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Stephen C. Warren-Smith, Erik P. Schartner, Linh V. Nguyen, Dale E. Otten, Zheng Yu, David G. Lancaster, and Heike Ebendorff-Heidepriem

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Microstructured optical fiber high-temperature sensors

Stephen C. Warren-Smith, Erik P. Schartner, Linh V. Nguyen, Dale E. Otten, Zheng Yu, David G. Lancaster, and Heike Ebendorff-Heidepriem

[1]Institute for Photonics and Advanced Sensing (IPAS) and School of Physical Sciences, The University of Adelaide, Adelaide, South Australia 5005, Australia
[2]ARC Centre of Excellence for Nanoscale BioPhotonics (CNBP), The University of Adelaide, Adelaide, South Australia 5005, Australia Laser
[3]Physics and Photonic Devices Laboratories, School of Engineering and Future Industries Institute, University of South Australia, Mawson Lakes, SA 5095, Australia
Author e-mail address: stephen.warrensmith@adelaide.edu.au

Abstract: At the University of Adelaide and the University of South Australia, we are utilizing the unique optical and material properties of microstructured optical fibers for new and challenging sensing applications. I will present our recent progress in using pure-silica microstructured optical fibers with femtosecond laser ablation fiber Bragg gratings (FBGs) for high temperature sensing up to and beyond 1000°C. In this project we are working with our industry partner, local engineering company SJ Cheesman, to develop multipoint sensors for pyrometallurgical applications.

OCIS codes: 060.2370, 060.3735, 060.4005.

1. Introduction

Temperature sensing in industrial environments is typically performed using thermocouples, which offer a simple, flexible and robust option for sensing. However, they are limited to a single-point measurement per cable and are subject to electromagnetic interference and corrosion. Optical fibers are attractive alternative for temperature sensing, as they offer the potential for either multi-point or distributed sensing [1,2].

Fiber Bragg grating (FBG) are of interest as they can be used as a straight-forward replacement to thermocouples. Traditional fabrication techniques based on ultra-violet exposure to photosensitive optical fibres are limited to operation at up to only several hundred degrees Celsius [3]. The fabrication of FBGs that operate at higher temperatures is an area of active research with multiple thermal processing techniques proposed [4-8].

We have recently used surface ablation FBGs written into in pure-silica suspended-core microstructured optical fibers (SCF) using a femtosecond laser [9,10]. Such sensors can operate up to 1300°C [9] and show long term stability up to 1100°C [10].

2. Sensor design

The high temperature sensors are fabricated from in-house drawn pure-silica SCF [Fig. 1(a)]. The FBGs [Fig. 1(b)] are written using a wavelength-doubled (524 nm), ultra-fast laser (IMRA DE0210) with pulse duration < 250 fs and pulse frequency of 1 kHz. The pulse energy was approximately 100 nJ. The laser pulses were using a 50× microscope objective (Nikon MUE13500) onto the surface of the core of the SCFs by focusing through the cladding. The SCFs are then translated along their axis to produce an FBG with a pitch the order of 1 µm giving second reflection wavelengths in the vicinity of 1557 nm. The fibers are then spliced to SMF28E using an arc splicer (Fujikura FSM-100P) and packaged in various materials such as glass or inconel capillaries or alumina ceramic.

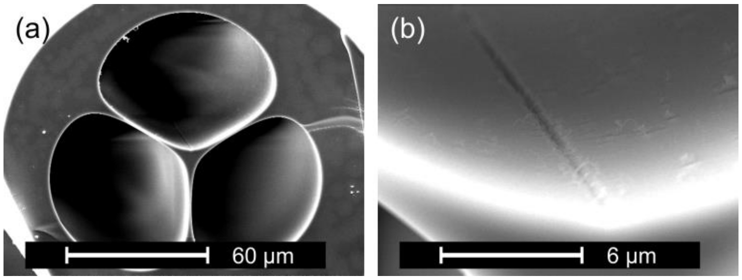

Fig. 1. Scanning electron microscope image of the suspended-core microstructured optical fiber (a) and the femtosecond laser ablation Bragg grating on the core (b). Reprinted from [9].

3. Sensor performance

The SCF with fs-laser ablation FBGs has been characterized at high temperature and shows a sensor drift of less than 0.2°C/day at 700°C and less than 0.5°C/day up to 1050°C after annealing [10].

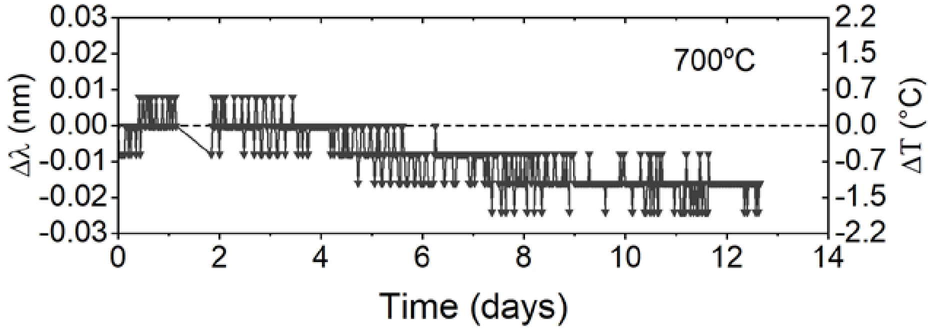

Fig. 2. Change in FBG wavelength position over 12 days at 700°C.

4. Acknowledgements

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5. References

1. B. Lee, "Review of the present status of optical fiber sensors," Optic. Fiber Technol. **9**, 57-79 (2003).

2. B. Culshaw, "Optical fiber sensor technologies: opportunities and-perhaps-pitfalls," J. Lightwave Technol. **22**, 39-50 (2004).

3. T. Erdogan, V. Mizrahi, P. J. Lemaire, and D. Monroe, "Decay of ultraviolet-induced fiber Bragg gratings," J. Appl. Phys. **76**, 73-80 (1994).
4. M. Celikin, D. Barba, B. Bastola, A. Ruediger, and F. Rosei, "Development of regenerated fiber Bragg grating sensors with long-term stability " Opt. Express **24**, 21897-21909 (2016).

5. D. Barrera, V. Finazzi, J. Villatoro, S. Sales, and V. Pruneri, "Packaged optical sensors based on regenerated fiber Bragg gratings for high temperature applications," IEEE Sens. J. **12**, 107-112 (2012).

6. J. Canning, S. Bandyopadhyay, M. Stevenson, P. Biswas, J. Fenton, and M. Aslund, "Regenerated gratings," J. Eur. Opt. Soc.-Rapid **4**, 09052 (2009).

7. V. I. Kopp and A. Z. Genack, "Chiral fibres: adding twist," Nat. Photonics **5**, 470-472 (2011).

8. V. I. Kopp, V. M. Churikov, G. Zhang, J. Singer, C. W. Draper, N. Chao, D. Neugroschl, and A. Z. Genack, "Single- and double-helix chiral fiber sensors," J. Opt. Soc. Am. B **24**, A48-A52 (2007).

9. S. C. Warren-Smith, L. V. Nguyen, C. Lang, H. Ebendorff-Heidepriem, and T. M. Monro, "Temperature sensing up to 1300ºC using suspended-core microstructured optical fibers," Opt. Express **24**, 3714-3719 (2016).

10. S. C. Warren-Smith, E. P. Schartner, L. V. Nguyen, D. E. Otten, Z. Yu, D. G. Lancaster, and H. Ebendorff-Heidepriem, "Stability of grating-based optical fiber sensors at high temperature," IEEE Sens. J., published (2019).