Pressure sensitive soft polymer optical fibers processed via microfluidic wet spinning technology

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Abstract

Polymer optical fibres (POFs) especially processed from soft and stretchable elastomers have recently demonstrated their potential for sensory applications. In our previous work, we have reported moulded polydimethylsiloxane (PDMS) based POFs, which exhibited force sensitivity as low as 0.1 N and accurate pressure sensitivity within 40 kPa to 350 kPa. The classical POF processing methods such as melt spinning, thermal drawing cannot be applied to spin thermally crosslinkable PDMS based elastomers, which calls for the need of development of new processing methods. In the current work, we have presented a new methodology called microfluidic wet spinning (MWS) for the processing of soft crosslinkable POFs. A modular microfluidic chip with co-axial capillary design, consisting of core and sheath flow channels was developed for the MWS. The flow rate optimization of sheath polymer solution (sodium alginate) and core polymer (PDMS) led to the formation of PDMS fibres encapsulated in sodium alginate shell inside the wet spinning bath. The cross-linking of PDMS inside the sodium alginate shell and further removal of the shell provided PDMS POFs. The processing-property relationship of these soft POFs was established with mechanical, surface and optical characterizations data. The modulus of these soft POFs could be tuned via simple post heat treatment process, which provided the modulus dependent load and pressure sensitivity. Moreover, MWS based soft POFs were successfully integrated to textile patch to develop wearable pressure sensor targeted for healthcare applications. The scope of this method is not only limited to the PDMS based POFs, but can be further applied to spin soft functional POFs incorporated with additives for the future development of novel soft photonic sensors.

Introduction

Soft materials offer a promising platform for the development of the photonics based sensing [1]. The typical characteristic of soft materials is low modulus range within 10^3-10^9 Pa [2, 3], which provides them easy deformation on the application of external stimulus such as mechanical forces [2]. PDMS, Hydrogels and some biological materials are the examples of the soft materials [3]. For example, such soft polymer systems for the processing of elastomeric POFs have not been completely explored to its full potential [4]. The processing of POFs from soft materials requires special processing methods such as Moulding and MWS [5-7]. In our previous work, we presented moulding strategy for the development of soft PDMS POFs for pressure sensing applications [8]. These PDMS POFs showed sensitivity to forces as low as 0.1N and accurate pressure sensing in the range 40 to 350 kPa [8]. The current work shows the application of MWS for the development of soft elastomeric POFs. To the best of our knowledge, until this date there exist only two studies, which have attempted the MWS of POFs [9, 10]. However, none of these studies has shown the continuous spinning of thermally crosslinkable PDMS in form of POFs, which is challenging system to spin because of it long curing times at low temperature conditions. Therefore, in this present work, we have demonstrated the MWS technology for spinning of the soft PDMS POFs[11]. The current work provides the brief discussion about processing and optical properties of these developed soft POFs.

Results and Discussion

The processing of soft POFs utilized the co-axial modular microfluidic chip with core and sheath channels. The optimized flow rates of the sodium alginate solution and PDMS formulation provided successfully formation of PDMS/Alginate (core/shell) fibres in the aqueous calcium chloride bath. The obtained core only POFs after the removal of alginate shell showed successful transmission of light up to certain lengths (**Figure 1a**), which is promising for sensing load, pressure and others kinds of external stimulus . Furthermore, these soft POFs were integrated to the textile patch (**Figure 1b**) for development of a wearable optical sensor.

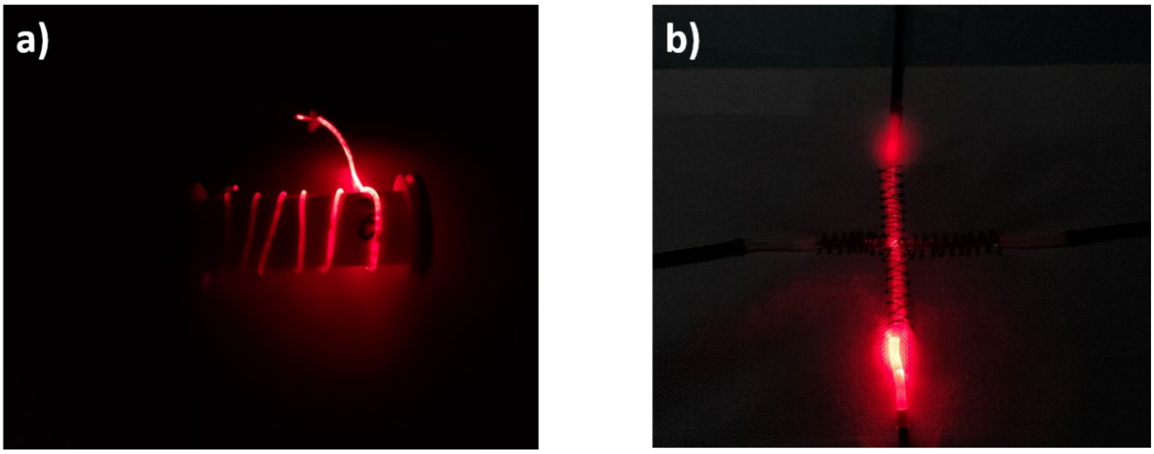

Figure 1. Digital images of soft PDMS POFs produced via MWS. a) POF showing successful transmission of light at the wavelength of 660 nm. b) Developed textile integrated soft POF based wearable optical sensor demonstrating transmission of red light with wavelength of 660 nm.

Conclusion

The current study has provided a method to spin soft PDMS based POFs via MWS. The produced soft POFs in this work possess adequate optical properties for the development of wearable optical sensors for healthcare applications.

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