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# SENSORS FOR OPTICS-BASED STRAIN, TEMPERATURE AND CHEMICAL SENSING

A thesis presented in partial fulfilment of the  
requirements for the degree of

Doctor of Philosophy  
in  
Physics

at

at Massey University, Palmerston North,  
New Zealand

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2015



# 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.

# Acknowledgements

I would like to express my most heartfelt thanks to my day to day supervisor Sebastiampillai Raymond who was always able to smile and encourage through the difficult times of this thesis and to my university supervisor Mark Waterland whose enthusiasm and guidance has been invaluable.

My sincere thanks to Jeremy Lovell-Smith for his assistance with making humidity measurements, guidance on humidity theory and his extensive proof reading of this thesis and publications. I am deeply indebted to Stefaan Janssens who has offered me invaluable advice, suggestions and ideas throughout my thesis. I would like to express my sincere thanks to the current and former Photonics team members at Callaghan Innovation in particular Robert Breukers, David Clarke, Reece Whitby, Andrew Kay, Gerald Smith, Nicola Winch and Delower Bhuiyan for their chemistry advice and Damian Carder, Dijana Bogunovic, Yasar Kutuvantavida, Ayla Middleton, Victoria Peddie, Andrew Best, Katrina Teu, Ann Manning for their support and especially Julien Hansen and Sebastian Hess for being the best German interns the Photonics team have ever had. I would like to mention a special thanks Philip Zhang for his mathematical help and to Xinjie Song for her invaluable advice and guidance.

I would like to express my sincere thanks to the Callaghan Innovation workshop team who were of great help in the development experimental equipment used in this thesis.

I would especially like to gratefully acknowledge the often overlooked thesis examiners Alan Mickelson, Ian Woodhead and Geoff Jameson who have taken time out of their busy schedules to read through this thesis ensuring its final high quality.

I am deeply grateful for the PhD scholarship from Callaghan Innovation funded by the Ministry of Business, Innovation and Employment New Zealand - for which this thesis would not be possible without.

I am immeasurably grateful to my parents Tony and Pat Swanson and to my sister Vanessa Baunton who have supported and encouraged me throughout this thesis.

Most of all I would like to acknowledge my partner Sophia (Cen Chen) who

was always working with me behind the scenes making sure I had a hot meal at home after a long hard day.

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# 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