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Ph.D. DISSERTATION DEFENSE

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Degree:	Doctor of Philosophy
School/Department:	Charles V. Schaefer, Jr. School of Engineering & Science / Chemical Engineering and Materials Science
Date:	Tuesday, May 6th, 2025
Time/Location:	12:00 p.m. Babbio 221
Title:	Gold Nanorod Arrays on Single Crystal Sapphire Fiber for Optical Sensing at Elevated Temperatures: A Numerical and Experimental Study
Chairperson:	Dr. Henry Du, Department of Chemical Engineering and Materials Science (CEMS)
Committee Members:	Dr. Matthew Libera, Department of CEMS Dr. Jae Chul Kim, Department of CEMS Dr. Stefan Strauf, Department of Physics Dr. Paul R. Ohodnicki, Jr., Department of Mechanical Engineering & Materials Science, University of Pittsburgh

ABSTRACT

This dissertation presents a comprehensive study on the design, simulation, fabrication, and testing of nanostructured sapphire optical fibers (NSOFs) embedded with gold nanorods (GNRs) for high-temperature optical sensing applications. Leveraging the thermal and chemical resilience of single-crystal sapphire and the plasmonic sensitivity of gold nanostructures, this work aims to overcome the inherent limitations of traditional silica fibers in harsh environments. A systematic finite-difference time-domain (FDTD) simulation framework is developed to explore how the aspect ratio (AR) and tilting angle (TA) of embedded GNRs influence their localized surface plasmon resonance (LSPR) response under temperature variations and hydrogen exposure. Special emphasis is placed on source-free sensing enabled by thermal energy harvesting, where the blackbody radiation from high-temperature environments excites plasmonic oscillations without the need for external illumination.

Experimental validation includes the fabrication of AAO-coated NSOFs with geometrically tuned GNRs, followed by spectroscopic characterization under temperatures up to 900 °C and exposure to hydrogen (H_2) and carbon dioxide (CO_2). Results demonstrate geometry-dependent LSPR behaviors, with higher AR and moderate TA yielding stronger and redshifted longitudinal mode (LM) peaks. Hydrogen exposure leads to a consistent decline in transverse mode (TM) intensity due to increased plasmonic damping, while CO_2 exhibits minimal optical response due to its high bond dissociation energy. Thermal emission tests confirm the viability of self-powered sensing in the visible–NIR range.

This research establishes a robust framework for high-performance, geometry-tailored plasmonic fiber sensors that can function reliably in extreme conditions. It also opens new avenues for advanced thermal-plasmonic integration and real-time sensing across a variety of industrial, aerospace, and energy applications.