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Publication details:
OFS'2002 - Technical Digest
pp. 71-74
0780372891 (ISBN)

Event details:
15th Optical Fiber Sensors Conference

Publication Date:
2002

Publisher DOI:
http://dx.doi.org/10.1109/OFS.2002.1000504

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Prospects of Polymer Optical Fibres and Gratings in Sensing

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Recent development of single-mode polymer optical fibres, polymer materials and polymer fibre gratings may provide new opportunities for sensor applications. This paper will report the recent progresses in polymer optical fibre areas and discuss their significance and potential for fibre sensor applications.

1. Introduction

Optical fibre sensing has great potential in most fields of modern science and technology, such as industrial manufacture, civil engineering, military technology, environmental protection, geophysical survey, oil exploration, medical and biological technologies etc. The popular optical fibre sensors include rotation, temperature, strain, stress, vibration, acoustic and pressure sensors etc [1]. Various sensor designs and system architectures have been investigated for various applications. However, so far the research and development work have been mainly concentrated on silica optical fibre based systems.

Polymer optical fibre technology has made remarkable progress in recent years. New polymer optical fibres based on perfluorinated polymers have been made with very low loss [2]. In addition to traditional step-index multimode fibres, graded-index polymer optical fibre with higher bandwidth has been developed with well-tailored index profile [3]. More significant for interferometric types of fibre sensing, techniques for fabricating single-mode polymer fibres have been developed [4,5]. Also relevant techniques for writing fibre Bragg gratings on polymer optical fibres have been developed [6,7]. All these developments provide opportunities for building up polymer optical fibre or grating based sensor systems.

The application of polymer optical fibre in sensing could be advantageous. A main advantage is its low Young's modulus. The Young's modulus of polymer fibre materials is typically many times less than that of silica glass. Hence, for strain related optical sensor such as fibre hydrophone, polymer optical fibres are intrinsically many times more sensitive to acoustic wave than silica glass fibres [8]. The use of polymer optical fibre in fibre hydrophones could revolutionise the sensor head design because of the much better acoustic compatibility between water and fibre. For the same reason, polymer optical fibre could be advantageous for sensing in environments of liquid and less rigid solid state materials.

2. Polymer optical fibres

Most of current polymer optical fibres are multimode and PMMA (poly methyl methacrylate)-based. These fibres have optical transmission windows in the visible wavelengths. Nevertheless

0-7803-7289-1/02/$17.00©2002 IEEE

the loss of the PMMA-based fibres is not particularly low, at a level above 80 per kilometre. It is significantly higher than that of silica-based optical fibres. This could be a factor that limiting the applications of polymer fibre sensor in long length situations.

However, remarkable progress has been made in improving the optical property of polymer fibre materials in recent years. Researchers in Asahi Glass Co. and Keio University in Japan developed excellent fluorinated polymer materials for making very low loss polymer fibres. At the International Polymer Optical Fibre Conference held in Boston, USA, in September 2000, it is reported that fluorinated polymer optical fibre achieved a loss as low as 16dB/km [2]. Fig.1 compares the attenuations of three types of polymer optical fibres. The fluorinated polymer developed by Keio University and Asashi Glass Co has the similar excellent chemical, thermal, electrical and surface properties as conventional fluoropolymers as teflon. In addition to its excellent optical property characterised by its high optical transparency, another very important feature of the material is its very broad transmission window, wide open from the 650nm right up to 1300nm. Theoretically it is even predicted that the loss could be as low as 0.3dB/km [9].

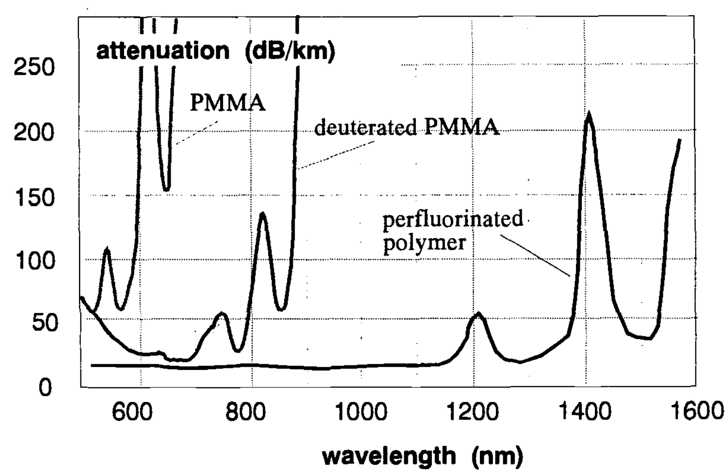

Fig.1 Characteristic attenuation spectra of polymer optical fibres based on different materials: (1) PMMA; (2) deuterated PMMA and (3) perfluorinated polymer.

3. Polymer optical fibre Bragg gratings

Optical fibre Bragg grating is one of very useful fibre-optic components for optical fibre communications as well as optical fibre sensing. It has excellent wavelength selectivity in its spectral characteristics. It could be used as sensing elements or optical fibre reflectors for measuring temperature, pressure and strain, hydro-sound and industrial process.

Due to the importance of fibre grating for a great spectrum of applications, the fabrication of fibre gratings have been one of the main research topics in recent years. So far work are dominantly concentrated on the silica optical fiber gratings. With regard to the fabrication of polymer fibre grating, remarkable progress has also been made by the researchers in the University of New South Wales in recent years. Photosensitivities of PMMA-based polymer fibres [6] and fluorinated polymer fibres [10] have been investigated and observed. Further work have lead to Bragg gratings being fabricated in various polymer optical fibres [11]. Good grating characteristics as shown in Fig.2 has been achieved in PMMA-based polymer fibre recently [12].

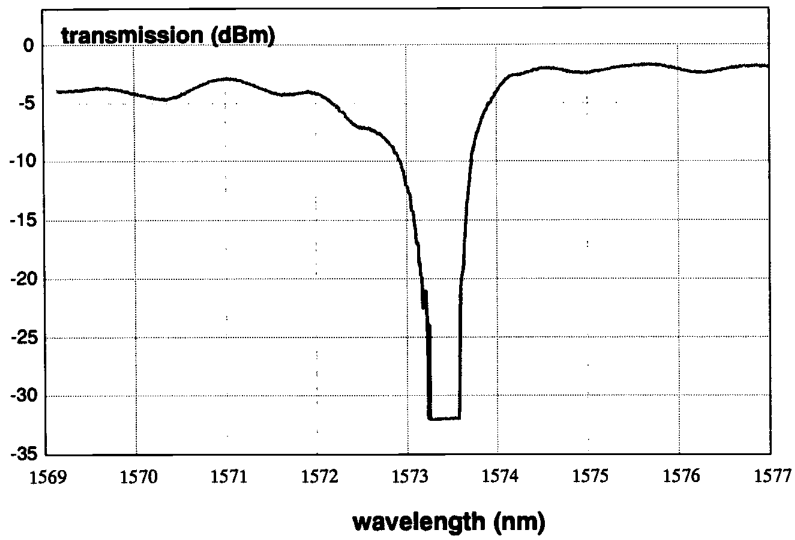

Fig.2 Transmission spectrum of a POF Bragg grating with high transmission rejection and narrow line width.

4. Prospects of POF sensor applications

Now both polymer optical fibres and polymer optical fibre Bragg grating have been developed to a stage useful for fibre sensor applications. As mentioned above, the low Young's modulus of polymer fibre could be a significant advantage for strain-related sensing applications. Table 1 briefly summarises the relevant characteristics of typical silica and polymer fibres for sensing:

Table 1 Comparison of relevant parameters of silica and polymer optical fibres

	Silica fibre	Polymer fibre
Attenuation (dB/km)	0.2~3	10 ~ 100
Young's modulus (Gpa)	100	3
Breakdown strain (%)	1~2	5 ~ 10

Since a strain ε is related the applied stress σ by $\varepsilon = \frac{\Delta L}{L} = \frac{\sigma}{E}$, with E the Young's modulus of material, under a certain stress, a much lower Young's modulus of polymer fibre means much higher strain and thus much higher sensitivity. Moreover, it is possible to tailor the Young's modulus and elasticity of a polymer fibre with readily available synthesis techniques or to select appropriate materials with desirable Young's modulus or elasticity from a wide range of optical polymer materials. This is another important feature that makes polymer optical fibres or polymer fibre Bragg gratings better candidates for sensing in various liquid and elastic material environment, duly covering a full range of strain-related sensor applications.

References

[1] For example: N. Takahashi, K. Tetsumura, K. Imamura and S. Takahashi, "Fiber-Bragg-grating WDM underwater acoustic sensor with directivity", Proc. of SPIE, v.3541,18-16, 1999; M. V. Dewernter, P. Ferdinand, E. Bocherens, R. Carbone, H. Berange, S. Bourasseau, M. Dupont and D. Balageas, "Embedded Fiber Bragg Grating sensors for industrial composite cure monitoring", J. of Intelligent Material System and Structure, v.9, 785-787, 1999

[2] K. Koganezawa and T. Onishi, "Progress in perfluorinated GI-POF", Proc. of the International POF Technical Conference, POF'2000, 19-21, 2000

[3] Y. Koike, "Progress in GI-POF: status of high speed plastic optical fiber and its future", Proc. of the International POF Technical Conference, POF'2000, 1-5, 2000

[4] D. Bosc and C. Toinen, "Fully polymer single-mode optical fiber", IEEE Photo. Tech. Lett. 4(7), 749-751, 1992

[5] G. D. Peng, P. L. Chu, L Xia and R. A. Chaplin, "Fabrication and characterisation of polymer optical fibres", *J. of IREEA*, vol.15, no.3, pp.289-296, 1995

[6] G. D. Peng, Z. Xiong, and P. L. Chu, "Photosensitivity and grating in dye-doped polymer optical fibres" *Optical Fibre Technology,* vol.5, 242-251, April 1999

[7] Z. Xiong, G. D. Peng, B. Wu and P. L. Chu, "Highly tunable single-mode polymer optical fibre grating", *IEEE Photonic Technology Letters,* vol.11, no.3, 352-354, March 1999

[8] G. D. Peng and P. L. Chu, "Optical fibre hydrophone systems", a book chapter *in Fiber Optic Sensors*, F. Yu and S Yin (ed.), Marcel Dekker, Inc., New York, Chapter 9, 417-447, 2001

[9] N. Tanio and Y. Koike, "What is the most transparent polymer?", J. of Polymer, v.32, 43-50, 2000

[10] H. Y. Liu, G. D. Peng, P. L. Chu, Y Koike and Y. Watanabe, "Photosensitivity in low-loss perfluoropolymer (CYTOP) fiber material", IEE Electronics Letters, vol.37, no.6, 347-348, 2001

[11] Z. Xiong, G. D. Peng, B. Wu and P. L. Chu, "Highly tunable single-mode polymer optical fibre grating", *IEEE Photonic Technology Letters,* vol.11, no.3, 352-354, March 1999

[12] H. Y. Liu, G. D. Peng and P. L. Chu, "Polymer Fiber Bragg Gratings with 28dB Transmission Rejection", submitted to IEEE Photonics Technology Letters