Tunable Anisotropic Strain in Laser Crystallized Silicon Core Optical Fibers

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Abstract: A laser processing method for tuning the size of the anisotropic strain in a silicon core optical fiber is demonstrated. We propose that this technique can be used to modify the core's opto-electronic properties for applications with specific requirements.

1. Introduction

Silicon optical fibers represent a novel medium in which the large $\chi^{(3)}$ non-linearity of the core material can be exploited for signal processing and optical frequency generation in a geometrically standardized platform. However, silicon's opto-electronic functionality is subservient to its molecular structure, for example it has an indirect band-gap and has no $\chi^{(2)}$ non-linearity. In this paper we investigate a laser processing technique as a means to alter the core material's intrinsic properties so that its optical and electronic functionality can be tuned for targeted applications.

2. Experiment

Silica clad amorphous silicon (a-Si) core optical fibers with diameters of 1.7 µm were fabricated using the high pressure microfluidic chemical deposition technique, see Fig. 1(a) [1]. The a-Si fibers were then crystallized using a focused CW argon-ion laser operating at 488 nm and a power of 2 W. A set of programmable nano-positioning stages were used to scan the fibers through the radiation focus so that each position along the core was irradiated for a time controlled via the scan speed.
The resulting fibers were analyzed using a Raman spectrometer and the results for fibers prepared at two different irradiation times (T_1=0.5 ms & T_2=500 ms) are shown in Fig. 1(b). The difference in the peak position for each spectrum (509 cm^{-1} for T_1 & 519 cm^{-1} for T_2) is a consequence of the strain induced by laser heating and indicates that the strain can be tuned as a function of irradiation time. The profile of the strain was measured using a synchrotron microfocus X-ray diffractometer and a 2-D diffraction pattern is shown in Fig. 1(c). The single Laue spot is a reflection from the <311> plane, and thus we can conclude that just one crystal is present at the sampled length The elongation of this spot is due to a variation of the crystal's lattice spacing which is indicative of an anisotropic strain that can be estimated to be ~ 3 %. Such a large anisotropic strain can profoundly influence the core material's electrical and optical properties, for example, the electron mobility can be modified, the electronic band-gap can be shifted, or a sizable $\chi^{(2)}$ susceptibility may be induced. The effect that the anisotropic strain has on the optical properties of our silicon optical fibers will be discussed.

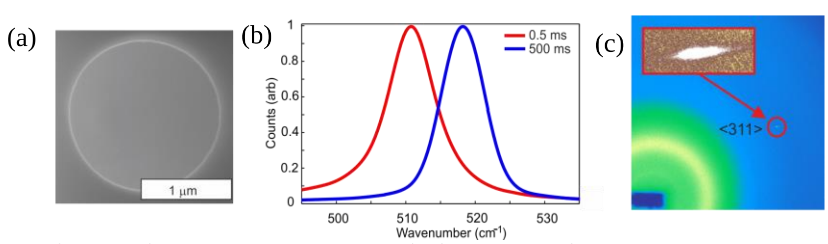

Fig. 1. (a) The cross-section of a silicon fiber. (b) The Raman spectra of 2 fibers exposed for 0.5 ms (red) and 500 ms (blue). (b) 2-D micro-focus X-Ray diffraction pattern from the core of a strained silicon optical fiber; inset is a close-up of the elongated Laue spot.

3. References

[1] L. Lagonigro, N. Healy, J. R. Sparks, N. F. Baril, P. J. A. Sazio, J. V. Badding, and A. C. Peacock, "Low loss silicon fibers for photonics applications," Appl. Phys. Lett. **96**, 041105 (2010).