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Feature issue introduction: Multimaterial and Multifunctional Optical Fibers

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Abstract: The development of multimaterial and multifunctional optical fibers is opening exciting opportunities in photonic and optoelectronic devices, optical probes, diagnosis and surgical tools, as well as advanced fibers and textiles. It also constitutes a rich platform for the fundamental study of novel materials science and processing concepts, as well as in optics and photonics. This Feature Issue is a collection of thirteen peer-reviewed articles that present original work in areas at the frontier of this emerging scientific and technological field. These contributions highlight the maturity of the techniques employed to date, their potential to further develop and the prospects for a new generation of optical fiber based devices.

OCIS codes: (160.2290) Fiber materials; (160.4670) Optical materials; (160.2750) Glass and other amorphous materials; (160.3900) Metals; (160.4760) Optical properties; (160.4890) Organic materials; (160.5298) Photonic crystals; (160.5335) Photosensitive materials; (160.5470) Polymers; (160.6000) Semiconductor materials.

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1. Introduction

Optical fibers have shown their great potential for use in wide-ranging applications including telecom to high power lasers, from lighting to structural health monitoring. They have revolutionized the way we communicate, process materials, sense, treat diseases and entertain. For decades optical fibers have largely been fabricated from a single class of materials, either inorganic glass (dominantly silica) or polymer, and a second material used to be included within the fabrication process but most of the times for protection purposes (e.g., polymide coating).

However, the last decade or so has witnessed pioneering efforts to combine highly dissimilar materials into a single optical fiber. Polymers, inorganic glasses, metals, semiconductors have all been explored in various combinations resulting in unprecedented properties and functionalities, thus paving the way to a new world of applications [1,2]. The impulse towards integrating different materials into a single optical fiber initially came from the need to mitigate the current limitations of conventional optical fibers; particularly at longer wavelengths. For example, the need to efficiently guide high power CO_2 laser beam at a wavelength of 10.6 μm led to the development of hollow polymer-glass optical fibers acting as Bragg reflector [3]. In another example, the desire for more highly nonlinear optical fibers led to the development of glass-clad crystalline semiconductor core fibers [4]. Recently the synthesis of new materials by thermally drawing optical fiber preforms has opened very interesting prospects for the onsite fabrication of exotic multimaterial fibers [5]. Continued efforts in these directions have led to advanced optoelectronic fiber configurations, multi-functional fibers as probes in bioengineering, and the ability to fabricate nano-scale objects at large scale [1,2].

This issue gathers thirteen original papers that represent the different research frontiers in this field. Novel material combinations are explored: Strutynski et al. from University of Bordeaux and University of Bourgogne, in France, developed a dual core tellurite optical fiber which is designed for future experiments involving hybrid optic/electric nonlinear effects [6]. In another research work, Guo et al. from Shangai University (China) studied the combination of YAP:Ce crystal and SiO_2 glass cladding to form a fiber for remote radiative environment monitoring and radiotherapy [7]. K. Krishnaiah et al. show the fabrication of Ytterbium based fibers for laser cooling via thermal drawing and via a crucible "direct melt" technique [8].

Novel processing including post-drawing schemes are studied. Selective injection of photopolymer materials inside a hollow core photonic crystal fiber for Bragg grating fabrication is numerically simulated by Flannery et al. at University of Waterloo (Canada) [9]. Novel effects induced by fs laser irradiation leading to Bragg grating formation on silicon

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core multimaterial fibers are demonstrated by Fokine et al. in collaboration between KTH (Sweden) and Clemson University (USA) [10]. Drug delivery using porous polymers fibers is possible by controlling water content, following a procedure described by Yu et al. at Virginia Tech (USA) [11]. Post drawing treatments are explored by Yan et al. from EPFL (Switzerland) on hybrid semiconductor-polymer fibers, paving the way towards high efficiency optoelectronic polymer fiber devices [12]. Tapering is carried out by Franz et al. from the group led by Clemson University (USA) on crystalline silicon optical fibers to improve the optical properties of the core material [13].

Novel applications are explored, by combining different materials. Using a germanium/borosilicate fiber, K. Sui et al. at Bejing University of Technology demonstrated high-speed response to a modulated 1.55 μm laser irradiation [14]. Gas sensing is demonstrated by Khalaf et al. from the group led by the University Putra Malaysia on plastic optical fiber coated with graphene/polyaniline composite [15]. Analysis of nanogap induced spectral blue shifts using metalnanowire embedded in silica optical fibers is carried out by Fatobene Ando et al. from IPHT and FSU Jena (Germany), which opens prospects for polarizers and directional couplers [16]. F. Scurti et al. show how fibers with metallic coatings can be used as sensors at cryogenic temperatures [17].

Finally, a step forward from the proof-of-concept toward the development of products has been initiated by the formation of AFFOA, a multi-hundred-million (USD) Institute aimed at transforming fabrics into high tech systems [18]. It represents a highly leveraged, government / university / industry partnership focused on the translation of these new technologies and prototypes towards commercial products. Prof. Fink, who is the initiator and now CEO of the AFFOA project, is giving an exciting perspective for the field in an invited paper, beyond just the use of fibers in the traditional Optics and Optoelectronics fields [19].

In conclusion, the Issue Editors wish to thank all the contributors for providing very interesting manuscripts. We also would like to acknowledge the Optical Society of America for supporting this effort, particularly the editorial boards and staffs for their great help in putting together this issue.