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A REVIEW ON APPLICATION OF POLYMER OPTICAL FIBER SENSORS

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Abstract:

Polymer optical fibers (POFs) have significant advantages for many sensing applications, including high elastic strain limits, high fracture toughness, high flexibility in bending, high sensitivity to strain and potential negative thermo-optic coefficients. The recent emergence of single-mode POFs has enabled high precision, large deformation optical fiber sensors. This article describes recent advances in both multi-mode and single-mode POF based strain and temperature sensors. The mechanical and optical properties of POFs relevant to strain and temperature applications are summarized in this study. POFs considered include multi-mode POFs, solid core single-mode POFs and microstructured single-mode POFs. Practical methods for applying POF sensors, including connecting and embedding sensors in structural materials, are also described. Recent demonstrations of multi-mode POF sensors in structural applications based on new interrogation methods, including backscattering and time-of-flight measurements, are outlined. The phase–displacement relation of a single-mode POF undergoing large deformation is presented to build a fundamental understanding of the response of single-mode POF sensors. Finally, this article highlights recent single-mode POF based sensors based on polymer fiber Bragg gratings and microstructured POFs.

Keywords: *Application, Material, Polymer Optical Fibers (Pofs), Sensors, Single mode operation.*

I. INTRODUCTION

Polymer optical fibers (POFs), also called plastic optical fibers, have some of the identical blessings as conventional silica optical fibers for sensing packages. These encompass low weight, immunity to electromagnetic interference and multiplexing capabilities. In preferred, POFs offer a far lower fee opportunity to silica optical fibers, albeit with higher transmission losses. POFs have hence been implemented for facts transmission over brief distances, e.g. neighbourhood to domestic net connections and automotive packages. As sensors, POFs have extra blessings, inclusive of high elastic stress limits, high fracture longevity and high flexibility in bending, excessive sensitivity to stress and capability bad thermo-optic coefficients [1]. Polymers additionally have top notch compatibility with natural substances, giving them notable potential for biomedical programs. Previously, sensors based on multi-mode POFs have been effectively applied to take blessings of those homes [2]. Lamentably, because of the characteristics of multi-mode fibers, these sensors are commonly larger than comparable single-mode, silica fiber sensors and produce lower dimension accuracy and backbone. But, recent successes in each the fabrication of unmarried-mode POFs and new interrogation methods for multi-mode POF sensors have enabled large deformation, excessive precision sensors [3].

The intention of this article is to highlight those recent advances and gift the new sensor abilties anticipated from this unexpectedly growing area. Additionally, the article will discuss the specific demanding situations and advantages to running with POF sensors compared with silica fiber primarily based sensors. Here we are able to focus on strain and temperature measurements; Researchers list many examples of chemical sensors primarily based on multi-mode POFs. The properties of POFs are first reviewed, consisting of multi-mode; solid middle, single mode; and microstructure, single-mode POFs. Next, sensible issues in applying POF sensors, consisting of connectorizing and integrating them into structures, are discussed. Finally, unique sensors demonstrating the capability of each of these POF types are highlighted [4].

II. DISCUSSION

Practical application of POF sensors

Connectorizing POF sensors

One of the most enormous, realistic demanding situations in making use of a few POFs as sensors is in getting ready the POF cease faces for connection to different optical fibers or instrumentation. On the one hand, a huge variety of connectors are commercially to be had for multi-mode POFs. Due to their huge diameter, those POFs are extraordinarily smooth to cut and take care of all through instruction. Moreover, the huge middle size reduces the center alignment necessities. Alternatively, the extraordinarily small core size and versatility of polymer materials makes connecting single-mode POFs tough. The high attenuation residences of single-mode POFs frequently requires that the POF sensor be connected to silica optical fibers as results in and from the instrumentation. Microstructure, unmarried-mode POFs have larger middle diameters, but the presence of small holes in the go-segment calls for higher manipulate to save you debris from clogging the holes or thermally brought about crumble of the holes. In this segment we talk a number of the success and unsuccessful techniques implemented to connectorizing single-mode POFs. The examples provided have all considered PMMA, unmarried-mode POFs [5].

For any optical fiber, the endfaces should first be cleaved to supply a surface this is easy and perpendicular to the axis of the optical fiber. For silica optical fibers, cleaving is performed by first notching the outer surface to produce a micro-crack within the fiber go-segment after which bending the optical fiber to propagate the crack across the crosssection. This nicely hooked up manner produces a clean fracture surface perpendicular to the fiber axis. Because of the viscoelastic nature of polymers and their low stiffness, making use of this cleaving approach to POFs produces a mixture of reducing and tearing which reduces the high-quality of the cleaved floor. The ductile conduct of the polymer produces plastic deformation at the fracture surface which warps the go-section. Whilst the PMMA is in a brittle country, the material anisotropy creates turning of the crack front and chipping, creating particles this is dragged over the fracture surface. Alternative strategies need to therefore be implemented for getting ready the POF endfaces and connecting them to optical fibers [6].

The most a success technique for realistic area cleaving of unmarried-mode, PMMA POFs has been via warm-knife cleaving, first applied to unmarried-mode microstructured POFs. The POF is set up at the platen and allowed to reach an equilibrium temperature before slicing. The slicing pace is controlled with a stepper motor and the blade slicing surface rotated in order that every POF is cut with a pristine blade surface. A writer performed a cautious evaluation of the cleaved POF end face for more than one fiber temperatures, blade temperatures and reducing speeds. The PMMA become ductile within the range 25–100 ◦C, with a transition in cloth shape round 60 ◦C (the glass transition temperature turned into round one hundred fifteen ◦C). The authors determined that the first-rate results were received when the blade temperature was barely lower than the fiber temperature and both had been round this structural transition temperature. Furthermore, lower blade cutting speeds produced higher endface surfaces. The surest consequences have been acquired for the subsequent stages: fiber temperature 70–80 ◦C, blade temperature 60–70 ◦C, blade speed 0.07–zero.five m s−1. The POF additionally required approximately 90 s to equilibrate to the platen temperature earlier than cutting.

A creator performed hot-knife cleaving of stable core, unmarried-mode PMMA POFs and determined best stages for cutting: (1) fiber temperature 30–forty ◦C, blade temperature eighty ◦C and (2) fiber temperature about 80 ◦C, blade temperature 80 ◦C. A negative aspect effect to heating the optical fiber above 80 ◦C for more than 6 min become embrittlement of the POF, tested via tensile testing of POFs with and without warmness publicity. Consequently the 30–40 ◦C fiber temperature range become advocated for exercise. The distinction in temperature tiers among this and the work of an author highlights the function of various fabrication tactics at the most beneficial temperature variety for person unmarried-mode POF configurations. Ultimately, chilling of the POF to low temperatures reasons chipping of the optical fiber and produces bad high-quality surfaces. Two other a hit methods of cleaving singlemode POFs are UV laser cleaving and centered ion-beam machining. Both of those strategies produce the very best great endfaces of the POFs for laboratory environments, but nor is practical for fast connecting of sensors in discipline applications.

As soon as the POF has been cleaved, the second step in making ready the sensor is to attach the POF to either some other unmarried-mode POF or to a silica, unmarried-mode optical fiber. The fulfillment of this coupling depends at the core alignment of the fibers, the gap distance between the two fibers, the diploma to which the endfaces are parallel and the distinction in middle sizes between the two fibers. For laboratory experiments, freespace coupling of lightwaves into the POF without a doubt produces the bottom coupling losses. However, in maximum area packages a more ruggedized connector is required that does not require precise alignment of the fibers and stops the fibers from transferring relative to each other. The high attenuation of single-mode POFs also approach that the sensor gauge period is regularly short and those connectors want to be mounted on the shape itself.

The most a hit technique to gain a field appropriate connector with extraordinarily low loss has been to first cleave the POF as mentioned above and then to glue it right into a ferrule for coupling. An author coupled pre-cleaved, singlemode POFs to unmarried-mode silica optical fibers the use of ferrules from general unmarried-mode FC connectors. The single-mode POF diameter was one hundred twenty five µm, which was perfect for alignment of the fibers within the ferrule. This connector became then glued to the floor of tensile specimens and survived beyond the software of 10% axial stress to the POF. A second method, based on inserting the POF right into a entire FC connector and polishing the endface, changed into unsuccessful. The PMMA cloth turned into extra bendy than the encircling ferrule, resulting in motion of the POF inside the connector at some stage in sprucing. Commonly, the POF fractured during the sprucing method, resulting in a POF pass-section which became no longer coplanar with the ferrule surface. Moreover, the submersion of the POF surface prevented the FC connector from transmitting lightwaves efficaciously [7].

The bigger center size of unmarried-mode microstructured POFs approach that they're often better ideal for connection to multi-mode instead of single-mode silica fibers. Lwin and Argyros measured coupling losses among unmarried-mode microstructured POFs of various middle diameters and multimode, silica optical fibers (a hundred μm center diameter) the usage of business SMA connectors. The input losses from the silica fiber to the microstructured POF were in most cases due to overfilled release situations because the silica fiber core diameter changed into notably larger than the POF center diameters. In the output coupling from the POF to the silica fiber, overfill did no longer arise and the loss became negligible. In overall, coupling losses up to 1.5 dB had been measured at a wavelength of 650 nm for the 24 μm core POF; this is underneath the POF facts verbal exchange requirements of two dB.

POF integration into material systems

Much like silica optical fiber sensors, POFs can be incorporated into structural substances for in situ strain and temperature tracking. While many of the combination troubles are comparable among silica fiber and POF primarily based sensors, a few variations are vital. In this phase, we summarize the knowledge won from 3 current research on POF sensors embedded in material structures; one in a concrete infrastructure machine, one in a geotextile and the alternative in a tumbler fiber–epoxy laminate.

A creator investigated the suitability of single mode POF sensors for in situ tracking of civil infrastructure systems. Unmarried-mode, PMMA POFs (diameter 115 μm) have been partly embedded in the course of casting of 3 common civil structural substances: mortar, hydrostone, and cement paste. The POFs had been then pulled from the forged specimens at a charge of two five tensile checking out device to evaluate the bonding electricity. From these results we can infer that the enormously large particle length of the mortar prompted premature failure of the POF, whilst the POF did not sufficiently bond to the hydrostone. The cement paste turned into consequently the optimal cloth gadget wherein to embed the POF because of the strong bond between the cement and the POF. Presumably, that is because of the small particle size of the cement paste [8].

The second one concern whilst embedding POF strain gauges in concrete structures is the massive shrinkage of the concrete for the duration of remedy and ability optical energy transmission losses inside the POF as a end result. To mitigate the results of the residual stresses, the POF turned into first embedded in a small pre-cast concrete block. The block turned into then fixed to the frame before casting of the strengthened concrete structural thing. The ribbed edges of the small blocks permit better bonding of the precast block to the surrounding concrete. No huge loss in optical transmission turned into measured after embedding and curing of the concrete. The pre-forged block was then embedded within the reinforced concrete structure, which changed into then loaded until failure. The POF confirmed no seen damage after the very last stages of the take a look at [9].

A creator embedded a PMMA multi-mode POF immediately right into a geotextile. On this application, the POF turned into unfastened to slip in the woven textile material. The sensors survived the set up process of embedding the geotextile into a railway embankment and have been nonetheless functioning nicely after nine months of operation.

Another writer lately embedded multi-mode POFs in glass fiber–epoxy laminates to evaluate the influence of the POF on the laminate microstructure and capability changes to the POF fabric at extended temperatures. The laminates had been cured at a constant temperature of 60 ◦C. 3 exclusive diameter multi-mode POFs have been embedded: 1 mm, 500 and 250 μm. At some stage in the curing procedure, the POF backscatter changed into measured the use of an optical time area reflectometry (OTDR) machine and found out no adjustments to the essential properties of the POF (PMMA) at this curing temperature and residual strain stage. The 1 mm diameter POF created an excessive amount of of a disturbance to the laminate geometry and ended in big air pockets surrounding the POF, consequently it became deemed no longer appropriate for integration. The amount of air and epoxy resin surrounding the 500 and 250 μm diameter POFs become notably less. As expected, the least disturbance changed into created with the aid of the 250 μm POF. But, this fiber was now not of a preferred length and consequently had a much larger attenuation than the greater standard 500 μm POF. Therefore, the 500 μm POF became selected because the optimum diameter for embedding. In comparing the POFs diameters to traditional silica optical fibers, it have to be stated that the POFs did now not require an extra coating. While fashionable silica optical fibers are 125μm in diameter, with delivered coatings (e.g. Polyimide) the actual embedded fiber diameter is often within the variety 200–250 μm.

In the end, A writer tested a laminate to failure in anxiety with an embedded 500 μm POF to assess the bonding between the POF and host cloth. The POF survived past the failure pressure of the glass fiber–epoxy composite (1.6%) and continued to offer true transmission even after failure of the laminate. The measured growth in backscattering lack of the POF before and after the laminate failure changed into only 0.6 db. These results indicate that the POF keeps its ductility even after the multiplied temperature cure of the laminate [10].

III. CONCLUSION

Recent advances in polymer optical fiber and interrogator era have brought about POF primarily based sensors which might be rapidly permitting high deformation, high accuracy optical fiber primarily based pressure and temperature sensing. Area programs with multimode POFs have also tested their compatibility with structural packages.

Fields wherein POF sensors can have strong near term influences are most probably to be the monitoring of large structures or geotechnical foundations wherein low price tracking of huge areas can be performed. Even as still retaining the blessings of silica optical fiber sensors, POF based sensors also offer the flexibility to be integrated into complicated structural geometries. Such deformation capabilities were carried out to the dimension of crack openings in concrete, the deformation of soil systems and the deformation of textiles. These are all programs where silica based totally optical fiber sensors present limitations. The introduction of new POF fiber types and materials additionally has wonderful promise for the near destiny. Whilst nevertheless at a development level, the capability for polymer fiber Bragg grating sensors or micro structured POF sensors that could deform alongside a flexible shape will be integrated into thin movie sensing devices or structural skins for a diffusion of erospace, marine and civil engineering programs.

Subsequently, this article emphasizes the significance of which includes stress charge and environmental conditions inside the calibration of the response of POF sensors. Moreover, it's miles critical to calibrate the unique POF kind to be implemented as a sensor due to the variations in material houses, which range drastically greater than those of equivalent silica primarily based optical fiber sensors.

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