Functionalization of optical fibers: The role of new materials

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Abstract: We demonstrate optical fiber functionalization with two examples a) the integration of chiral cellulose nanocrystals on fiber facets and b) the realization of a thermally tuned variable attenuator with a PDMS polymer embedded microfiber.

Keywords: Optical fibers, hybrid optical fibers, cellulose nanocrystals, chirality, PDMS.

1. Introduction

Hybrid optical fibers are a hot topic in photonics research [1,2]. Recent work from our group focuses on the passive and the reversible modifications (tuning) of the properties of photonic crystal fibers (PCFs) and tapered microfibers (TMFs) [3-5] by including materials which typically cannot be integrated into fibers using common fiber fabrication techniques. Both the incorporation of new materials and the control of fiber geometry can be achieved easily and inexpensively using a dedicated optical fiber processing workstation without the need to fabricate different fiber designs from scratch - a process that is both highly specialized and costly – while still exploiting the mature technological status of silica optical fibers. By controlling the material properties and geometrical features of these specialty fibers at the post-processing stage, key waveguide properties, such as chromatic dispersion, birefringence, nonlinearity and absorption, can be engineered and dynamically tuned for specific uses. Here, we demonstrate two examples: a) The integration of cellulose nanocrystals (CNCs) in optical fibers and b) The thermal tuning of the waveguiding properties of TMFs embedded in a PDMS polymer matrix and the realization of a variable attenuator.

2. Results and discussion

In the last few years, CNCs have attracted a lot of attention in the photonics community for their intrinsic optical chirality [6,7]. However, until now CNCs have only been studied in planar (non guiding) devices. Integration of CNCs to fiber optic systems can have an impact on the future study of chiral fiber optics. Recently, we have demonstrated [8] the fabrication of silica optical fibers incorporating chiral cellulose nanocrystal (CNC) films into their input facets (see figures 1a, b, c). To our knowledge, this is the first time that chiral CNCs have ever been integrated in optical fibers. The transmission properties of these CNC hybrid fibers (CNC-HFs) are polarization-dependent, they exhibit strong circular dichroism (33%) and they can act as all-fiber polarization filters.

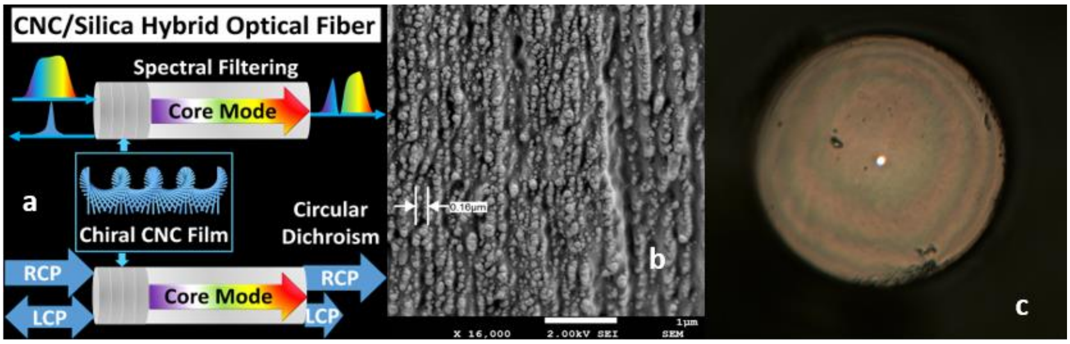

Figure 1 a) Schematic diagram of the principle of the CNC integration on the facets of opical fibers. RCP and LCP (Right and Left Circular Polarization b) SEM image of the cross-section of the layered periodic CNC film. c) Optical microscope image of a fiber facet with CNC film.

As a second example, we demonstrate a thermally tuned variable attenuator using a tapered microfiber embedded in PDMS polymer. The tapered fiber is fabricated by heating and stretching a piece of SMF-28 fiber in an oxygen/butane flame to a final taper waist diameter of 1.9µm. The taper is then placed in the fiber groove of a purpose-made PDMS substrate. The length of the groove is such that fits the entire taper waist, taper transitions and some length of the untapered fiber. A quantity of uncured, fluid PDMS mixture (10:1 ratio of base to curing agent) is then poured onto the substrate until the fiber groove is overfilled. It is then allowed to cure at room temperature (RT) for 48 hours, after which time a solid block of elastomer is formed that fully encapsulates the tapered fiber, as shown in Fig.2a. This form of packaging results in a fiber device that is very robust and can be easily handled with bare hands. The PDMS-packaged taper is then placed in a custom-built fiber furnace with controllable temperature regulation. Light from a supercontinuum source is coupled in the input pigtail of the tapered fiber, while the output pigtail is directly inserted in an optical spectrum analyzer (OSA). The thermo-optic coefficient of PDMS is negative (the refractive index increases with temperature), which results to an increased confinement of the taper mode at higher temperatures. The evolution of the attenuation of the PDMS-embedded taper with temperature at a specific wavelength (λ = 1550 nm) is presented in Fig.2b for heating up and cooling down (two cycles).

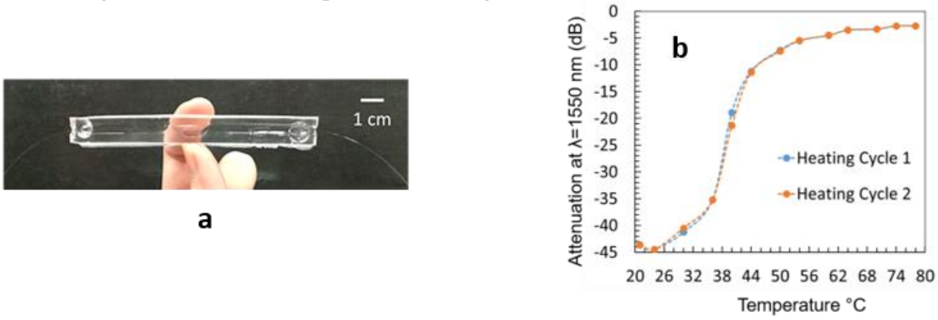

Figure 2 a) Photograph of the PDMS-embedded tapered fiber device. b) Optical attenuation of a thermally tuned tapered microfiber embedded in PDMS polymer Heating Cycle 1 (heating), Heating cycle 2 (cooling).

3. Conclusions

We demonstrate a) the integration of CNCs in optical fibers. The CNC functionalized SMF28 fibers exhibit strong circular dichroism and b) a thermally tuned variable attenuator using a tapered microfiber embedded in PDMS polymer. The incorporation of new materials in optical fibers at a post-processing stage, can potentially lead to a new class of fiber devices.

Acknowledgments

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