Integrated Fiber Optic Sensors for Strain, Temperature and Corrosion-induced Mass Loss Measurement

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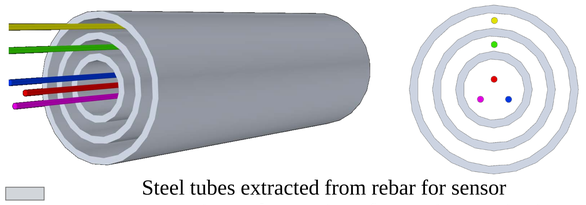
INTRODUCTION

In this study, a fiber optic sensing system based on long period fiber gratings (LPFG) in LP06 and LP07 modes is designed, fabricated and tested for simultaneous measurements of strain, temperature and corrosion-induced mass loss. It consists of three steel tubes and several Fe-C coated LPFG sensors for long- and short-term corrosion monitoring, respectively, when deployed in proximity and parallel to a steel member. Graphene/ silver nanowire (Gr/AgNW) composite was coated on the LPFG surface for efficient Fe-C electroplating due to its high optical transparency and conductivity. The sensor was subjected to both tensile strain and temperature, and submerged in 3.5wt.% NaCl for 72 hours during corrosion tests. The results showed high accuracy and sensitivity of the integrated sensor.



Steel tubes extracted from rebar for sensor protection and extension of corrosion monitoring

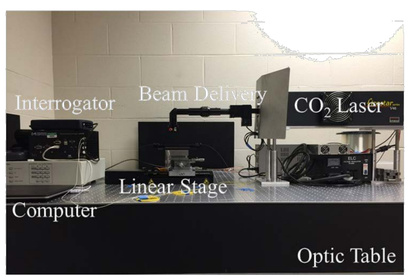
Three Fe-C coated LPFG sensors for various stages of corrosion monitoring

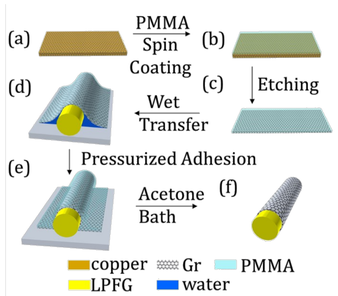
LP06 and LP07 modes used for strain and temperature measurement

Schematic view of an integrated sensor

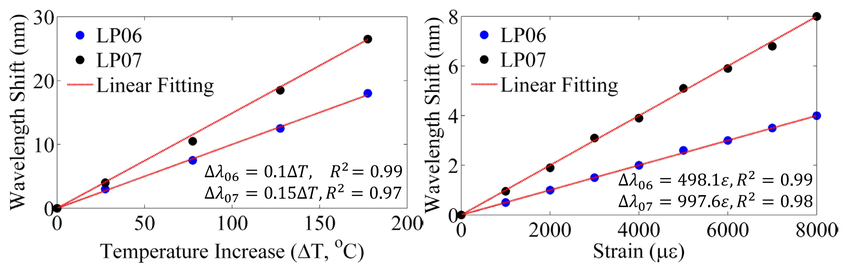
METHODS

A CO_2 laser grating system was used to fabricate LPFG on each single-mode bare fiber. By controlling the grating period, both LP06 and LP07 modes were produced as sensors. Graphene was grown on copper foil through the low pressure chemical vapor deposition method, synthesized and wet-transferred onto the LPFG surface for Fe-C electroplating.

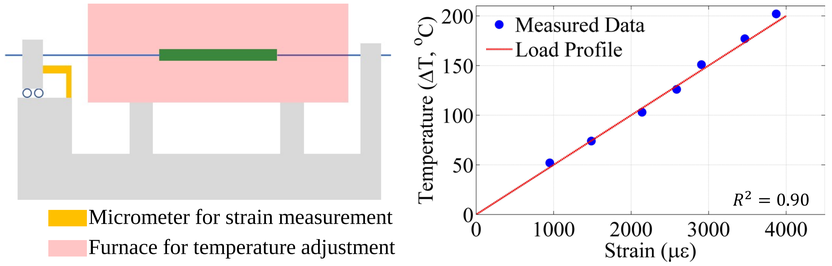




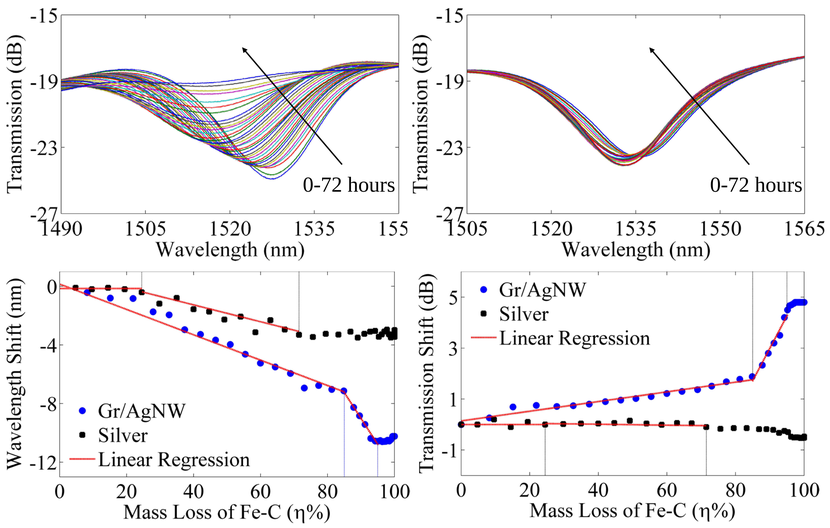
RESULTS



Temperature and strain sensitivity calibration results of LP 06 and LP 07 modes



Test setup and results of simultaneous strain and temperature measurement with LP06 and LP07 modes in two LPFG sensors

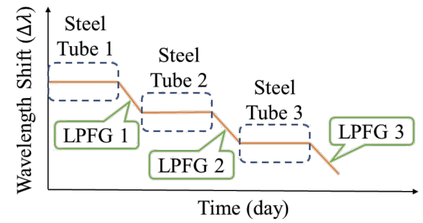


72-hour corrosion tests: transmission spectral evolution (top), and wavelength and transmission shifts (bottom) with mass loss

CONCLUSIONS & FUTURE WORK

The proposed integrated sensor consists of three steel tubes, three Fe-C coated LPFGs, and two bare LPFGs for strain, temperature and corrosion monitoring. The following conclusions can be drawn:

- The use of LP06 and LP07 modes in two LPFG sensors can simultaneously determine strain and temperature with high accuracy and sensitivity.
- Compared with a silver coating as conductive layer for electroplating, Gr/AgNW composite has much higher optical transparency and thus increases the sensor service life and sensitivity for corrosion monitoring.
- Point LPFG sensors will be combined with (Brillouin scattering based) distributed fiber optic sensor to determine multiple parameters at multiple locations.
- Long-term corrosion monitoring will be conducted with steel beams to validate the performance of an integrated sensor of three steel tubes and three LPFG sensors as illustrated below.



REFERENCE

Chuanrui Guo, Liang Fan, Chenglin Wu, Genda Chen, Wei Li. "Ultrasensitive LPFG corrosion sensor with Fe-C coating electroplated on a Gr/AgNW film", *Sensor and Actuator B: Chemical* (Under Review)

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