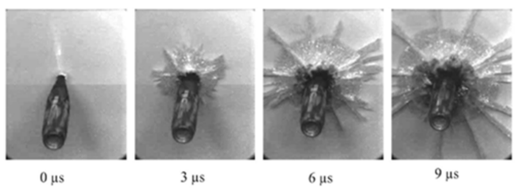
Modeling of Liquids and Solids with Electromagnetic Influence

S&T Campaign: Sciences for Lethality and Protection
Kinetic Protection
Vehicle Protection

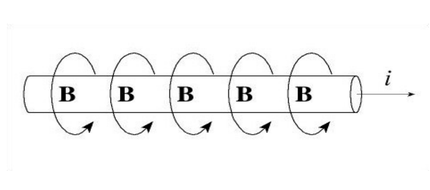
Michael Greenfield
(410) 278-7030
michael.greenfield4.civ@mail.mil

Research Objective

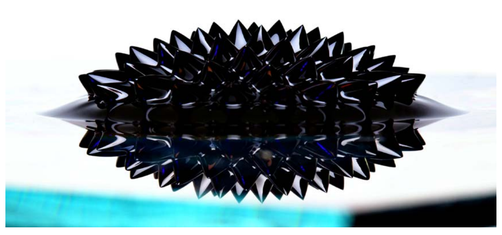
- **Development of mathematically, thermodynamically, and electrodynamically consistent theory of damage of solids in electromagnetic fields**
- **Implementation of the analytical model into government computer code, including verification and validation procedures**



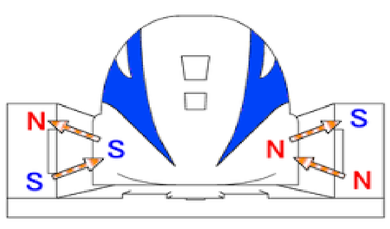
Radial cracking in terminal ballistics



Electric current-induced instabilities



Morphological instabilities in ferrofluids



Magnetic levitation

Challenges

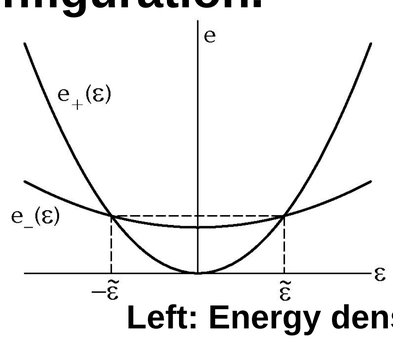
- **Development of thermodynamically consistent theory of**
  - **ponderomotive forces**
  - **levitation in magnetic fields**
- **Development of stable numerical codes, exact analytical solutions, and experimental setup**
- **Computer modeling of morphological instabilities in magnetohydrodynamics**
- **Computer modeling of the surface patterns in ferrofluids caused by static magnetic field**
- **Computer modeling of fracture in electromagnetic field**

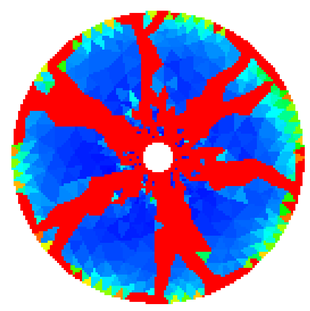
ARL Facilities and Capabilities Available to Support Collaborative Research

- **Laboratory for high-rate experiments in solids**
- **Laboratory for electromagnetic experimentation**
- **DoD high performance computing center with 100,000 compute cores and access to state of the art software**

Phenomenological Mechanochemistry of Damage with Electromagnetic Forces

The asymmetric radial crack patterns that occur in brittle targets when impacted by high-velocity projectiles are explained using a phenomenological mechanochemistry of damage (PMD) engineering model. The developed model, reveals an energy instability during failure of brittle materials configured in a purely symmetric geometry and impact configuration.





Left: Energy density for two different values of damage.
Right: Damage morphology of a brittle plate (Bjerke et al, Procedia Engng, 2015, 103, 35-42)

Conceptually new features in the suggested theory:

- **Based on consistent usage of the Gibbs variational paradigm**
- **Rejects the concept of a scalar chemical potential, using, instead, various tensorial chemical potentials**
- **Rejects various ad hoc conjectures regarding the generalized Maxwell stress tensors and uses, instead, novel formulations derived in a thermodynamically consistent way**
- **Based on the novel mechanisms of the bulk and interface instabilities, both mechanical and electrodynamical**

Complementary Expertise / Facilities / Capabilities Sought in Collaboration

Experimenters and theorists equally experienced in fracture of solids, electromagnetism, and applied mathematics