Introducing Jie Huang

Presentation to the Academy of Electrical and Computer Engineering, April 21, 2016
Professional Background

- BS, Optical Engineering, Tianjin University, China, 2009
- MS, ECE, Missouri S&T, 2012
- PHD, ECE, Clemson University, 2015
Research Interests

– Fiber optic sensors
– Ultrafast laser machining, processing and characterization of micro/nano structures, materials and devices
– Sensors and Instrumentation for applications in harsh environments
– Optical biomedical imaging and sensing (Photoacoustic tomography/spectroscopy)
**Optical fiber:** A light pipe made of optical materials

- Buffer/jacket (polymer, aluminum, gold)
- Cladding (fused silica, ~125µm dia.)
- Core (Doped Silica, ~9µm dia.)

Total internal reflection when $n_1 > n_2$

**Fiber sensors:** proven advantages for applications in hostile environments

- Small size/lightweight
- Immunity to electromagnetic interference (EMI)
- Resistance to chemical corrosion
- High temperature capability
- High sensitivity
- Remote operation
- Multiplexing and distributed sensing
Objectives

• Main objective: Development and demonstration of sensors that could survive at high-T (up to 1600 °C) and dynamic gas pressure

• **Requirements:** Survive and operate in the high-T, high-P and corrosive/erosive harsh environments for a long period of time

<table>
<thead>
<tr>
<th>Temperature</th>
<th>up to 1600 °C, highly erosive and corrosive Packaging for extreme conditions</th>
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<tr>
<td>Pressure</td>
<td>Up to 10000 psi, high temperature, erosive &amp; corrosive Dynamic pressure for turbine applications</td>
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• Very challenging engineering goals
  – Dependable performance
  – Robustness to survive the harsh environment
  – Long term stability
Fs Laser Micromachining

- Femtosecond (fs) laser micromachining
  - High accuracy (sub-micron)
  - One-step, fast ablation or material modification
  - Works for a diverse variety of materials including metal, silica, polymer, sapphire, etc.
  - 3D capability, inside the material (underneath the surface)
Solution: fs-laser manufacturing

- Assembly-free fiber optic sensors
- Photonic micro/nanostructures
- Microfluidics and optofluidics

J. Huang et al., Optics Express, 2014
J. Huang et al., Optics Express, 2015
L. Yuan, J. Huang et al., Optics Letters, 2013
Y. Zhang, J. Huang et al., PTL, 2012
Early Detection of Skin Cancers Using a Novel Acupuncture MRI Probe

Funded by Innovation@Missouri S&T
Work with Dr. Klaus Woelk
Fiber optic cavity ring-down spectroscopic sensor

(A) Microwave-photonics system
- Tunable diode laser source
- Electro-optical modulator
- Microwave source
- Frequency scanning
- Vector microwave detector
- Control & processing
- Data acquisition

(B) Sectioned methane and T measurement
- Methane detection ring (1m per section) covering an area of 10m × 10m
- Fs laser inscribed reflector inside an optical fiber
- Tap > 99.9%
- Synchronized detection

(C) Fiber optic ring-down spectroscopy
- Ring-down curve of the i-th reflector, based on which the absorption up to the i-th reflector position is calculated
- Number of ring-downs
- Reflection
- Time
- i-th reflector

(D) Molecular sieve zeolite film enhanced evanescent wave attenuation sensor
- Interface film to enhance evanescent wave penetration
- Zeolite coated section for methane detection
- Uncladded optical fiber
- Zeolite adsorbing film

Ch_4 Sensing Area

Funded by UM-Research Board
Understanding Fracture Toughness of Ceramics at High Temperatures via Embedded Sapphire Optical Fiber Strain Sensors

Jie Huang, Assistant Professor of Electrical and Computer Eng.
Charles S. Wojnar, Assistant Professor of Mechanical and Aerospace Eng.

Aerospace structures require high-temperature ceramics:
- leading edges of hypersonic aircraft
- heat shields for atmospheric reentry
- there is a need to understand their mechanical response at high temperatures
- however, existing measurement devices cannot survive

Microwave-photonic based fiber optic sensing technology:
- fully distributed strain/temperature sensing
- real time and remote monitoring
- high spatial resolution (100 microns)
- immune to Electromagnetic Interference (EMI)
- sensors are operational up to 1600 °C

Embed sensors via extrusion additive manufacturing process:
- embed fibers between extruded layers
- distribute sensors for measuring spatially-varying strain
- measure sensor output during mechanical testing (e.g. 3-point bending)

Validate sensor data with full field measurements:
- measure full-field displacements via Digital Image Correlation (DIC)
- compare strains from DIC with sensor data

Variational approach to brittle fracture:
- modeling to determine $E$ and $G_c$ at high-temperatures
- crack set: $\nu \in [0,1]$, fractured: $\nu = 0$ undamaged: $\nu = 0$

\[ U(u,\nu) = \int_{V} \left[ \frac{1}{2} (\nu^2 + \eta)\varepsilon(u) : \varepsilon(u) + \frac{G_c}{C_y} \left( 1 - \nu \right) \epsilon |\nu|^2 \right] dV \]

\[ \sigma = \frac{\partial U}{\partial \varepsilon} \]

\[ u,\nu = \arg\min [U(u,\nu)] \]

Outcome:
- an experimental method and model for understanding the mechanical behavior of ceramics at high temperatures
Concept of Smart City
Pure ceramic coaxial cable (PC³) sensors under ultrahigh temperature (>2000°C)
Smart Parts = Parts + Sensors

• Traditional approach
  – *Install* sensors into the parts after the parts are being made

• Current approach
  – *Embed* sensors into the parts during the parts are being made

• How about?
  – *Make* sensors while the parts are being made

New requirements on sensors, processes, and materials
Instructional Focus

• EE3600: Electromagnetics

• EE3420: Communication Systems