National Textile Center

FY 2003 (Year 12) Continuing Project Proposal

Project No.

M02-CL06

Competency: Materials

Photonic Crystal-Based Polymer Optical Fibers

Project Team:
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Objective:

This Research will fabricate optical fibers which use a photonic crystal approach to guiding light. These fibers will be a low-loss guide with tunable characteristics that are fully integrateable into a textile composite. We propose to develop methods for the manufacture of photonic crystal fibers, make hollow optical fiber composites and finally demonstrate tunability in these fibers. When accomplished, these objectives will yield a fully integrated textile composite capable of transmitting and receiving information.

Progress Statement:

Initial trials have attempted to produce photonic crystal fiber like structures by direct melt spinning [1]. This approach is attractive for a number of reasons. Firstly, if successful it offers the possibility of producing enormous continuous lengths and large amounts of optical fiber, thus eliminating the need to join short lengths of photonic fiber, which proves to be extremely difficult. The joining/welding of fibers each containing multiple holes is not an easy option. Also the throughput rates available on melt spinning these fibers would be extremely high. Whereas draw tower technology production rates for producing PCFs might be in the region of 5-10m/min, melt spinning of such fibers could occur at 2000/3000 meters/minute.

Initially we chose to produce a simple sixteen hole fiber structure. Fibers were made by melt spinning using a twin screw extruder. Two polymer components were chosen for the fiber base and initially these were chosen for ease of use rather than optical properties associated with them. The polymers used were PET and Nylon 66. A dissolvable polymer, polyvinylalcohol, was chosen to produce structured hole precursors. This component is removed post fiber production to leave holes in the fiber as required. The objectives of the spinning runs were to ascertain the accuracy of size and shape of the holes and determine the suitability of this method. A number of spinning runs were performed. These examined the effect of base polymer and dissolvable component ratio, windup speed and draw effects of the different components. The analysis of these fibers in terms of their optical transmission properties is still ongoing.

Figure (1) Initial attempts to produce a photonic crystal fiber-like structure by direct melt spinning (fiber diameter approx 40 microns)

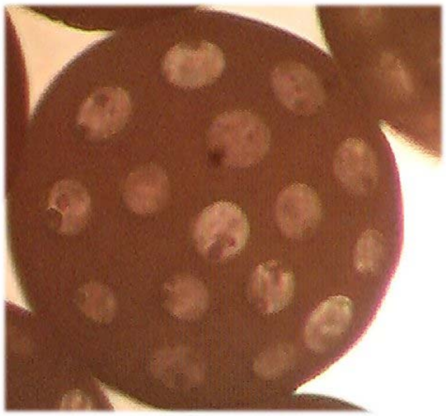


Figure (1) PET

Figure (2) Nylon

Not all the runs were as successful as that shown in Figure (1) and in particular, the structures formed with PET were much better than those from nylon due to polymer compatibility with the dissolvable component (see Figure (2)). The accuracy of size and placement of the holes still needs improvement. However, the spinning trials have shown PCF like structures can be formed and we hope to achieve better fiber structures shortly. Interestingly the properties of the fibers produced (Figure 1) are not unlike those of conventional textile fibers in terms of tensile properties, with an elongation at break of 21% and tenacity of 1.43 g/denier which is encouraging from the point of view that we are trying to achieve fully integrated textile composite capable of transmitting and receiving information.

Next Year's Goals:

Next years goals are essentially to produce photonic crystal fibers optical fibers with improved microstructural characteristics, i.e, improved hole accuracy, size and placement with a larger number of holes and optimized design to provide a fiber with low loss characteristics. Fibers will be produced with the desired microstructural characteristics from conventional optical fiber polymers such as PMMA, rather than PET as used in our initial work and will be characterized for optical properties as well as "conventional" fiber properties.

Future goals

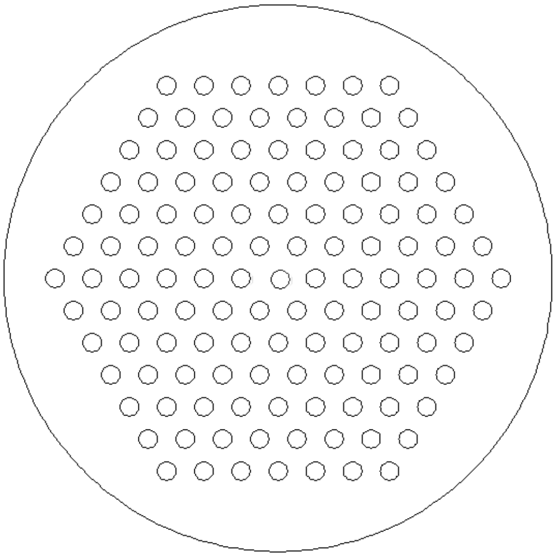
Upon successful production of polymer PCFs further modification of the fibers will be performed to assess the degree of tunability available with these fiber structures. It seems likely that given the chemical flexibility offered with polymeric optical fibers we will have to assess a number of possibilities such as the inclusion of dyes, photochromic materials and electo or magneto-optic materials as well as nanoparticles.

Approach:

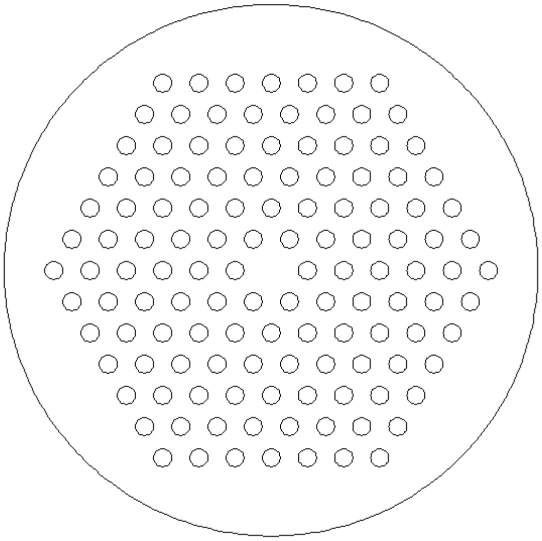
In the coming year we will produce fibers of the 6 layer concept designs shown below to obtain true PCFs with low and high index fiber defects/centers. In structure (B), the central hole is absent. This high-index "defect" in the repeating structure acts like the core of an optical fiber. Future work will aim to produce polymer fibers with photonic band gap effects by making use of a accurate hole placement on a heavily layered repeating structure with a scale of the order of optical wavelengths across the fiber section. A change from conventional textile fiber polymers to optical grade polymers will be made once forthcoming production runs prove successful. The fibers will be analyzed for mode guidance to check for single mode at optical wavelengths. Once the base PCF structures have been made, further work will examine the optical properties of such fiber systems under mechanical strain and chemical swelling.

In structure A (predicted fiber to be 80 microns in diameter), the core region has a hole, which is termed a low-index defect. The cladding therefore effectively will have a higher refractive index than the core, and so guidance by conventional total internal reflection is not possible. This kind of fiber should be highly dispersive and exists/is useful only for narrow wavelength ranges. Confirmation of this will be explored since once our fiber is produced and is illuminated with white light it should transmit strongly colored symmetrical mode patterns. Fibers will also be characterized by tensile testing (you've mentioned this earlier), thermal analysis (DSC TGA) and cross-sections will be examined by optical microscope as well as by SEM/ TEM and possibly AFM.

(A)



(B)



An alternative approach to making PCFs and one that we are currently pursuing with the intension of taking further (as a new draw tower is now available) is to stack relatively thick hollow fiber structures into tube like arrangements to make holey preforms. These preforms will then be drawn down in a conventional manner to produce a variety of PCF structures. Stacking and drawing will produce PCF structures of limited length but perhaps with greater accuracy than those achievable by direct melt spinning.

Outreach to Industry:
A number of established telecommunication companies have interest in low loss tenable polymer optical fibers as low loss optical guides.

New Resources Required: NONE