Optical Fiber Technology 38 (2017) 41–45

Contents lists available at ScienceDirect

Optical Fiber Technology

journal homepage: www.elsevier.com/locate/yofte

Regular Articles

Polishing parameter optimization for end-surface of chalcogenide glass fiber connector

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ARTICLE INFO

Keywords:
Chalcogenide glasses
Polishing
Connector
Surface roughness

ABSTRACT

We have investigated the optimization parameters for polishing end-surface of chalcogenide glass fiber connector in the paper. Six SiC abrasive particles of different sizes were used to polish the fiber in order of size from large to small. We analyzed the effects of polishing parameters such as particle sizes, grinding speeds and polishing durations on the quality of the fiber end surface and determined the optimized polishing parameters. We found that, high-quality fiber end surface can be achieved using only three different SiC abrasives. The surface roughness of the final ChG fiber end surface is about 48 nm without any scratches, spots and cracks. Such polishing processes could reduce the average insertion loss of the connector to about 3.4 dB.

1. Introduction

Chalcogenide glasses (ChGs) are materials containing one or more of chemical elements in group VIA of the periodic table—such as sulfur (S), selenium (Se), and tellurium (Te). They exhibit excellent physical characteristics including wide infrared (IR) transparency (up to 20 μm), high refractive index (2.0–3.5), low phonon energy (less than 350 cm^{-1}), and high nonlinear coefficient (n_2 = 2–20 × 10^{-18} m^2/W, 100–1000 times of the silica glass) [1–3]. Therefore ChGs have received extensive studies in infrared (IR) laser guiding [4–6], mid-infrared (MIR) supercontinuum generation [7–10] and Raman fiber laser [11–13]. For instance, commercial available As_2S_3 and As_2Se_3 glasses show excellent thermal stability, outstanding rheological property and low transmission loss in the mid-IR region, have been widely used in various waveguide- or fiber-based optical devices [14,15].

For practical applications, one of the challenging issues for ChG glasses is their poor mechanical properties, For example, it is difficult to integrate ChG fibers with traditional silica fiber due to the large contrast of the mechanical properties between ChG and silica, which usually causes large optical loss due to poor connection between ChG and silica fibers. Therefore it is critical to develop a solution to get perfect end surface of ChG fiber in order to minimize the loss of the connection and improve the whole performance of the optical devices. Early researchers have developed the fusion melting method to realize the connection between ChG fibers [16]. Unfortunately, this method is unrepeatable, and the end surface of the fiber usually is oxidized and thus resulting in a large optical loss. Direct coupling or lens coupling mode methods have also been used to realize the connection [17–19], but the two coupling processes are not practical for real devices because they are easily affected by environmental factors, such as temperature, humidity, and air fluctuations. Moreover, the coupling efficiency for the direct coupling method is relatively low [16,20]. While, it is also difficult to adjust the optical path and control the optical power for the lens coupling method, especially optically induced damage on the surface of the end fiber occurs when the optical power is too large [18,21,22]. Instead, the ChG fiber connector is a good alternative with advantages of high flexibility, low insert loss, and simple all-fiber structure. However, there are only few reports about the processing of ChG fiber end surfaces. Fiber connectors generally use high-precision components (two ferrules and a coupling tube) to achieve the connection of the fibers. In this method, the fiber is inserted and fixed in the ferrule, and polished to realize the alignment in the coupling tube.

In this work, we have investigated the polishing process for end surfaces of ChG glass fiber. We fabricated As_2S_3-$As_{38}S_{62}$ single-mode chalcogenide fiber via a modified one-step co-extrusion process and evaluated transmission performance of the fiber. Then, we used SiC abrasives of different particle sizes to polish the fiber end surface, including rough grinding, fine grinding and polishing. The effects of grinding parameters, such as particle size, grinding speed and polishing duration, on the end face of fiber were analyzed, and the causes of the defects in the grinding process were investigated. Finally, we determined the optimized polishing parameters, and successfully

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http://dx.doi.org/10.1016/j.yofte.2017.07.004
Received 5 June 2017; Received in revised form 3 July 2017; Accepted 18 July 2017

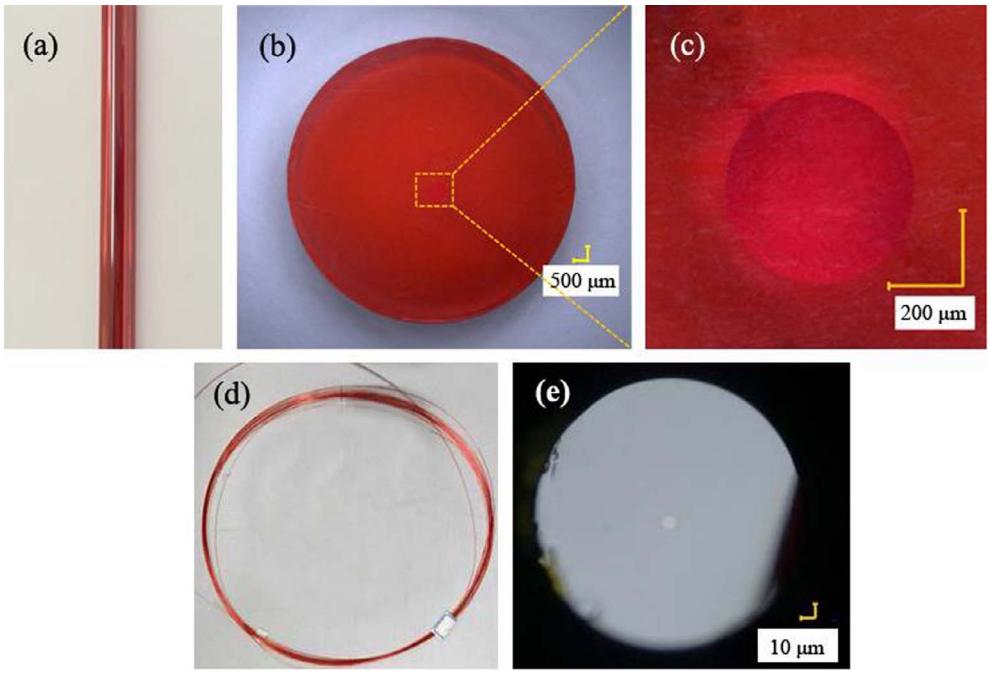

Fig. 1. (a) Core-cladding As_2S_3-$As_{38}S_{62}$ ChG fiber preform; (b) Cross section image of fiber preform; (c) Enlarged cross section of core; (d) A coil of fabricated fiber; (e) Cross section image of fiber.

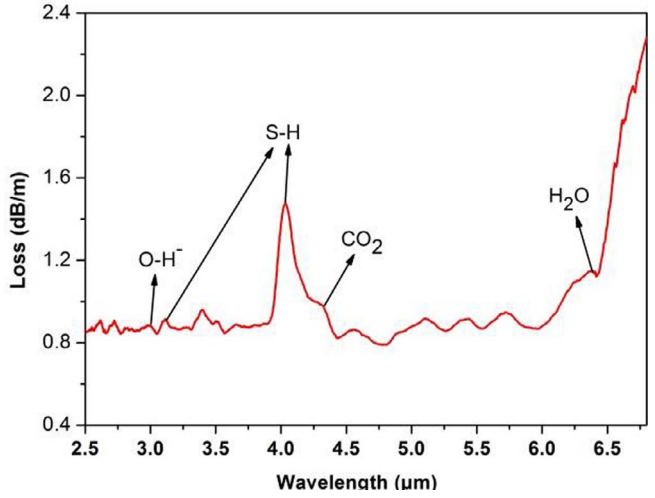

Fig. 2. Transmission loss spectrum of as-fabricated As_2S_3-$As_{38}S_{62}$ core/cladding fiber.

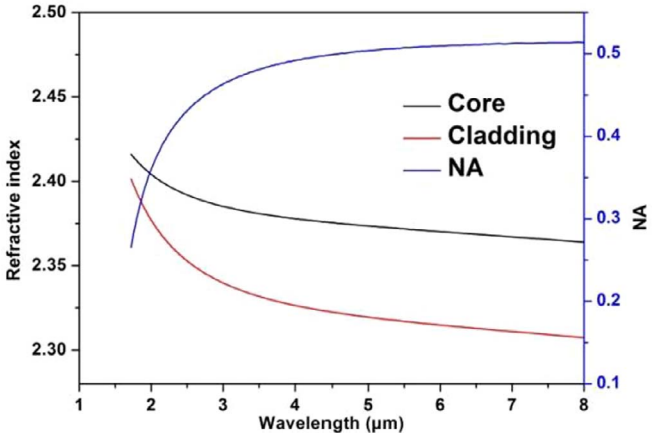

Fig. 3. Refractive indices and calculated NA values of the core and cladding glasses.

fabricated high quality ChG optical fiber connector.

2. Experimental

2.1. Fiber fabrication

As_2S_3 and $As_{38}S_{62}$ were selected as core and cladding materials, respectively. The glasses were synthesized using the conventional melt-quenching technique [23,24]. High purity (6N) As and S had been purified by distillation for three times before they were melted. The as-prepared glasses were used to fabricate a core-cladding fiber preform (Φ13 mm × 50 mm, shown in Fig. 1(a)) with core-cladding diameter ratio of 1:20 (Fig. 1(b) and (c)), using a modified one-step co-extrusion process as described in our previous work [15], Given that bare ChG fibers are fragile, we rolled 400-μm-thick polyethersulfone (PES) films up to about 1.2 mm thickness around the extruded rod and consolidated the films and rod under vacuum at 200 °C to form a preform. The preform was drawn into fiber with a cladding diameter of 198 μm using a fiber-drawing tower (SG Controls, UK). Fig. 1(d) shows a coil of final fabricated ChG fiber, and the core and cladding diameters were 10 μm and 198 μm, respectively (Fig. 1 (f)).

2.2. Optical performance test

The refractive indices of the core and cladding glasses were measured by an Infrared-Variable Angle Spectroscopic Ellipsometer (IR-VASE Mark II, J. A. Woollam, USA) at different wavelengths. The loss of the fabricated ChG fiber was measured by a Fourier Transform Infrared Spectrometer (FTIR, Thermo scientific, Nicolet 5700, USA) with the conventional cut-back technique. The FTIR light was coupled into the 2–3 m long fiber via a ZnSe lens with 0.67 NA and 12.7 mm focal length. The cross section of the fiber was observed by a Super Long Depth of View Optical Microscope (Keyence, VHX-1000E, JAPAN).

2.3. Fiber end face polishing and testing

We used a fiber polishing machine (Fiber. Lensing Machine, ULTRAPOL-1200, USA) polishing ChG fiber end face. Before polishing, the PES cladding of ChG fiber were dissolved by immersing the fiber into dimethylacetamide (DMAC) solvent. Then, the optical fiber was