Distributed Fiber Optic Sensing: Measuring Strain with PEEK-Buffered Fiber Optic Sensors

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Introduction

Optical fibers are manufactured with a variety of coatings to shield the fibers from abrasion and preserve their strength. The user's end application and environmental conditions inform the choice in fiber coatings. Luna's standard strain sensors are made using polyimide coated optical fibers. This coating type was selected for its excellent strain transfer properties. As a comparison, the backing of resistive foil gages is also made of polyimide. While polyimide-coated optical fibers work well when bonded to metals and composites, or when embedded within composites, it might not be suitable for applications where the fiber will be subjected to large impingements transverse to its axis. As an example, for applications where the fiber optic sensor is to be embedded within concrete, the user might want to up-jacket the fiber to a more ruggedized configuration for better protection to casting, aggregate shifting or crushing, and the long term alkaline environment of the concrete. An alternative to polyimide coating is PEEK-buffered (Polyether Ether Ketone), polyimide coated low bend loss optical fiber. PEEK is resistant to chemicals, performs well at high temperatures up to 240°C, and is mechanically tough. This Engineering Note discusses strain measurements obtained from PEEK fiber compared to polyimide fiber, when bonded onto a fiberglass coupon and loaded in tension.

Test Setup

A strain sensor, the first half of which was polyimide coated low bend loss fiber (standard strain sensor) and the second half PEEK-buffered fiber, was made as depicted in the schematic of Figure 1. This sensor was bonded to a 3/4" wide, 1/16" thick fiberglass coupon with M-Bond 200. The PEEK fiber has a larger diameter of 500 µm, compared to the polyimide fiber's 150 µm. Therefore more M-Bond 200 had to be applied in order to create a good meniscus between the fiber and the coupon surface.

The sensor was looped back to create two passes of polyimide fiber and two passes of PEEK fiber.

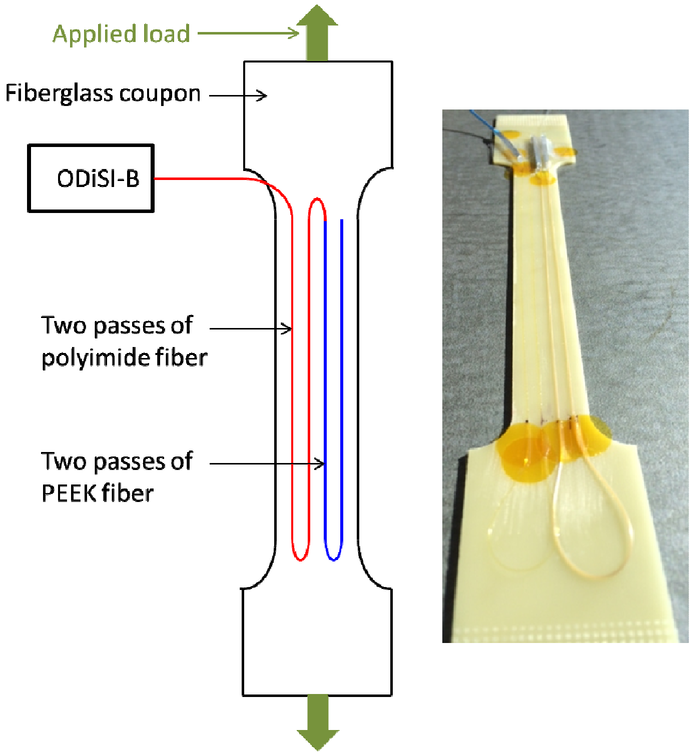

Figure 1: Diagram and image of fiberglass coupon with fiber sensor bonded onto it

The instrumented coupon was tested in an MTS load frame. Load was applied in steps of 100 lb up to 700 lb, corresponding to strain increments of approximately 620 με. This loading cycle was repeated three times. Strain data was taken with an ODiSI-B in high acquisition rate mode – 5 mm gage length with 5 mm sensor spacing at an acquisition rate of 250 Hz. Data was recorded at 5 Hz.

Results

The difference in fiber coating results in a slight difference in strain coefficient. The coefficient for the polyimide fiber is -6.668 με/GHz while the coefficient for the PEEK fiber is -6.605 με/GHz. Figure 2 shows strain along the length of the fiber at maximum load. The bonded regions experience ~4750 με. A couple of locations along the PEEK fiber are seen to have become unbonded from the coupon (Figure 2, circled) during loading. Perhaps a more careful application of epoxy or a choice of a more viscous epoxy would help fiber adhesion to the coupon surface. Within each fiber pass, there is visually no difference between measurements obtained from the polyimide fiber (red) compared to PEEK fiber (blue).

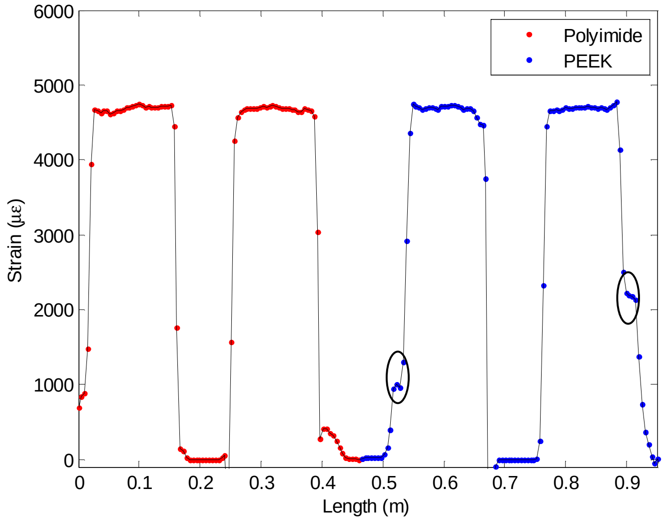

Figure 2: Plot of strain along sensor length

The correlation of strain measurements from the two fiber coatings is further shown in Figure 3 below. A plot of strain from the PEEK fiber against strain from the polyimide fiber follows a linear fit (R^2=1), with a slope of 1.0.

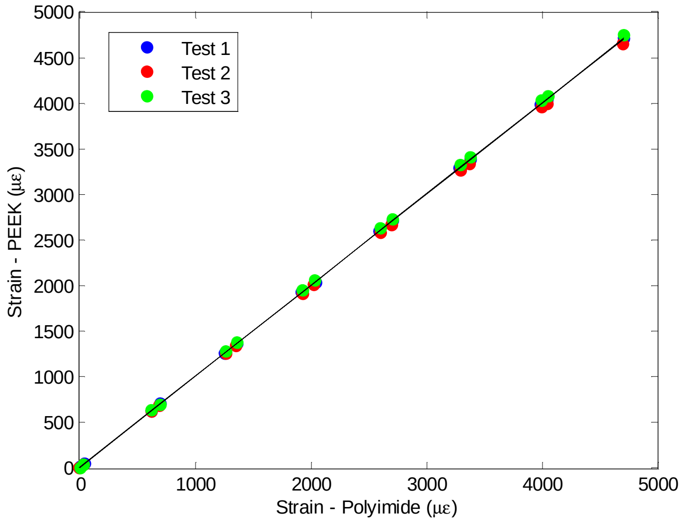

Figure 3: Plot of strain from PEEK fiber against strain from polyimide fiber

Summary

The PEEK fiber displays similar performance to the polyimide fiber, in terms of its strain transfer coefficient, even at strain levels approaching 5000 με. Its added mechanical toughness makes it an ideal candidate to be considered for tests in harsher environments, for example when embedding within concrete.

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