Integrated Bragg Grating Sensors: Achieving Chemical Sensing in Liquid and Gas Flow Systems

Dominic Wales[1,2]
1. Optoelectronics Research Centre, University of Southampton, Southampton, SO17 1BJ, U.K.
2. School of Chemistry, University of Southampton, Southampton, SO17 1BJ, U.K.
***R. Parker**[1]**, J. Gates**[1]**, M. Grossel**[2]**, P. Smith**[1]*
1. Optoelectronics Research Centre, University of Southampton, Southampton, SO17 1BJ, U.K.
2. School of Chemistry, University of Southampton, Southampton, SO17 1BJ, U.K.

The sensing of chemical species is required within a diverse set of fields including industry, environmental monitoring and homeland security. The sensing of chemicals in liquid and gaseous environments has been traditionally achieved by electronic and electrochemical sensors. However, optical sensors demonstrate many benefits over these electronic systems, including remote interrogation of large sensor arrays via optical fibre and telecoms equipment, immunity from EM interference and absence of spark risk in flammable environments [1].

Optical waveguides containing Bragg gratings can be written with a UV-laser into a photosensitive silica-on-silicon substrate to produce a wide range of optical devices [2]. The wavelength reflected by a Bragg grating is dependent on the refractive index of the material the light passes through. These Bragg gratings are inherently sensitive to temperature and strain. However, etching away the silica surface exposes the evanescent tail of the optical mode within the grating to its surroundings (**Fig. 1a**). The corresponding observed shift in Bragg wavelength can be used to detect changes in refractive index of the surrounding environment, with the potential to detect a single molecular monolayer upon the sensor surface, as demonstrated previously [3,4]. By detecting the associated effective refractive index change upon binding of a specific chemical analyte to its corresponding chemical receptor these devices can be made chemically specific. Specific sensing of analytes in the liquid and gas phases has been achieved through a range of techniques, including the use of size-selective macrocyclic receptors, metal phthalocyanine receptors and encapsulated organic dyes.

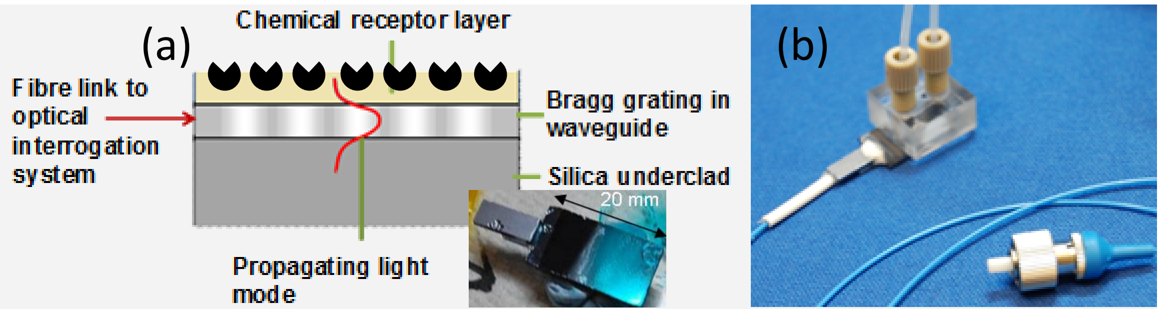

Fig. 1: (a) Cross section of a Bragg Grating sensor showing the interaction of light with a layer of chemical receptors (black symbols) and **(inset)** an image of a Bragg grating sensor modified with a layer of a metal phthalocyanine functionalised polymer. **(b)** Photograph of a microfluidic Bragg grating sensor device and the fibre connector (foreground)

We will present an overview of the approaches used to achieve selective sensing of a range of chemical analytes using these integrated optical Bragg grating sensors. In the liquid phase, sensing has been achieved through the use of a sensor device modified with receptor molecules within a microfluidic network (**Fig. 1b**). This has been demonstrated through use of a self-assembled monolayer of benzo-15-crown-5, a size selective macrocycle, which exhibited enhanced sensitivity towards sodium cations in methanol. In contrast, sensing in the gas phase has focused upon the use of porous structures to enhance detection. Current work focuses upon the encapsulation of an organic dye in a porous silica sol-gel for sensing of gaseous oxygen. In addition, polymers modified with metal phthalocyanines are being explored for the detection of volatile organic compounds. The results from these studies will be reported.

References

[1] B.D. Gupta, *Fiber Optic Sensors: Principles and Applications*, 1st ed., (New India Publishing Agency, New Delhi, 2006).

[2] I.J.G. Sparrow, P.G.R. Smith, G.D. Emmerson, S.P. Watts, C. Riziotis, "Planar Bragg Grating Sensors-Fabrication and Applications: A Review", Journal of Sensors , 1-12, (2009).

[3] R.M. Parker, J.C. Gates, M.C. Grossel, P.G.R. Smith, "*In vacuo* measurement of the sensitivity limit of planar Bragg grating sensors for monolayer detection", App. Phys. Lett., **95**, 173306. (2009)

[4] R.M. Parker, J.C. Gates, M.C. Grossel, P.G.R. Smith, "A Bragg Grating Sensor for Detection of Monolayers at a Surface", Presented at CLEO/Europe-EQEC 2009, Munich, Germany, June 14-19, (2009)