Additive Manufacturing of Smart Parts with Embedded Sensors for In-Situ Monitoring in Advanced Energy Systems

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Objective

Prove and demonstrate the new concept of sensor-integrated “smart part” that can be easily installed in existing and new energy systems for in situ monitoring of the health statuses of critical components and key operational parameters under harsh conditions.

Background

INTRODUCTION

- Demands: Success of clean coal technologies will rely heavily on sensors and instrumentation for advanced process control/optimization, key components protection, system maintenance and lifecycle management
- Requirements: Sensors need to survive and operate in the high-T, high-P and corrosive/hot environments for a long of time.
- Status: Current sensor and monitoring technologies capable of operating in harsh conditions are extremely limited

CURRENT TECHNOLOGIES AND LIMITATIONS

- Traditionally, sensors are attached to or installed onto the component after the structure is fabricated
- Costly and complicated sensor packaging before installation
- Poor survivability and reliability of the sensors
- Discrepancy between the sensor reading and the actual status
- Potential performance compromise of the host materials/structures

OPPORTUNITIES: SENSOR-EMBEDDED “SMART PARTS”

- Smart parts – widely used and proven successful in structural health-monitoring (SHM)
- Provide the real-time information on the component and system
- Reduce the complexity in sensor packaging and installation
- Increase the robustness and reliability of the system

Scope of Work

- Robust, high-temperature tolerated, embeddable optical carrier based microwave interferometry (CCMI) sensors
- Novel signal processing and instrumentation for distributed sensing
- Comprehensive thermal and mechanical models for optimal sensor embedment and rational interpretation of the sensor outputs
- Multifunctional protective layers between the sensor and the host for thermal, mechanical and chemical protection of the sensors
- Additive manufacturing of the “smart parts”
- Feasibility tests and performance evaluation

Summary

- Sensor-integrated smart parts: a new paradigm for sensing in advanced energy systems
- Innovative approaches to tackle challenging problems
  - Robust sensors: The novel concept of OCMI and its laser assembly-free device fabrication
  - Sensor embedment: Additive manufacturing
  - Survivability: Transition layers between the sensor and host
  - Dependable performance: Comprehensive thermal-mechanical modeling/simulations of the “smart parts”
- Distributed sensing: Joint frequency-time domain method uniquely enabled by mixing microwave with optics
- Demonstration: Tests and performance evaluations in simulated laboratory conditions using existing facilities

Summary (cont.)

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Additive Manufacturing of Smart Parts

- Dual-laser additive manufacturing of metal smart parts
- Additive manufacturing (AM) of ceramic smart parts based on freeze-form extrusion process

Assembly-Free Sensor Fabrication

- Femtosecond laser machining
  - Multiple layers of coatings to interface the embedded sensor and the host to provide the chemical, thermal, mechanical, and optical protections of the embedded sensors.