Sensors for Optics-Based Strain, Temperature and Chemical Sensing

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Abstract

This thesis is a study of optical sensor development with two themes. Firstly, the development of polymer coated glass optical fibre sensors for relative humidity sensing. Secondly, the development and characterisation of novel planar dye-doped polymer waveguide sensors for strain, temperature and chemical sensing. This thesis was motivated by the need to measure strain, temperature and chemicals in harsh conditions with high precision (including compact, high electric field or explosive environments where traditional sensors can not be used). In addition, dye-doped polymer optical chips are being developed for telecommunication applications and their dependence on humidity, temperature and strain will be a key consideration. Sensor applications utilising dye-doping can achieve a greater sensitivity over traditional undoped sensors.

The developed polymer coated glass optical fibre sensors were characterised with humidity calibration experiments. A polyimide based coating was found to have a humidity response of 7.2 pm/%rh corresponding to a coefficient of moisture expansion of 74 ppm/%rh. A series of modified block co-polymer coatings was investigated to identify important chemical structure features. Enhanced performance was achieved by the modification of the chemical structure of an existing commercial polyetherimide. A correlation between coating thickness and optical fibre diameter was observed where the humidity response was enhanced by using thicker coatings or smaller diameter fibres due to a fibre to coating ratio effect. The time response of the sensor's to a humidity step change was measured. To explore the response time dependencies the sensors humidity step change response a novel two-layer model was proposed. A mesh model was also utilised to calculate the diffusion coefficient for each coating. The time response was found to be highly dependent on coating thickness with response time increasing significantly with thickness.

Novel dye-doped polymer sensors were developed by photo-bleaching waveguides containing Bragg gratings, with Bragg reflections observed. The sensor fabrication process was refined by modifying the waveguide dimensions and utilising precise phase mask alignment to obtain a single-mode waveguide with a single Bragg reflection. Methods of coupling the film sensor to a single-mode fibre with a housing unit was explored and a novel method proposed and tested. The film sensors were characterised with strain, temperature and chemical sensing experiments. A strong humidity response in the range of 55 to 65 pm/%rh and the time responses to a humidity step change were measured. Strain responses

in the range of 1.70 to 1.80 pm/$\mu\epsilon$ were observed, exceeding that of comparable silica and PMMA sensors.

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Contents

Abbreviations

APC	Amorphous polycarbonate
BA	Poly(methyl methacrylate-co-butyl methacrylate)
BAF-1	A photo-switchable chromophore
CME	Coefficient of moisture expansion
DMF	Dimethylformamide
DNT	2,4-dinitrotoluene
EA	Poly(methyl methacrylate-co-ethyl acrylate)
FBG	Fibre Bragg grating
FOS	Fibre optic sensor
FWHM	Full width half maximum
MA	Poly(methyl methacrylate-co-methacrylic acid)
Mod PEI	Modified polyetherimide
NEP	N-ethyl-2-pyrrolidone
OSA	Optical spectrum analyser
PEI	Polyetherimide
PMMA	Poly(methyl methacrylate)
PVOH-ET	Polyvinyl alcohol-co-ethylene vinyl alcohol
PYR-3	A second-order non-linear optical chromophore
TCE	1,1,2-Trichloroethane