Compatibility, hysteresis and the direct conversion of heat to electricity

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Abstract

Big first order phase transformations in solids can be highly reversible, if the lattice parameters are “tuned” to satisfy certain relations that promote the compatibility between phases. We outline the basic theory behind this tuning and give examples of recently discovered alloys. One of these alloys has thermal hysteresis as low as 0.2°C despite having a 6% transformation strain. Another very recent example exhibits exact reproducibility of full stress-induced hysteresis loops even after 10 million cycles of stress-induced transformation, at a peak tensile stress (each cycle) of 400 MPa. We use this kind of tuning to find some interesting new reversible multiferroic Heusler alloys: briefly, ferromagnetism is sensitive to lattice parameters, and so, at a martensitic transformation, ferromagnetism can be switched on or off, and ferroelasticity comes for free. These alloys can be used in several ways for the direct conversion of heat to electricity, and provide interesting possible ways to recover the vast amounts of energy stored on earth at small temperature difference.

About the Speaker

Richard James is Distinguished McKnight University Professor in the Department of Aerospace Engineering and Mechanics at the University of Minnesota. He has a Sc.B. in Biomedical Engineering from Brown University and a Ph.D. in Mechanical Engineering from the Johns Hopkins University. He has authored or co-authored some 140 articles, has given 40 plenary and named lectures, and was awarded the Humboldt Senior Research Award (2006/7), the Warner T. Koiter Medal from ASME (2008), the William Prager Medal from the Society of Engineering Science (2008), the Brown Engineering Alumni Medal (2009), and the Theodore von Karman Prize from SIAM (2014, joint with Weinan E). Prof. James' research is at the center of mass of mathematics, materials science and mechanics. His current research concerns (i) the study of “Objective Structures”, a mathematical way of looking at the structure of matter, (ii) the study of the origins of the reversibility of solid-solid phase transformations, and (iii) the direct conversion of heat to electricity using phase transformations in multiferroic materials.