Laser Cleaning of Silica Wires

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Abstract

A preliminary study into laser cleaning of silica wires has been carried out using a pulsed fiber laser. Silica wire size reduction was attempted to manipulate the shape and size using a CH_3OH fueled flame. Contamination occurred by the reduction is meant to be removed by the laser radiation. The pulsed laser beam at a wavelength of 1064 nm was focused and scanned across the contaminated wires. The scanning electron microscope (SEM) reveals the size and cleaning condition of the wires. Low laser fluencies are required to allow the cleaning without the damage to the wire. Laser assisted cleaning of silica wires provides opportunity to the fields related to silica wire size reduction and plays an important role to achieve an all-optical circuit.

Keywords: Laser, Laser cleaning, Silica wire

Introduction

The traveling of photons in silica waveguides provides opportunities for photonic sand sensor technology [1-10]. The size reduction of silica wire supports the creation of optical circuits. Several materials and technologies have proposed to produce small waveguides, including semiconductor nanowires, plasmonic waveguides, lithographical nanowires and silica nanowires [11-13].

The silica wire size reduction has been demonstrated as a promising solution to provide smaller optical waveguides approaching the wavelength of light. These techniques including flame-brush taping, directly from bulk glasses and CO_2 heated oven [14-17]. These studies have focused to the small size, surface roughness and mechanical properties of the silica wires.

In this paper, we bring an aspect of laser cleaning to remove contaminations occurred by the size reduction. To explore the laser cleaning process, we use a CH_3OH fueled flame for the pulling method to fabricate the wires. The removal of contamination using a pulse fiber laser will be demonstrated.

Methodology

The silica wires for the demonstration on laser cleaning were fabricated with a conventional fiber tapering set up shown in Figure 1. The conventional optical fiber is held by the mounts on the automatic-controlled stage. The stage can move at speeds ranging 0.05-3 mm/s. We use a CH_3OH fueled flame as the heat source for the experiments. The fabricated wires perform as the samples for the laser cleaning application.

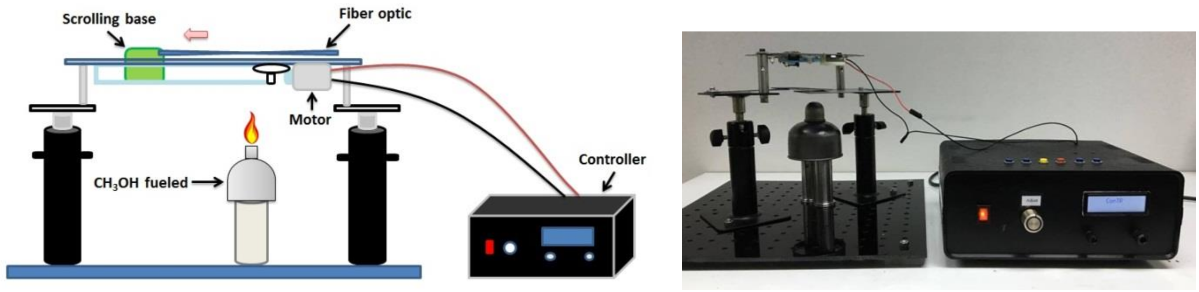

Figure 1: Schematic diagram of the automatic-controlled fiber drawing process.

For the cleaning procedure, the use of a Q-switch fiber laser operating at repetition rate between 50 kHz and 100 kHz was investigated. The duration of the laser pulse was measured as 100 ns (FWHM) Q-switched. The laser offers up to 0.5 mJ per pulse. Figure 2 shows the setup of the cleaning experiments. The fabricated wires were held at the focal point of the laser beam. The diameter of the focus beam was at 100 microns. The laser beam was scanned on the wire.

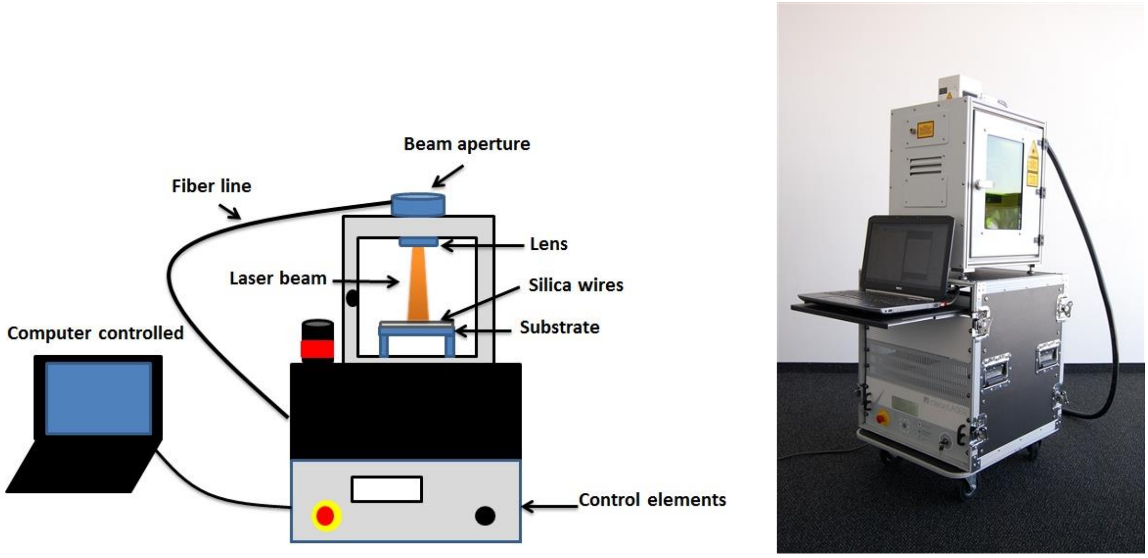

Figure 2: Schematic representation of the laser cleaning of silica wires.

Results and Discussion

As shown in Figure 3, the size reduction of the silica wire using the heat flame can produce the contamination. The contamination is required to be removed for the use of the wires in photonics applications.

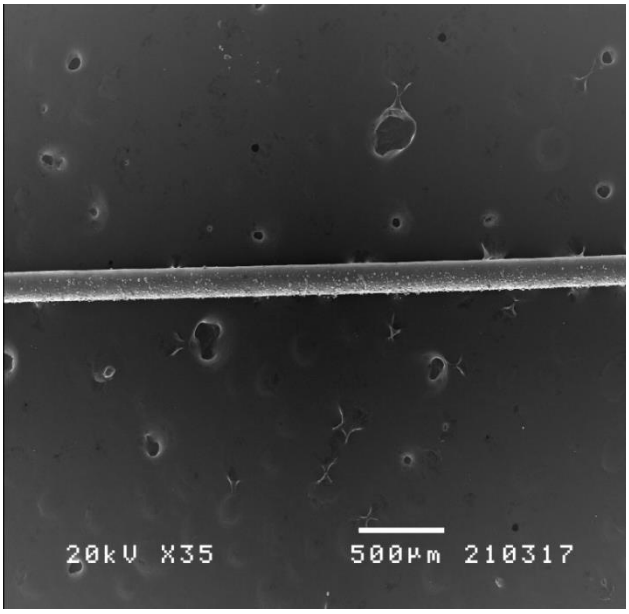

Figure 3: SEM image of a fabricated wire with contamination.

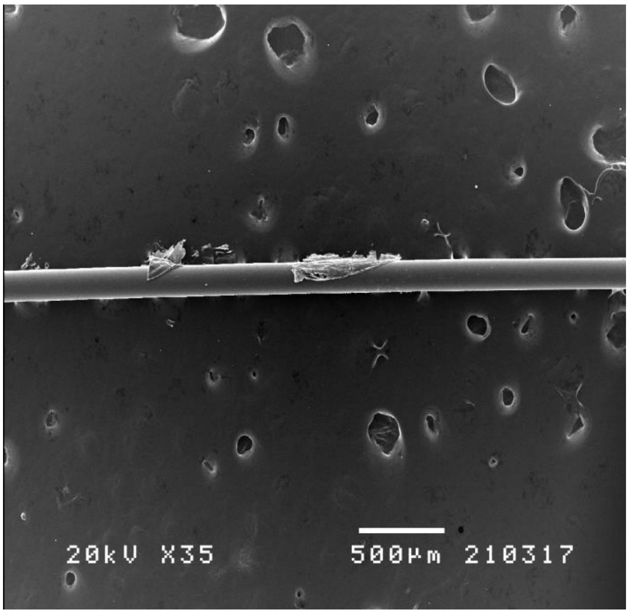

Figure 4: SEM image of an area of the wire cleaned by Q-switch radiation at 1 Jcm^{-2}.

Q-switched fiber radiation was found to be efficient in the removal of the contamination occurred by the fabrication process. The experiments reveal that a fluence of 0.30 Jcm^{-2} was sufficient to remove the contamination from the wires. Figure 4 shows an area of the fabricated wire which has been cleaned by a Q-switch radiation. The contamination was removed leaving a surface with a similar appearance to the clean area of the wire. The irradiated area was obtained at 1 Jcm^{-2}.

Conclusion

The preliminary study shows that controlled cleaning of silica wire is possible with Q-switched fiber lasers. At a low fluence, cleaning by Q-switched fiber laser appears to be a suitable, efficient and selective process. The laser beam interacts more intensely with the contamination than the wire. After the removal of contamination, the cleaned wire appears to have no heat effect due to the short duration of the Q-switched pulse condition.

References

[1] J. Hecht,2004, City of light : the story of fiber optics. Oxford: Oxford University Press, rev. and expanded ed.

[2] G. P. Agrawal, 2001, Nonlinear fiber optics. Optics and photonics. San Diego: Academic Press, 3rd ed.

[3] G. P. Agrawal, 2001, Applications of nonlinear fiber optics. Optics and photonics, San Diego: Academic Press.

[4] M. Sumetsky et al., 2004, Fabrication and study of bent and coiled free silica nanowires: Self-coupling microloop optical interferometer. Optics Express, vol. 12, no. 15, pp.3521-3531.

[5] S. G. Leon-Saval et al., 2004, Supercontinuum generation in submicron fibre waveguides. Optics Express, vol. 12, no. 13, pp.2864-2869.

[6] P. Domachuk& B. J. Eggleton, 2004, Photonics - shrinking optical fibres. Nature Materials, vol. 3, no. 2, pp. 85-86.

[7] F. Bilodeau et al., 1988, Low-loss highly overcoupled fused couplers - fabrication and sensitivity to external-pressure. Journal of Lightwave Technology, vol. 6, no. 10, pp. 1476-1482.

[8] T. A. Birks & Y. W. Li, 1992, The shape of fiber tapers. Journal of Lightwave Technology, vol. 10, no. 4, pp. 432-438.

[9] L. M. Tonget al., 2003, Subwavelength-diameter silica wires for low-loss optical wave guiding. Nature, vol. 426, no. 6968, pp. 816-819.

[10] L. M. Tong et al., 2004, Single-mode guiding properties of subwavelength-diameter silica and silicon wire waveguides. Optics Express, vol. 12, no. 6, pp. 1025-1035.

[11] L. M. Tonget al., 2005, Assembly of silica nanowires on silica aerogels for microphotonic devices. Nano Letters, vol. 5, no. 2, pp. 259-262.

[12] L. M. Tong& E. Mazur, 2006, Silica nanowires andsubwavelength-diameter fibres.in Specialty Optical Fibers Handbook.

[13] L. M. Tong et al., 2012, Optical microfibers and nanofibers: A tutorial. Optics Communications, vol. 285, pp. 4641-4647.

[14] L. M. Tong et al., 2005, Self-modulated taper drawing of silica nanowires. Nanotechnology, vol. 16, no. 9, pp. 1445.

[15] G. Kakarantzas et al., 2001, Miniature all-fiber devices based on co2 laser micro structuring of tapered fibers. Optics Letters, vol. 26, no. 15, pp. 1137-1139.

[16] G. Brambilla et al., 2005, Compound-glass optical nanowires. Electronics Letters, vol. 41, no. 7, pp. 400-402.

[17] L. M. Tonget al., 2006,Photonic nanowires directly drawn from bulk glasses. Optics Express, vol. 14, no. 1, pp. 82-87.