Present

Nanopatterning, Nanostructures & Probe Microscopy

2001 - Present

Devices & Systems

Advanced Electron, Ion, Photon Microscopy, Diffraction and Spectroscopy

1985 - Present

VPD Group

Academic Philosophy

• Emphasis on BIG picture
• Interdisciplinary, collaborative and “center” exposure
• Seamless integration of research, teaching and outreach
• Emphasis on global and international engagement
• Encouragement for independent and individual creativity
• Emphasis on communication skills
• Bloom’s taxonomy in 21st century:
  – Knowledge, synthesis, analysis, creativity and dissemination
Facts, Figures and Anecdotes

- Money is not a problem (!?!)  
- Risk taking and out-of-the-box initiatives are a must!  
- Collaboration across disciplines (and overseas) is often the norm!  
- Graduate research and teaching awards/honors  

- ¼ graduates in faculty position (PennState, Florida, France)  
- ½ graduates in core industries (GE, Intel, IBM..)  
- ¼ graduates in national labs/other industries

FAQs..

- **Time for PhD graduation:**  
  - ~ 3.5 – 5 years, typical ~ 4.5 yrs  

- **Historical graduations..**  
  - > ~ 100 "graduates" of VPD group, spanning UGs to Postdocs  
  - 40+ full-time PhD graduates,

- **Representative Graduates:**  
  - V. Ravikumar, 1996 PhD, GE Global R&D, NY  
  - Shelly St. Louis-Weber, 1997 PhD, Head, Intel Phoenix, AZ  
  - Beth Dickey, 1998 PhD, Professor, PennState NC State  
  - Sylvie Mao, 2001 postdoc, Professor CRISMAT/CNRS, France  
  - Kevin Johnson, 2002 PhD, Senior Manager, Intel Corp., Oregon  
  - Lei Fu, 2003 Postdoc, Engineer, AMD, TX  
  - Luke Brewer, 2003 PhD, Associate Professor, Naval PostGrad. School, CA  
  - Ming Su, 2004 PhD, Assoc. Professor, Univ. Central Florida, FL  
  - Suresh D., 2007 PhD, Specialist, Rio Tinto Mining, Singapore  
  - N. Alem, 2008 PhD, Asst. Prof., PennState  
  - Z. Pan, 2008 PhD, Flextronics, CA, S. Tark, 2009 PhD, Intel Corp., OR  
  - Tao Sun, 2010 PhD, Argonne – APS; Bin Liu, 2012 PhD, Intel Corp, CA  
  - Stan Chou, 2014, PhD, Sandia National Labs.; Shanwei Lin, 2015, Intel Corp.; Jeff Cain, 2017; LBNL/Cat., Eve Hanson, 2018 (Citrione Info.).
VPD Group PhD Open Position Themes: Fall 2018

1. Patterning and Architecture in 2-D and 0-D Structures:
   - Radial and vertical heterostructures; 2-D + nano composites/assembly
   - Magneto-Photo-Transport, correlated phenomena and gas-solid interactions
   - Colloidal- and Self-Assembly of 2-D sheets, composites
   - Ex-situ & in-situ microscopy and analysis

   - Hierarchical microstructure tailoring
   - Novel chalcogenides and multicomponent, dual nanostructuring
   - Thermal and charge carrier transport
   - In-situ defect and interfacial phenomena; and “structure-property” correlation

   - Electron microscopy for characterizing protein-based architectures: structure & dynamics
   - Soft matter imaging and analysis through liquid-cell methodologies
   - 3D and 4D characterization of proteins and mega-molecules
   - Sparse imaging, dynamic sampling and pattern recognition in imaging

4. Misc. -- unknown unknowns!

Moving Forward

Intellectual Excitement

Mixed Anions & Atomically-layered structures

Nonlinear Phenomena

Synthetic approach for creating multilayer architecture for charge-spin-lattice coupling

Orbital influence Symmetry/Overlap Correlated System

Magnetism Q = -e 

Electricity

Spin Charge Lattice Photon

Coupled Nonlinear Phenomena
Positioning, patterning & stacking of (Nano)Structures

Multifunctional Nanostructures:
Going Beyond Silicon/Electronic Functionalities

“We have lots of information technology. We just don’t have any information.”
Polylelemental nanoparticle libraries:
Dravid, Mirkin et al., Science 2016

Capabilities

2D Materials
Cain et al. JAP 2018

Synthesis Techniques

Advanced Microscopy
BF HAADF @80kV

Surface Functionalization
Chue et al. JACS 2013
Future Research Directions:

Nanopatterning and Assembly:
Ferroelectric-Ferromagnetics
Atomically-layered Halides, Chalcohalides & mixed Anions
DNA-NP assemblies

In-situ EM and x-ray scattering – nucleation, growth & assembly:
  In-situ TEM, energy filtered e-diffraction, RDF and PDF
  Fluidic-Cell S/TEM

Localized measurements and coupling phenomena:
  In-situ synchrotron GIWAXS/GISAXS, PFM/MFM
  Transistors and sensors

No.. Its wind & geothermal stupid!
Wrong.. Looks like all Bio-Fuels to me..
Renewable/Alternate Energy Strategy
Solar it is!
Hierarchically Structured Thermoelectrics

- Thermoelectric materials create an electric potential when exposed to a heat gradient, and could be used to recover waste heat generated whenever energy is utilized in our society.

\[ ZT = \frac{S^2\sigma}{\kappa T} \]

- The structure of thermoelectric materials across all length scales has profound effects on thermal conductivity, charge carrier mobility, and thermoelectric performance.

Nanostructured PbTe-4% SrTe \( ZT=2.2 \)

Single Crystal SnSe \( ZT=2.6 \)


Equine Paintings: *Galloping Horses Before 1878 AD*

*A picture is worth a thousand words*
The Horse in Motion: Muybridge 1878

A video is worth a thousand pictures!

In-situ/operando TEM

- Probing direct material response to multiple stimuli applied to the nanoscale system.
- Enabling real-time and spatially-resolved observation at all relevant length scales and dimensions.
- A Nano Lab inside Microscope!
Lithiation/delithiation process of Graphene-Si spheres


Electron Probe Instrumentation Center
EPIC – TEM Facility
NUANCE
Northwestern University
www.nuance.northwestern.edu

JEOL JEM-ARM200CF S/TEM

www.nuance.northwestern.edu
Non-Invasive Theranostics: “Integrated Diagnostic Therapy”

**Magnetic Core**
- High Magnetism

**Surface Coating**
- Colloidal Stability
- Biocompatibility

**Targeting Multimodality**
- Functionality

**Design, optimize and implement:**
- **MNS based**
- **Cellular and Molecular**
- **“Diagnostic Therapy”**

**Translate**
- Theranostic Agents:
  - from bench to bedside

**Theranostic Prescription**

Magnetic Nanostructures (MNS)

**Synthesis and Characterization**

- **Thermal Decomposition**
- **MRI Contrast Enhancement**
- **Thermal Activation**

Inv. Disclosure # NU29172 (2009), NU29169 (2009), NU27101 (2007)
ACS Nano, NanoLett, 2017-18

**Therapy and Diagnostics (Theranostics)**

- **Cardiovascular Disease**

- **Cancer**
  - Nature Nanotech. (Under Prep)

- **Alzheimer’s Disease**
  - Nat. Nanotech 2015-17,

**Biosensing**

- **MNS/2D Nanocomposite**
- **Non-Invasive Glucose Detection**

Adv. Mater. (Under Prep)
Inv. Disclosure #: NU2017-094 (2017)
ACS Appl Mater/Inter; Sensors & Actuators, 2016-18

**Tissue Engineering**

- **Hydrogel-MNS Nanocomposite**

Invention Disclosure: 2018
ACS Appl Mater/Inter: 2017-8

Theranostic Magnetic Nanostructures (MNS) in Dravid Group

**Cardiovascular Disease Diagnostics and Therapy**

HDL-MNS (Non-invasive Imaging + Therapy)

**Lipid Nanoparticle Nanoconstruct**

Inv. Disclosure #: NU29172 (2009), NU29169 (2009), NU27101 (2007)

Lipid-MNS Construct: Imaging + Drug Delivery
Nature Nanotech. (Under Prep)

**Alzheimer’s Disease: Diagnostics**

MNS-Ab (Non Invasive Imaging)

**Tissue Engineering: Diagnostics and Therapy**

Hydrogel-MNS: Imaging + Regeneration
Invention Disclosure: Under Prep.
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   - Magneto-Photo-Transport, correlated phenomena and gas-solid interactions
   - Colloidal- and Self-Assembly of 2-D sheets
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2. **Microscopy of Energy Materials: Thermoelectrics**
   - Hierarchical microstructure tailoring
   - Novel chalcogenides and multicomponent, dual nanostructuring
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### Q & A