

Mechanics, Materials and Computing

Vision The design and functionality of existing materials used in structural, energy, and sensing applications, the design of new materials providing targeted structural and electrical functionality, the design of earthquake-resilient structures and materials, and the prediction of natural disasters like earthquakes and landslides all require a fundamental understanding of the mechanics of crystalline, granular and amorphous materials under normal and extreme conditions. The MMC group will carry out world-class research and education focused on the scientific understanding and practical application of the emergent complex behavior of materials through computer simulation techniques for the analysis of deformation, flow and failure of natural and engineered materials.

The MMC Group Faculty in CEE



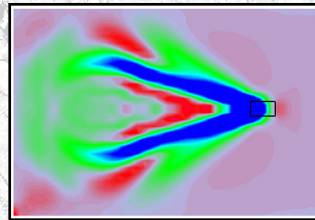
Pictured (l to r): Craig Maloney, Jacobo Bielak, Amit Acharya and Kaushik Dayal

Example Research Projects:

Crystal Plasticity

The study of the solid mechanics of crystalline bodies of structural dimensions in the 1m-10nm range requires the consideration of crystal lattice defects, the most common of which is the crystal

dislocation. Some technologically interesting examples of such structures are semiconductor thin films used in electronic devices (LEDs, transistors),

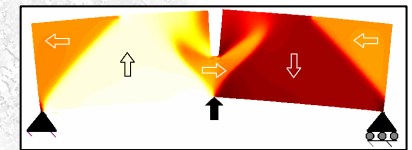


metallic interconnects in integrated circuitry and actuators in MEMS devices. It is well known that deformation microstructures in macroscopic structural metals critically affect their response to loads – such microstructures are also the result of plasticity in the length-scale range mentioned above. The goal of Professor Acharya's research in field dislocation mechanics and plasticity is the understanding of crystalline plasticity from the nano to macro scales, with a view towards developing predictive theory and computational tools for deformation-induced microstructure evolution.

Defects in non-crystalline systems. Many non-crystalline materials exhibit a macroscopic mechanical response quite similar to the plasticity observed in crystals. Prime examples are soils and clays, glassy polymers such as Plexiglass, and metallic glasses; all of which are tremendously important engineering materials. In crystals, the microstructural objects that govern the mechanical response are a class of defects known as dislocations. In the case of non-crystalline systems, despite decades of work, the situation is not so clear. Professor Maloney is currently performing atomistic computer simulations of model non-crystalline materials to identify and understand the nature of the defects, and how they might play an analogous to role to dislocations in crystals.

Active materials and devices at the nanometer scale. Active materials display unusual couplings between deformation, temperature, optics, and electromagnetism. Current research and

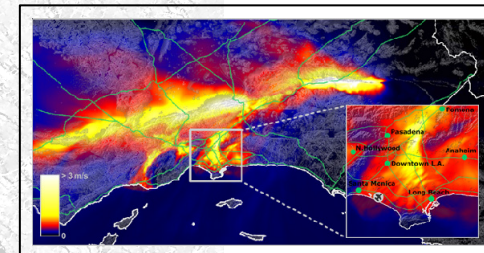
development of micro-nano electromechanical systems (MEMS/NEMS) provides new



opportunities for exploiting active materials. Professor Dayal's research aims at formulating models and developing numerical techniques to aid design and fabrication of future devices. Currently, he focuses on using ferroelectrics to design new optical switching devices. He also works on questions related to device reliability.

End-to-end earthquake modeling and infrastructure response.

To prevent earthquakes from becoming disasters, it is essential to gain a better understanding of how earthquakes originate, how the seismic waves propagate from the source, how they amplify as they enter alluvial basins, and how the built environment



responds to such excitation. Professor Bielak is working on different aspects of this problem, including the forward and inverse-based simulation of the earthquake ground motion in large basins using high performance computing, and on the effect of this ground motion on portions of an entire city, including buildings, bridges, and underground structures. In addition, he and Professor Acharya use concepts of dislocation mechanics to study the dynamic rupture process on faults. The objective is to be able to generate realistic scenario earthquakes that can be used as input in end-to-end, or rupture to rivets, simulations.

M.S. and Ph.D. degree programs in this area are available to qualified students. Financial aid is possible.

MMC Graduates will:

1. Gain fundamental understanding and mastery of technical skills in mathematics, mechanics and numerical computation
2. Apply their knowledge and skills to provide solutions to applied and theoretical questions in the setting of cutting-edge research in structures and materials
3. Exit the program well-equipped for successful careers in industry, government and academia

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www.ce.cmu.edu/admissions

MMC MS and PhD-core Program

Fall Semester:

- Elasticity Theory
- Finite Elements in Mechanics I
- Mathematical methods for engineers
- Numerical methods in mechanical engineering

Spring Semester:

- Special Topics course
- Special Topics course
- Extra-departmental elective
- Extra-departmental elective

MMC Special Topics Courses:

- Finite Elements in Mechanics II
- Inelasticity: Theory and Computation
- Dislocation Mechanics: Theory and Computation
- Particle-Based Modeling in Mechanics
- Nano-mechanics

Extra-departmental electives:

- Fundamental Data: Structures and Algorithms
- Principles of Programming
- Special Topic: Parallel Algorithms
- Algorithms in the Real World
- Models and Methods for Optimization
- Partial Differential Equations
- Introduction to Continuum Mechanics
- Geometric Modeling
- Mechanics of Fracture and Fatigue
- Foundations of Material Science

Enabling Material Systems of the Future



Mechanics, Materials and Computing Research and Education Opportunities

Civil and Environmental Engineering
Carnegie Mellon University