

Electrical Asset Temperature Monitoring Using Optical Fiber Based Sensors

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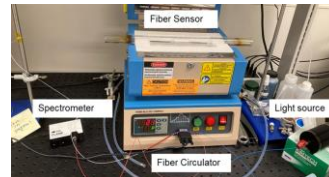
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Motivation and Objectives

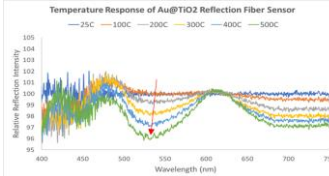
The diagram shows a cross-section of the sensor structure with layers: optical fiber probe, heat-sealing film, separators, Au-metal-oxide nanocomposite-based sensing layer, and electrode active materials. It also shows a Utility Li-Ion Battery Stack with Distributed FBG Fiber Optic Sensors, an Optical Switch, Light Source, and Spectrometer. A detailed view of the End-Coated Fiber shows a Step Index MM Fiber (0.22 NA), Cladding, Core, and Au-Oxide Film.

Sensing Applications in Electrical Equipment

Tests Under Lab Conditions

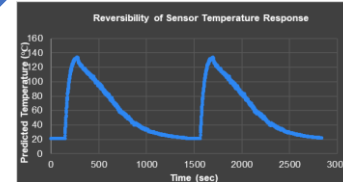
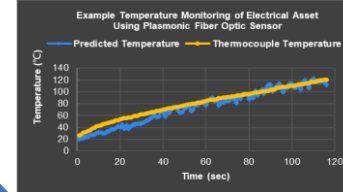


Heat Treatment and Temperature Test Set-up

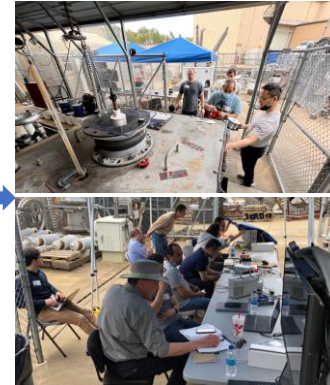


Experimental Results

Lab-Scale Equipment Tests



Field Tests

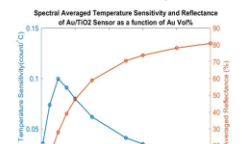


Thin Film Optics-Based Waveguide Modeling

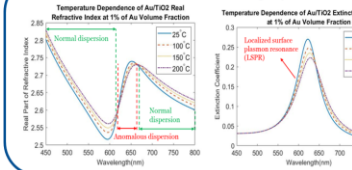
Thin Film Optics-Based Optical-Waveguide Model

Assumptions:
 • Assumes a ball lens free space coupling
 • Assumes $M_{\text{Au}} = M_{\text{TiO}_2}$ range distribution of gives angle θ_0^*
 • Given $n_{\text{Au}} = 1.317$, $D = 8$ nm, and $NA_{\text{fiber}} = 0.22$

Performance Metrics and Optimization



Optical Constant Model of Sensing Layer Material



- Temperature response analyzed at characteristic LSPR band (800-700 nm)
- Temperature sensitivity of Au@TiO₂ reflection fiber sensor peaks when 10 vol% of Au nanoparticles are embedded
- Au@TiO₂ shows higher sensitivity than other oxide matrix due to higher optical constant and smaller bandgap
- Trade-off between reflectance and temperature sensitivity

Acknowledgement

This work is supported by Grid Modernization Laboratory Consortium and Solar Energy Technology Office DOE

Low-Cost Wireless Interrogator

Photograph of the Low-Cost Wireless Interrogator setup, including a Fiber Circulator, LED Connector, and a Microcontroller-Transceiver Integrated Circuit. The circuit diagram shows a PLL-R Power-Supply Circuit and an LED Light Source Drive Circuit.

Sensor Materials Fabrication and Characterization

Layered Thin Film Deposition of Au and Metal-Oxides:
 • DC/RF Magnetron Sputtering
 • Electron-Beam Evaporation

Oxide	20 nm	900 °C Calcine	80-100 nm thick
Au	2 nm		
Oxide	20 nm		
Au	2 nm		

Fiber substrate → Fiber substrate

XRD of Au@TiO₂ Thin Film Post 900°C Annealing
 Peaks: TiO₂ rutile (101), Au (111), TiO₂ rutile (111), Au (200), TiO₂ rutile (211), Au (120)

Spectrophotometry of Au/TiO₂ Film Calcinated at 900 °C
 — Transmittance — Reflectance — Absorbance
 LSPR Absorption Band