Contents

Conference Program

Keynote Address – 8:00 am to 8:50 am

Mechanics of Gecko Adhesion-Modeling and Issues, *Prof. Chung-Yuen Hui*

Session I – Post Comprehensive, 9:10 am to 10:40 am

1. Thermoelastic Waves in an Anisotropic Infinite Plate - *Hussain Al-Qahtani*
2. Thermomechanical Behavior of Shape Memory Polymers - *Yiping Liu*
3. Atomistic simulatoin of the yielding of gold nanowires - *Jiankuai Diao*
4. Theoretical and Experimental Investigations of Stability for Rotating Viscous Liquid Columns - *Joseph P. Kubitschek*
5. Critical Value of Spanwise Vorticity in the Formation of Side Jets and Split Flames - *John D. Carlton*
6. Design and Package 2-D MEMS Variable Capacitor for RF-MEMS Applications - *Faheem F. Faheem*

Session II – Master's Students, 10:50 am to 12:21 pm

1. Thermomechanics of Shape-Memory Polymers for Biomedical Applications - *Chris Yakacki*
2. Cast Nickel-Titanium Shape Memory Alloys - *Alicia M. Ortega*
3. Liquid Oxygen Droplet Evaporation in Cryogenic Gaseous Hydrogen with Application to Charging a Pulse Detonation Engine - *Seth Friedly*
4. Electrostatically Activated Resonant Fan Micromixer - *Chia-Wen Tsao*
5. Simulation Of An Electrostatically Driven Microinjector Pump - *Gopi C Krishnan*
6. A Stereoscopic Micro-PIV System for Gaseous Flows - *John P Giardino*
7. Velocities of Aerosols Generated by Coughing - *Meg VanSciver*
8. Study of Structural and Mechanical Properties of Si Nanowires using Atomistic Simulations (MEAM Approach) - Gurpreet Singh

Session III – PhD candidates, 1:10 pm to 3:10 pm

1. Micro-Mechanical Characterization of Thin Film Materials - *David Miller*
2. Multi-Scale Structure and Properties of Deformation Processed Polycrystalline NiTi Bars - *Carl P. Frick*
3. Ultrahigh Temperature Semiconducting Polymer Derived Ceramics - *Hee-Yeon Ryu*
4. Photolithography of Polymer Precursors En Route to Ceramic MEMS - *Tsali Cross*
5. The Structure of Highly Impinging Flames on a Rotating Cylinder - *Colleen Stroud*
6. Moffatt Vortices Between Concentric Cones - *Chetan P. Malhotra*
7. Numerical Simulation of High Pressure Supersonic Multi-phase Jet Flow through a Gaseous Media - *Randy S. Lagumbay*
8. Advantages in Using Multi-frequency Driving Ultrasound for Optimizing Echo Particle Image Velocimetry Techniques - *Hairong Zheng*
9. Design of Laminar Entrained Flow Reactor for Pyrolytic Study of Pulverized Biomass - *Myongjai Lee*

Session IV – PhD candidates, 3:30 pm to 5:40 pm

1. Atomic Layer Deposition of Al_2O_3/ZnO Nano-scale Films for Gold RF MEMS - *Frank DelRio*
2. Tether System Designed for flip-chip bonded MEMS - *Alexander Laws*
3. Optical Assembly for Chip Scale Frequency Reference - *Yuan-Jen Chang*
4. Thermal Management and Packaging for Chip-Scale Atomic Clock - *Simone Lee*
5. Thermal Characterization of Carbon Nanotube - Epoxy Composite - *Vivek Sundaram*
6. Packaging of Mems Actuators and Sensors for Use in Aquaeus Media for Biomems and Microfluidics Applications - *Hrishikesh V Panchawagh*
7. Numerical Simulation and RF Applicator Design for Clinical Hyperthermia Treatment - *Ming Yi*
8. A Model to Study Capacitive Micromachined Ultrasonic Transducers Fabricated Using Atomic Layer Deposition Process - *Lingli Liu*
9. Evaluation of ISCST3 and AERMOD for Modeling Benzene Dispersion in Commerce City - *Tanarit Sakulyanontvittaya*
10. The effect of Multi-branching in the dynamics of the blood flow in pulmonary arteries - *Behzad Elizeh*

Keynote Address

Mechanics of Gecko Adhesion-Modeling and Issues

Prof. Chung-Yuen Hui
Theoretical and Applied Mechanics
Cornell University

Abstract
Many organisms employed a highly fibrillated microstructure for adhesion. Two examples are the Gecko and the beetle (Hemisphaerota cyanea). Adhesion in the beetle is achieved by capillary interaction (wet adhesion) [1]. In the Gecko, the adhesive interaction is provided by a high localized field of attractive forces commonly known as van der Waal force [2]. Despite the low intrinsic energy of the van der Waals forces ($\approx$ 50 mJ/m^2), the Gecko can achieve remarkable adhesion. This motivates us to study the mechanics of contact and adhesion of highly fibrillated microstructure. Specifically, we study how contact and adhesion is controlled by the fibril geometry and material behavior (e.g. elastic modulus, interaction energy, and cohesive strength). We proposed a mechanism of energy dissipation in a purely elastic structure. We demonstrated that in order for good adhesion to occur, the geometry of the fibril structures has to satisfy certain requirements. These are:

1. The fibrils should establish good contact with the substrate.
2. The fibril diameter should not exceed a certain critical size.
3. The neighboring fibril should not stick to each other
4. Buckling of fibrils should be avoided.

Our ideas have been tested on a model experimental system made by molding PDMS stamps into lithographically defined and etched molds.

References

[1] T.Eismer and D.J. Aneshansly, PNAS, (2000), v97, 12, 6568-6573.
[2] K. Autumn, M. Sitti, Y. A. Liang, A. M. Peattie, W. R. Hanen, S. Sponberg, T. W, Kenny, R. Fearing, J. N. Israelachvili, and R. J. Full, (2002), v99, 19, 12252-12256.

Background of Prof Chung-Yuen Hui

Prof. Hui majored in physics and mathematics as an undergraduate and did his doctoral work in applied mechanics. After receiving his Ph.D. at Harvard University, he joined the Cornell faculty in 1981. His current interest is in areas connecting mechanics and materials. In the past years, he has published in the area of adhesion science, fracture mechanics of aging aircraft, fracture mechanisms of polymer/polymer interfaces, fracture mechanics and statistical theory of failure of composite materials, high temperature creep crack growth in metals, swelling kinetics and diffusion of organic molecules in polymer glasses, hypersingular integrals and boundary element method, sintering of ceramics, fluid mechanics of aircraft, electronic-packaging and micro-electromechanical systems.

ABSTRACTS

Session I – Post Comprehensive
9:10 am to 10:40 am

Chair – Seth Friedly
(6 x (12+2+1) minutes)

Thermoelastic Waves in an Anisotropic Infinite Plate

Hussain Al-Qahtani
Advisor: S. K. Datta
Contact – alqahtah@Colorado.Edu

Abstract: Analysis for the propagation of thermoelastic waves in a homogenous, transversely isotropic, thermally conducting plate is investigated in the context of the generalized (L-S) theory of thermoelasticity. Three different methods are used in this analysis: two of them are exact and the third is a semi-analytic finite element method (SAFE). In our exact analysis, two different approaches are used. The first one, which is applicable to transversely isotropic plate, is based on introducing displacement potential functions, whereas in the second approach, which is applicable to any triclinic material, we rewrite the governing equations and boundary conditions in a matrix form. Finally, In SAFE method, the plate is discretized along its thickness using N parallel, homogeneous layers, which are perfectly bonded together. Frequency spectrum and dispersion curves are obtained using the three methods and are shown to agree well with each other. The effects of relaxation time and coupling term are also investigated. Numerical calculations have been presented for a silicon nitride plate.

Thermomechanical Behavior of Shape Memory Polymers

Yiping Liu
Advisor: Ken Gall and Martin L Dunn
Contact – Yiping.Liu@Colorado.Edu

Abstract: Shape memory polymers (SMPs) have the capacity to recover large strains when pre-deformed at an elevated temperature, cooled to a lower temperature, and reheated. The thermomechanical recovery behavior of a SMP is examined in three-point flexure for various pre-deformation and recovery conditions. Results indicate that when pre-deformed well above the glass transition temperature, T_g, the stress-strain response at the pre-deformation temperature governs the relationship between the recovery stress/strain and the corresponding pre-deformation strain/stress. When pre-deformed at a temperature below T_g, the relationship between recoverable stress and strain level in the SMP is not governed by the stress-strain response of the material at the pre-deformation temperature. Rather, a peak recovery stress, which is less than the applied pre-deformation stress, appears near T_g. In this study, we investigate the dependence of SMP recovery behavior on the pre-deformation temperature/stress and the cooling/heating rate. Particular emphasis is placed on understanding the coupling between the pre-deformation and the evolution of the recovery behavior with and without constraint. Based on the pure SMP, we also study the thermomechanics of a SMP nanocomposites made by using the polymers as matrices and adding nano-scale SiC reinforcements. The results show that the SMP nanocomposites have higher modulus and are capable of generating higher recovery force compared to the SMP resin. Ramifications of the results on medical application are discussed.

Atomistic simulatoin of the yielding of gold nanowires

Jiankuai Diao
Advisors: Ken Gall and Martin L. Dunn
Contact - diao@Colorado.Edu

Abstract: We performed atomistic simulations to study the effect of free surfaces on the yielding of gold nanowires aligned in the <100> crystallographic directions. We formed a nanowire by assembling gold atoms into a long wire with free sides by putting them in their bulk fcc lattice positions. We then relaxed the assemblage to equilibrium. The tensile surface stresses on the sides of the wire cause the wire to contract along the length with respect to the original fcc lattice, and we characterize this deformation in terms of an equilibrium strain versus the cross-sectional area. While the surface stresses cause wires of all sizes to increasingly contract with decreasing cross-sectional area, when the cross-sectional area of a <100> nanowire is less than 2.45 nm x 2.45 nm, the wire yields under its surface stresses, via <112> partial dislocation. When nanowire size is less than 1.63 nm x 1.63 nm, reorientation from fcc <100> to fcc <110> occurs, via the progressive <112> partial dislocation. Starting from the equilibrium configuration of the nanowires that do not yield upon rexation, we next performed uniaxial tension and compression loading on the relaxed nanowires until they yield. Nanowires yield via <112> partial dislocation. The magnitude of the compressive yield strain decreases with a decrease of the wire cross-sectional area. The compressive yield strain calculated with respect to unrelaxed nanowire configurations does not change much with a decrease of the wire cross-sectional area. The magnitude of the tensile yield strain increases with a decrease of the wire cross-sectional area. The magnitude of the yield strain calculated with respect to unrelaxed nanowire configurations slightly decreases with a decrease of the wire cross-sectional area. The magnitude of the tensile yield stress increases slightly with a decrease of the wire cross-sectional area. The magnitude of compressive yield stress decreases slightly with a decrease of the wire cross-sectional area. As a nanowire cross-sectional area is equal or less than 2.244nm x 2.244nm, the nanowire yields under its own surface stress and no external force is needed.

Theoretical and Experimental Investigations of Stability for Rotating Viscous Liquid Columns

Joseph P. Kubitschek
Advisor: Patrick Weidman
Contact – jkubitschek@do.usbr.gov

Abstract: Linear stability analysis is applied to investigate stability for rigidly rotating viscous liquid columns in the absence of gravity. The critical physical parameters for this problem include column radius a, uniform rotation rate Ω, density ρ, kinematic viscosity ν, and surface tension γ. The crux of the problem is highlighted by past work of Hocking and Michael (1959), Gillis (1960), Hocking (1960), and Gillis and Kaufman (1961). The results of those theoretical investigations indicate that stability is independent of viscosity. Yet, Hocking clearly shows that although the axisymmetric disturbance case remains unchanged when viscosity is included, the viscous planar disturbance problem is less stable than the inviscid problem. However, the full range of parameter space has yet to be investigated. This research intends to fill the knowledge gap by computing instability growth rates σ as a function of axial wave number k and azimuthal mode number n for given values of the dimensionless parameters $Re = a^2\Omega/\nu$ and $L = \gamma/\rho a^3\Omega^2$ to determine maximum growth rates and therefore conditions of instability. Progress to date includes the problem formulation and preliminary theoretical results. Finally, a series of experiments is proposed to measure disturbance wave numbers, amplitudes, and growth rates for comparison with theoretical results.

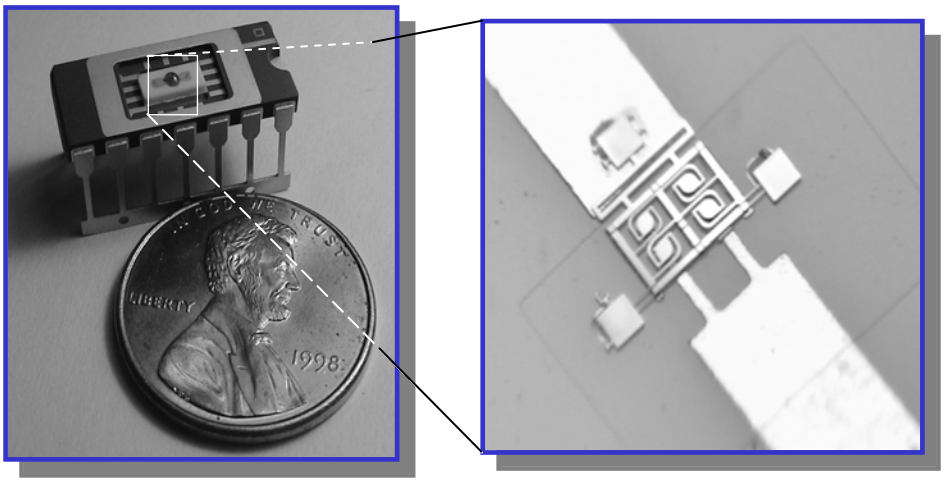
Critical Value of Spanwise Vorticity in the Formation of Side Jets and Split Flames

John D. Carlton
Advisor: Jean Hertzberg
Contact – John.Carlton@Colorado.Edu

Abstract: Experimental studies of the stabilization process of transitional and turbulent lifted jet flames have illustrated the importance of large-scale shear layer structures and their three-dimensional evolution in time. These results have important consequences for the control of efficiency and pollutant formation in laminar and turbulent jet flames via shear layer control techniques. However, while entrainment and mixing in isothermal jets are easily controlled by such techniques, jet diffusion flames are more difficult to control. Nevertheless, we have found that high amplitude forcing has a profound effect on a jet diffusion flame. The flame can be driven to split into a central jet and one or two side jets. The split is accompanied by a partial detachment of the flame from the nozzle exit, a shortening of the flame by a factor of two, and a change from the common yellow color of soot radiation to a predominantly blue flame. Our results show that the flame splits in response to side jet formation in the fuel jet. Explanations for the formation of side jets in non-reacting flow focus on an interaction between rollers and streamwise braid filaments, which causes jet fluid to be ejected from between braid pairs. We propose that side jets are the result of a reconnection event involving pairs of streamwise braid filaments. The resulting loops then propagate perpendicular to the jet due to self-induction. The evidence of streamwise vortex structures in the side jets and the position of braid filaments relative to the rollers support this hypothesis.

Design and Package 2-D MEMS Variable Capacitor for RF-MEMS Applications

Faheem F. Faheem
Advisor: Y. C. Lee
Contact – Faheem@Colorado.Edu



Abstract: Packaging is a well-known barrier to the advancement of microelectromechanical systems (MEMS) for RF applications. To pave the way for the removal of this barrier, we have developed a flip-chip assembly technology to transfer foundry- fabricated MEMS devices from the host silicon substrate to a ceramic substrate. Specifically, posts have been designed and fabricated to assure excellent RF performance by achieving a precise gap between the device and ceramic substrate. In addition, a novel liquid crystal polymer (LCP) encapsulation technology has been developed to protect the RF MEMS device. LCP is a good encapsulation material for non-hermetic packaging because it significantly reduces the packaging cost. We have demonstrated excellent RF performance of variable MEMS capacitors that have been flip-chip assembled and LCP encapsulated. The quality (Q) factors of such capacitors were measured to be higher than 300 at 1.0 GHz.

ABSTRACTS

Session II – Master's Candidates
1:10 pm to 3:10 pm

Chair – Anant Gunari
(8 x (8+2+1) minutes)

Liquid Oxygen Droplet Evaporation in Cryogenic Gaseous Hydrogen with Application to Charging a Pulse Detonation Engine

Seth Friedly
Advisor: David R. Kassoy
Contact – seth.friedly@colorado.edu

Abstract: Air Force Research Laboratory personnel have begun experimental operation of a detonation tube fueled by a mixture of liquid oxygen (LOX), gaseous oxygen, and cryogenic gaseous hydrogen. A mathematical model is being developed to describe the physical processes that take place in the operation of this detonation tube. The model development begins by studying evaporation of LOX droplets just after injection into cold gaseous hydrogen. This analysis will result in information about the mixture composition prior to ignition. The evaporation process is limited by the relatively small amount of internal energy in the volume of cold hydrogen gas available to each droplet. A quasi-steady spherically symmetric analysis is used to describe evaporation of a liquid oxygen droplet in a finite volume of cold gaseous hydrogen. The results for a single droplet are applied to a cloud of droplets flowing down the detonation tube to determine the amount of gaseous oxygen at a specified distance from the LOX injector. Comparison with data taken from experimental operation of the detonation tube is reasonably good even though the analysis presented is based on several simplifying assumptions. An improved model is based on a spatially resolved transient description of cryogenic evaporation. This model provides a more accurate description of the time-history of droplet evaporation and will be used to determine the accuracy of the quasi-steady model applied to cryogenic evaporation dynamics. This work has applications in the study of advanced propulsion technologies such as pulse detonation engines (PDE). A PDE for use in space propulsion applications would likely be fueled by oxygen and hydrogen stored at cryogenic temperatures.

Thermomechanics of Shape-Memory Polymers for Biomedical Applications

Chris Yakacki
Advisor: Ken Gall
Contact – chris.yakacki@Colorado.Edu

Abstract: Shape-Memory Polymers (SMP) have a great potential in biomedical applications due to their ability to regain large amounts of strains through thermal activation. Demonstrative prototypes have shown strain recovery and biocompatibility, however a robust understanding of the thermomechanical behavior of SMPs does not exist. Successful future applications require knowledge of optimized recovery properties achieved through a fundamental understanding of the relationship between polymer structure and ensuing shape-memory characteristics. Photo-initiated SMPs made with di-ethylene-glycol-di-meth-acrylate (DEGDMA) and poly-ethylene-glycol-di-acrylate (PEGDA) cross-linking on tert-butyl acrylate monomer chains show significant changes in stiffness and glass transition temperatures with the variation of percent cross-linking. Storage and recovery parameters such as deformation temperature, reformation temperature, and percent strain will also affect the thermomechanics of the SMP. Strain was set at 30% while the deformation and reformation temperatures were varied to show that both parameters are proportional to each other. Results can then be used to tailor SMPs to a specific application.

Cast Nickel-Titanium Shape Memory Alloys

Alicia M. Ortega
Advisor: Ken Gall
Contact – Alicia.Ortega@Colorado.Edu

Abstract: Nickel-Titanium's unique shape memory behavior has made it an ideal candidate for many applications ranging from use in biomedical devices to large restrainer bars in civil infrastructure. Almost all of these applications make use of Nickel-Titanium (NiTi) that has been formed through a deformation process (like cold-drawing). However these deformation processes are often times a costly additional processing step. Thus it would be desirable to find a way to process the material for its various applications with minimal or no deformation processing while still having the material maintain its shape memory behavior. Although direct casting could circumvent these processing steps, the thermo-mechanical properties of NiTi in the cast state are not well known. The purpose of this study is to characterize NiTi in its cast state linking such things as nominal composition, structure, and resulting behavior. Techniques used in this investigation include optical microscopy, x-ray diffraction, transmission electron microscopy, differential scanning calorimitry, and tension/compression testing. Parameters to be varied are radial location within the cast ingot, orientation of uniaxial loading, tensile or compressive loading, and heat-treatment of the material. Minimal differences in the thermo-mechanical behavior of the cast material as a function of radial position or orientation of loading were observed. Additionally, the cast material showed recoverable strains on the order of 5% under both tensile and compressive loading. This observed lack of tension/compression asymmetry is due to the random texture found in the cast material.

Electrostatically Activated Resonant Fan Micromixer

Chia-Wen Tsao
Advisors: Kamran Mohseni
Contact – Tsao@colorado.edu

Abstract: The performance of microfluidic diagnostic systems capable of handling difficult real-world biological and clinical samples strongly depends on an efficient mixing of the involved agents. At small length scales, mixing is mainly relied on molecular diffusion which is a slow process. A key concept to increase microscale mixing is to increase the interface area between the two fluids. An electrostatically activated resonant microfan micromixer is designed, fabricated, and tested for efficient mixing. The microfan is placed at the interface between the two incoming streams at the junction of a Y-shaped microchannel. An electrode lies on each side of the channel in the vicinity of the junction to actuate the microfan at its first resonant mode. Vortices are formed and shedded at the tip of the microfan during its operation. In the present design, mixing is enhanced by increased interface area between the two fluids during the vortex formation. Vortex formation involves significant entrainment and results in efficient mixing. Fabrication of the micromixer is achieved in two steps: First, commercial MetalMUMPs process is used to fabricate the microfan and electrodes. Then SU-8 is coated over the chip to pattern the Y-shaped microchannel. The performance of the micromixer is characterized by a Laser Induced Fluorescence (LIF) technique for flow visualization. A scaled micromixer is also designed and built in order to investigate vortex formation at the tip of the flap and to characterize mixing properties.

Simulation Of An Electrostatically Driven Microinjector Pump

Gopi C Krishnan
Advisor: Prof. John Daily
Contact – Gopi.Krishnan@Colorado.Edu

This paper presents results of numerical simulations of an electrostatically actuated fuel microinjector with passive valves. An accurate simulation of the device must take into account inertia, damping and elastic restoration effects coupled with viscous forces. The ANSYS finite element analysis code is used to capture the dynamic and unsteady flow effects. Optimizing the design parameters in order to maximize the mass flow rate and droplet formation rate provides the motivation for the current study.

A Stereoscopic Micro-PIV System for Gaseous Flows

John P Giardino
Advisor: Jean Hertzberg
Contact: giardino@colorado.edu

Abstract: Recent progress in the application of micron-resolution Particle Image Velocimetry (micro-PIV) has been limited to two-dimensional liquid flows. Many micro-scale flows of interest are both gaseous and highly three-dimensional, but currently no technique exists to measure them. Substantial challenges are associated with both the stereoscopic PIV technique and the seeding requirements of micro-scale gaseous flows. A stereoscopic micro-PIV system is presented that overcomes these challenges and can measure all three velocity components of gaseous flows with micron resolution. A stereomicroscope provides the two perspectives required by stereoscopic PIV, and a calibration of the imaging system is presented in order to transform the 2-D image space of the cameras to the 3-D fluid space of the experiment. Multiple flow seeding techniques are discussed, as well as a processing technique that allows some flexibility in the density requirements of the seeding particles. Future applications of the system are also discussed.

Velocities of Aerosols Generated by Coughing

Meg VanSciver
Advisor: Jean Hertzberg
Contact – vanscive@Colorado.Edu

Abstract: Saliva and nose secretions contain viruses and bacteria when an individual has an infection. These fluids can be spread into the air via aerosols to become contagious to others when a person coughs or sneezes. The object of this study is to improve our understanding of how infectious diseases spread in indoor environments and to determine the area infected by an airborne disease. We evaluated the velocities of the aerosols that were produced by several coughs by using a Particle Imaging Velocimetry (PIV) system to illuminate the particles with an ND:YAG laser as they are released from the subject. The cough flow was seeded with water for clearer representation of the aerosols. A cross-correlation algorithm was used on the images to determine the particle displacement, and the time difference between laser pulses was used to determine the particle velocity. The velocities of the particles released during these trials had velocities ranging from 2m/s to 28m/s.

Study of Structural and Mechanical Properties of Si Nanowires using Atomistic Simulations (MEAM Approach)

Gurpreet Singh
Advisors: Prof. Ken Gall & Martin.L.Dunn
Contact – Gurpreet.Singh@Colorado.Edu

The study of mechanical and structural properties of nanowires has been an area of interest for the past few years. This advancement in nanostructure studies can be attributed to the advancement in the preparation methodology of the materials. Si nanowires, in-particular have generated interest because of its numerous applications in the field of various nano-scale devices such as nanoprobes, etc. The objective will be obtained using the MEAM (Modified Embedded Atom Method) based atomistic simulations with Semi-empirical modified embedded-atom potentials already developed for Si. Using this technique an atomic model of the nanowire is created and static and dynamic simulations are then run by varying the different boundary conditions. The study would specifically examine the effect of variation in temperature, cross section area, length; orientation on the atomic arrangement of the nanowires.The research work is in-line with various other researches providing a basis for foreseeing how the quantum mechanical effects that dominate behavior of materials at this size scale will alter the operation of future generations of electronic devices.

ABSTRACTS

Session III – PhD Candidates
1:10 pm to 3:10 pm

Chair – Hrishikesh Panchawagh
(9 x (10+2+1) minutes)

Micro-Mechanical Characterization of Thin Film Materials

David Miller
Advisor: Ken Gall
Contact - dcm@Colorado.Edu

Abstract: We utilize micro-scale mechanical devices to study the mechanical properties of thin film materials. Specifically, we study the gold and polysilicon laminated composite structures to gain insight into time dependent mechanical response for these structures, when subjected to thermomechanical loading. Nanometer thick coatings are also investigated to improve the stability of the material. If sufficiently thick, the ALD deposited nano-coatings can prevent damage to the microstructure. We found that at least 50 – 250 "monolayer" cycles of alumina are required to prevent a certain device "failure" mechanism, that occurs above 200 deg C. Thermomechanical response has been characterized. The behavior of the microcantilever devices studied is unique from other previous wafer-based studies. Specifically the change in device shape occurs more readily and may serve to terminate microstructural evolution. Some investigation of the material structure before and after exposure to thermal conditions has also been performed.

Multi-Scale Structure and Properties of Deformation Processed Polycrystalline NiTi Bars

Carl P. Frick
Advisor: Ken Gall
Contact - Carl.Frick@Colorado.edu

Abstract: The objective of this study is to examine fundamental processing-structure-property relationships in polycrystalline NiTi bars. Two different polycrystalline Ti-50.9 at.%Ni (Ti-55.7 wt.%Ni) materials were examined: (1) cast then hot rolled, and (2) cast, hot rolled, then cold drawn. The structure of the materials was investigated at various scales ranging from nanometers to micrometers. The hot rolled and cold drawn materials contained a strong <111> texture parallel to the deformation processing direction. The high temperature hot rolling process facilitated recrystallization, recovery, and suppressed precipitate formation, leaving the hot rolled material in near solutionized states. The cold drawn material contained a high density of dislocations and martensite. After a mild aging treatment, both materials contained distributed coherent Ti_3Ni_4 precipitates on the order of 10 nm in size. The hot rolled and cold drawn materials demonstrated significant tension-compression stress-strain asymmetry owing to their strong crystallographic texture. Under compression, the deformation-processed materials were only capable of 3% strain recovery while under tension they were capable of nearly 7% strain recovery. Based on the present results, the presence of small coherent Ti_3Ni_4 precipitates is determined to be the driving force for the favorable strain recovery properties, despite drastically different grain sizes and crystallographic textures. The unique dependence of elastic modulus on stress-state, temperature, and structure is also shown for the deformation-processed materials. In addition, we demonstrate that the appearance of a Lüders band transformation under tensile loading can be controlled by materials structure. Specifically, the presence of significant martensite and dislocations in the cold drawn material was shown to mitigate the Lüders band propagation and result in a more gradual transformation.

Ultrahigh Temperature Semiconducting Polymer Derived Ceramics

Hee-Yeon Ryu
Advisors: Rishi Raj
Contact – Hee.Ryu@colorado.edu

Abstract: In this research, photolithographic MEMS fabrication technology and titanium nitride (TiN) interconnects were employed to measure and the electrical behavior of the polymer derived Silicon Cabonitride (SiCN) and Boron doped Silicon Cabonitride (SiBCN) ceramics at temperature up to 1300°C. These results are the first known measurements for these ceramics at this very high temperature range. These materials are of interest for fabricating electronic devices, e.g. diodes and sensors, which can operate at high temperatures and harsh environments, since SiBCN exhibits "p" type and SiCN shows "n" type semiconductivity. Both materials remain semiconductive at all temperatures, and follow Mott's VRH (variable rate hopping) mechanism for amorphous semiconductors. Possible structural origins for the nanostructural stability and the electronic properties of these polymer derived ceramics will be discussed.

Photolithography of Polymer Precursors En Route to Ceramic MEMS

Tsali Cross, Neil Cramer, Christopher Bowman, Sirish Reddy, and Rishi Raj
Advisor: Rishi Raj
Contact -Crosst@Colorado.Edu

Abstract: We present a new process based on contact-photolithographic techniques for fabricating polysilazane-derived MEMS components with ultra high aspect ratios. The fabrication process is based on contact lithography of a liquid photopolymer precursor, poly urea methyl vinyl silazane, PUMVS (CerasetTM Kion, Corp.), with photoinitiator 2,2 dimethoxy, 2-acetophenone, DMPA (Irgacure 651, Aldrich) for polysilazane. The cure times and cure depths are dramatically improved by adding thiols to the PUMVS photopolymer solution is reported. Thiol addition accelerated the cure from 20 minutes to 5 seconds, while the cure depths increase from 700 microns to 1.5mm. This fabrication technique may be extended to a wide variety of photopolymerizable sol-gels, preceramics, and photopolymers.

The Structure of Highly Impinging Flames on a Rotating Cylinder

Colleen Stroud
Advisor: Melvin Branch
Contact - Colleen.Stroud@Colorado.Edu

Abstract: Interest in the study of flame treatment processes has increased over the years due to improvements in their safety, control, efficiency, ease of operation, and the increased awareness of implementation opportunities. Studies are being done to understand better what happens during the flame treatment process, including efforts to define more clearly the chemical kinetics and heat transfer involved. The process can become quite involved when the affects of such things as entrainment, turbulence, interference, and varying transport properties have to be taken into account and the processing anomalies that can occur have yet to be fully explained. In this study, we are investigating the affects of highly impinging flames on the roller surface where high fuel and oxidizer flow rates, or flame powers, are involved. These are common treatment conditions used in the polymer processing industry to provide improved polymer surface energy and other desirable physical surface alterations. Under these manufacturing conditions, unexplained anomalies do occur which result in the uneven treatment of the material. This study includes schlieren imaging, temperature and species concentration measurements, and flame modeling as part of the detailed process analysis. Results to date have shown that highly impinging flames produce more uniform treatment, which in turn, should reduce the processing anomalies encountered.

[+]Research sponsored by 3M Corporate Research

Moffatt Vortices Between Concentric Cones

Chetan P. Malhotra[1], Patrick D. Weidman[1] & Anthony M.J. Davis[2]

[1]University of Colorado, [2]University of Alabama

Contact - malhotra@colorado.edu

Abstract: The eigenvalue equation describing Moffatt vortices in a cone reported by Liu & Joseph (1978) is extended to Moffatt vortices formed between concentric cones of semivertex angles $\theta_2 > \theta_1$. Eigenvalue diagrams are numerically computed for all θ_2 at fixed values $\theta_1 = 1^o$, 10^o, 30^o, 45^o, 60^o, 90^o. These are used to determine the critical angles $(\theta_2)_c$ as a function of θ_1 for the existence of Moffat vortices for modes n = 1, 2, 3, 4. Features of vortices that appear when the cone boundaries are symmetrically disposed about the equator are very similar to Moffatt vortices in a wedge, and indeed one can prove that the asymptotic distribution of eigenvalues are the same in both cases. In particular, both the symmetric cones and the wedge exhibit a free vortex along the bisecting angle for n = 3. As the cone angles are opened symmetrically or anti-symmetrically, the free vortex disappears, leaving behind a single free stagnation point located at the bisector or on one side of the angle bisecting the cavity respectively. Some errors in the computations of Liu & Joseph (1978) for a cone are found and corrected.

Numerical Simulation of High Pressure Supersonic Multi-phase Jet Flow through a Gaseous Media

Randy S. Lagumbay
Advisor: Oleg V. Vasilyev
Contact – lagumbay@Colorado.Edu

Abstract: A Computational Fluid Dynamics (CFD) analysis is used to numerically study the structure and dynamics of a high-pressure, high-speed jet of a gas/liquid mixture through a gaseous media close to the nozzle region. The complex structure of the jet near the nozzle region is captured before it breaks-up downstream. A new multi-phase model based on a mixture formulation of the conservation laws for a multi-phase flow is used in the simulation. The model does not require ad-hoc closure for the variation of mixture density with pressure and yields thermodynamically accurate acoustic propagation for multi-phase mixtures. The numerical formulation has been implemented to a multi-physics unstructured code "RocfluMP" that solves the modified three-dimensional time-dependent Euler equations for a multi-phase framework. The Roe's approximate Riemann Solver for the Euler equations is used to allow capturing of shock waves and contact discontinuities. Preliminary results are presented for a shock tube analysis and a gas/liquid free surface jet flow through a gaseous media.

Advantages in Using Multi-frequency Driving Ultrasound for Optimizing Echo Particle Image Velocimetry Techniques

Hairong Zheng
Advisor - Robin Shandas
Contact - Hairong.Zheng@Colorado.Edu

Abstract - We have recently developed an ultrasound based velocimetry technique, termed echo particle image velocimetry (echo PIV). This method takes advantage of the non-linear backscatter characteristics of ultrasound contrast microbubbles when exposed to certain ultrasonic field. Preliminary *in vitro*, animal and clinical studies have shown significant promise of this method for measuring multiple velocity components with good temporal and spatial resolution. However, there is still difficulty in maximizing the non-linearity of bubble backscatter using conventional Gaussian-pulse excitation techniques because significant harmonic components may not be produced at modest pressure amplitudes and the higher incident pressure amplitudes required to induce non-linear behavior may cause bubble destruction. We present here a potential solution to this problem through the use of multi-frequency excitation. A rectangular pulse with multiple harmonics is used to drive the bubble. The backscatter process is studied through a modified Rayleigh-Plesset equation. Results show that the rectangular wave is effective in improving the visibility of microbubbles with ultrasound backscattered efficiency significantly higher than the widely used Gaussian waveform. Use of rectangular pulses with 4 and 2 harmonics showed no significant difference in bubble backscatter behavior, indicating that a two-frequency excitation may be sufficient to induce non-linear behavior of the microbubbles practically at modest incident pressures.

Design of Laminar Entrained Flow Reactor for Pyrolytic Study of Pulverized Biomass

Myongjai Lee
Advisors: John W Daily and David C Dayton
Contact – Myongjai.Lee@Colorado.Edu

Abstract: Biomass is a potential renewable energy source in the United States. In this study, a couple of continously fed, laminar entrained flow reactors were designed for pyrolytic analysis of pulverized biomass in the temperature range from room temperature to 800^{o}C. A laminar entrained flow reactor should provide a fast pyrolysis regime, with peak heating rates on the order of 10^4 [K/s] and deliver the pyrolyzed intermediates and products to the mass spectrometers interfaced with the reactor. Computational fluid dynamic (CFD) software was used for the preliminary simulation of the flow and temperature field inside the flow reactor. Two types of flow reactors slightly different each other in their design were compared through the simulation. One is a simplified, circular pipe type reactor for easy fabrication, and the other one is more complicated in shape but easier for the temperature measurement, modified from the original reactor with longitudinal holes for the thermocouple installation inside the pipe. The velocity vectors and temperature distribution of flow inside the reactor, trajectory of biomass particles carried by Helium gas were simulated. For the accuracy analysis of the simulation, the simulated temperature profiles were compared with the measured ones.

ABSTRACTS

Session IV – PhD Candidates
3:30 pm to 5:40 pm

Chair – Hairong Zheng
(10x(10+2+1) minutes)

Atomic Layer Deposition of Al_2O_3/ZnO Nano-scale Films for Gold RF MEMS

Frank DelRio
Advisor: V.M. Bright and M.L. Dunn
Contact – Frank.DelRio@colorado.edu

Abstract: Atomic layer deposition (ALD) was used to create an Al_2O_3/ZnO thin film for gold capacitive RF MEMS switches. These films exhibited a widely tunable range of physical properties, allowing the creation of a material capable of dissipating trapped charges and maximizing the on-capacitance of the switch. Predicted pull-down voltages of the ALD-coated switches underestimated the experimental findings due to residual stresses in the ALD film and annealing of the gold during ALD deposition. Switch cycles to failure were measured using a 10 dBm, 10 GHz, CW signal with a bipolar actuation voltage of 25-55 V. Preliminary testing showed lifetimes of 400 million cycles using 50/50 ALD Al_2O_3/ZnO films, with ultimate failure due to moisture-induced stiction and particulate contamination, not dielectric charging. The insertion loss and isolation for the switches was typically < 0.35 dB and > 25 dB, respectively, over a 10-25 GHz frequency range.

Tether System Designed for flip-chip bonded MEMS

Alexander Laws, Faheem Faheem
Advisor: Y.C. Lee
Contact: Alexander.Laws@Colorado.edu

Abstract: Flip-chip bonding is important to integrate MEMS devices with other components or to make novel devices. The use of tethers when flip-chip bonding is valuable because it enables the release of the MEMS based device prior to bonding. Releasing the device prior to bonding allows the possibility to bond to a substrate that includes materials that are incompatible with the release process, increase yield since any devices lost during release are not bonded, and avoid damage to the bond. This paper presents a set of design rules for devices created with the MUMPs process that can be implemented to allow the device to be tether flip-chip bonded. The rules outline the design of tethers, mechanical stops, and locking bumps, which work as a system to keep the device from slipping or twisting during bonding, but break free from the donor substrate after bonding. Examples of success, reasons for past failures and the solutions are presented.

Optical Assembly for Chip Scale Frequency Reference

Yuan-Jen Chang
Advisors: Victor M. Bright and Y. C. Lee
Contact - changy@Colorado.Edu

Abstract: The technology of coherent population trapping shows the capability of a more compact, low cost frequency reference which is desirable in global positioning system receivers and wireless communication systems. Four main optical components were included in the optical assembly. They were a vertical cavity surface emitting laser (VCSEL), a collimating lens, a mirror, and a quarter waveplate. The VCSEL was glued conductively onto a dielectric substrate, alumina, and wire bonded to a coplanar waveguide transmittance line for applying the radio frequency signal. A ball lens was placed on top to collimate the laser beam, the position of which was manually adjusted with two thin alumina blocks. After being positioned, the ball lens was affixed by UV-cured optical epoxy. A wet etched silicon substrate provides precise alignment of optical components. A 2 mm x 2 mm right angle mirror and a 1mm x 1 mm x 0.07mm quarter waveplate were placed in an etched area on a silicon substrate. The silicon substrate was flipped over and aligned manually to the VCSEL with two additional alumina blocks. Two important optical characteristics were determined, divergent angle and degree of circular polarization. After the collimation, the divergent angle of the beam was improved from 25 degree to 8 degree. The degree of circular polarization was 0.06 after passing through the quarter waveplate. The optical assembly for a frequency reference has been demonstrated. The frequency stability, $2 \times 10^{-11} / \sqrt{\tau}$ over one hour, of a specific frequency reference with the optical assembly has been obtained.

Thermal Management and Packaging for Chip-Scale Atomic Clock

Simone Lee
Advisor: Y.C. Lee
Contact - Simone.Lee@colorado.edu

Abstract: The goal of this project is to develop a chip-scale atomic clock with a size of 10mm x 10mm x 2mm (0.2 cm^3) and a power dissipation level less than 30 mWatt while providing frequency accuracy on the order of +/- 1 x 10^{-11} (Allen deviation at one-hour integration time). In addition, the clock will experience an ambient temperature change from 0°C to 50°C. Three important parts of the project includes: RF components, optical components, and thermal management. Since different components used in the clock require different temperature specifications and power, a well-designed package is needed to achieve the tight power specification. This paper discusses the thermal management issues and packaging considerations for chip-scale atomic clock. Different approaches had been considered where the design of the heating elements in the package have to be within the power specification from an ambient temperature of 0°C to 50°C. Phase change material has been identified to be the key solution to this thermal management problem. The design of the thermal modeling has been carried out in FEA software, Coventorware. Different heater configurations have been considered and will be discussed. The detail design and modeling of the package will be discussed at the conference.

Thermal Characterization of Carbon Nanotube - Epoxy Composite

Vivek Sundaram
Advisor: Roop L Mahajan
Contact – vivek.sundaram@Colorado.Edu

Abstract: Future requirement of dissipating about 200 watts per chip for high performance applications poses a challenge for the thermal management of electronic packages. To meet this challenge, it is imperative that the thermal interfaces such as those between the chip, the heat spreader and the heat sink introduce minimum thermal resistance. To this end, we propose in this paper, novel carbon nanotube-epoxy composites. Both single and multi-walled carbon nanotubes are considered and the matrix selected is Hysol 4511 epoxy. The latter is one of the commonly used underfill materials in flip-chip on board applications. Two techniques: Mechanical dispersion and Ultrasonic dispersion to embed the carbon nanotubes in the epoxy matrix are described. Both these techniques are compared through examination of microstructure of the composite using scanning electron microscopy (FE-SEM) and transmission electron microscopy (TEM). The specimens for TEM were prepared using Cryo Ultramicrotomy technique. It is noted that curing plays an important part in determining the structure as well as the properties of the composite. To fully understand this, Differential Scanning Calorimetry (DSC) results are presented. The thermal, mechanical and electrical properties were measured as a function of the SWNTs content in the matrix. A standard sandwich experiment was used to study the interface resistance of the epoxy composite as a function of temperature and the concentration of nanotubes (0 to 5 wt. %) used in the epoxy. Finally, a thermal model relating the nanotube concentration to the interface resistance is presented.

Packaging of Mems Actuators and Sensors for Use in Aquaeus Media for Biomems and Microfluidics Applications

Hrishikesh V Panchawagh
Advisors: Dudley S Finch and Roop L Mahajan
Contact - Hrishikesh.Panchawagh@Colorado.Edu

Abstract: MicroElectroMechanical Systems (MEMS) based sensors and actuators have great potential in biomedical applications both *in vitro* and *in vivo*. The major obstacle in integrating MEMS actuators or sensors such as comb drive or thermal actuator for biological or microfluidics applications is the presence of aqueous media, which causes problems like electrolysis and heating of media. We propose a solution to this problem, specifically for *in vitro* devices by encapsulating actuators/sensors in such a way that there will be no aqueous media in contact with the charged electrodes of comb-drive or thermal actuators. However, motion can be transferred from actuator to outside using a piston which can move through a small clearance. A conformal hydrophobic coating on the device prevents the liquid from flowing into the actuator encapsulation due to surface tension. MEMS actuators are fabricated using commercially available multi-user MEMS process (mumps, ® MEMSCAP) are encapsulated using polysilicon caps using flip-chip bonding technique. The device then is conformally coated with alumina terminated with hydrophobic monolayer through atomic layer deposition (ALD). Un-packaged and packaged devices are be submerged in water and tested. It is expected that the un-packaged devices fail to work properly while packaged actuator device works successfully due to sealing from the liquid. Numerical modeling is used to predict pressure head to which the actuator can be sealed under static conditions as a function of clearance. The dynamics of the movement of the liquid-gas interface due to piston motion is under investigation. This packaging concept can be extended to *in-vivo* actuators with further development.

Numerical Simulation and RF Applicator Design for Clinical Hyperthermia Treatment

Ming Yi
Advisors: Roop L Mahajan
Contact – Ming.Yi@Colorado.Edu

Abstract: It has been found out for a long time that the elevation of temperature from 41-49 can kill the tumor cells without harming the normal tissues, which is called hyperthermia treatment of cancer. It is a promising technique for cancer treatment and has been used for a practical treatment for cancer for a long time. But, the accurate temperature control is still a problem. The hyperthermia treatment has been practiced in CSU for a long time. But numerical and analytical evaluation has not been tried to improve the clinical treatment. We developed a numerical method to evaluate the temperature distribution of the treatment. The parametric study has been performed in this paper. The results showed close temperature distribution by numerical method with experimental results in some conditions. Also, it shows that the temperature profile is determined largely by the SAR pattern produced by applicator and scale of temperature is determined by Q/k (the ration of input power and thermal conductivity) if it is under the same boundary condition. But, the perfusion rate will affect both of them if it changes a lot. An improved RF applicator is also developed to heat different size of the tumor just by changing the frequency. The numerical simulation validated the feasibility of this applicator and showed the capability of this applicator.

A Model to Study Capacitive Micromachined Ultrasonic Transducers Fabricated Using Atomic Layer Deposition Process

Lingli Liu
Advisor - Robin Shandas
Contact - Lingli.Liug@Colorado.Edu

Abstract: In this paper, we present the model study of capacitive micromachined ultrasonic transducers (CMUTs) fabricated by atomic layer deposition (ALD) technology, which uses a self-limiting binary reaction process to produce ultra-thin membranes. Advantages of ALD include precise control of membrane thickness, lower cost due to a reduction in the number of fabrication steps, the potential to use a large variety of materials, and increased reliability due to the enhanced surface quality of the membranes. These capabilities promise fabrication of transducers with superior operating characteristics. However, no study has yet documented sensitivity and power requirements for CMUTs created using ALD. We present here a first-order mechanical and equivalent circuit analysis along with a fabrication process to create and characterize CMUTs using ALD. Simulation results show that these systems have the potential for excellent sensitivity and decreased power requirements. Work to test the fabricated elements is currently underway.

Evaluation of ISCST3 and AERMOD for Modeling Benzene Dispersion in Commerce City

Tanarit Sakulyanontvittaya
Advisor: Jana B. Milford
Contact - Tanarit.Sakulyanontvittaya@Colorado.Edu

Abstract: This study evaluates two dispersion models, ISCST3 and AERMOD, as applied to multiple emission sources for benzene in Commerce City, CO. The study also adapts AERMOD for use in a real time modeling and web dissemination project. AERMOD was developed from ISCST3, but incorporates recent understanding of dispersion in the planetary boundary layer (PBL) and more advanced features. The first part of the study covers the evaluation of ISCST3 and AERMOD with two sets of surface characteristic parameters. Archived meteorological data for 1990 and most recent emission data from the Colorado Department of Public Health and Environment are used in this evaluation. Ratios of concentrations predicted with AERMOD to those from ISCST3 range from 0.5 to 2 for 1-hr and 24-hr average concentrations. The concentration ratios are higher for monthly-average concentrations with a range of 1.5 to 2.5. The spatial distribution patterns of concentrations are similar between the two models. The difference in magnitudes of the concentrations is believed to be the result of differences in dispersion algorithms between the two models. The concentrations from both models are strongly sensitive to wind speed and meteorological conditions, but only AERMOD is sensitive to surface roughness length. With the same input meteorological data, AERMOD processes the data differently and uses different meteorological parameters between convective and stable conditions, and correspondingly causes greater variations in concentration, which can be seen from 1-hr average concentration data. A comparison between 24-hr average concentrations computed with AERMOD and measurements from 10 monitoring sites during the years 2000, 2001, and 2002 shows good agreement in average concentrations by season. The average concentration ratios of measurements to computational results are in the range of 1.0 – 2.1. The computational standard deviations are lower than those of the measured concentrations.

The effect of Multi-branching in the dynamics of the blood flow in pulmonary arteries

Behzad Elizeh
Advisor: Robin Shandas
Contact: ghorbani@colorado.edu

Abstract: Advances in the treatment of pulmonary hypertension during the past decade have significantly improved patient survival. The focus of this study is to study, develop, and validate numerical models of Primary Pulmonary Hypertension especially concentrate on the Pediatric PPH. In this preliminary study, the focus is on the effect of multi-branching of the pulmonary arteries to the fluid dynamics of the blood flow. Then compare the numerical model with the in-vitro experimental analysis.

Notes

Feedback

Your feedback is valuable for us. Please email us at megsrc@colorado.edu with your suggestions and comments about this GEARS 2004.

Thank you for attending GEARS 2004