Stripping Optical Fibers Utilizing the Fujikura Polyimide Coating Stripper (PCS-100)

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Abstract

The recently released Fujikura PCS-100 is a novel stripping tool for removing polyimide coating from optical fibers. Extensive testing on the stripping ability of this equipment has demonstrated repeatable high tensile strength values with narrow distributions, both for polyimide and acrylate-coated optical fibers. Additionally, the PCS-100 stripping process has been shown to create an evenly beveled coating edge, ideal for applications that include recoating.

Keywords: Polyimide coating, optical fibers, stripping, acrylate coating

1. Introduction

Polyimide coated optical fibers are widely utilized throughout industries whose applications require high levels of heat and chemical resistance. These applications range from fiber optic sensing assemblies in the oil and gas industry to endoscopic surgical devices in the biomedical industry [1,2]. A crucial part of preparing polyimide fibers for use in these applications is removing polyimide coating. Several methodologies are available for achieving this goal, with the more prevalent being chemical stripping using heated sulfuric acid and flame-based removal [3,4]. However, both of these methodologies have significant drawbacks. Stripping with heated sulfuric acid imparts a significant exposure risk onto the operator and requires substantial documentation, while flame-based removal of polyimide coatings often results in charring the exposed glass. A precisely-controlled, mechanical method for stripping these fibers is available in the recently released Polyimide Coating Stripper (PCS-100) by Fujikura (Fig. 1).

Fig. 1: Fujikura's Polyimide Coating Stripper (PCS-100)

1.1 Standard Stripping

The PCS-100 has two stripping methods: standard and window offset stripping. The standard stripping method is used for applications involving standard fiber preparation, with only one even coating edge needed. If two beveled coating edges and/or recoating is a requirement of the application, it is recommended that the window offset stripping methodology be used (see section 1.2).

Standard stripping, like window offset stripping, utilizes two key parameters to optimize strip quality: shaving number and blade height. Shaving number is the number of total passes the blade makes across the fiber length. After each pass, the fiber holder stages rotate in angular intervals determined by the shaving number. For example, a shaving number of six denotes that the blade will make six total passes and the fiber holder stages will rotate in six 60° increments (Eq. 1).

$$f(\chi) = \frac{360^\circ}{\chi}$$

Eq. 1: Total Number of strips, where "x" is equivalent to [Shaving Number] and $f(\chi)$ is equivalent to angular rotation of the blade after each stripping pass

Blade height is the vertical position of the blade and is adjustable from -150 µm to 150 µm. Decreasing or making this value more negative will lower the blade closer to the fiber. Conversely, increasing or making this value more positive will lift the blade away from the fiber. Performing a standard strip can be accomplished by optimizing these parameters based on observations of the end product (Table 1).

	BLADE HEIGHT	SHAVING NUMBER
Blade does not strip fiber	Decrease	No change
Fiber breaks	Increase	Decrease
Some coating left unstripped	Decrease	Increase

Table 1: Stripping optimization matrix for PCS-100

1.2 Window Offset Stripping

Window offset stripping can be utilized when an application requires two clean, evenly beveled coating edges. If this area is uneven (Fig. 2a), the potential is created for an air pocket to form during recoating, thus impacting the quality of the final product. Two even coating edges create an ideal surface for recoating (Fig. 2b). The window offset stripping process is used to achieve such results.

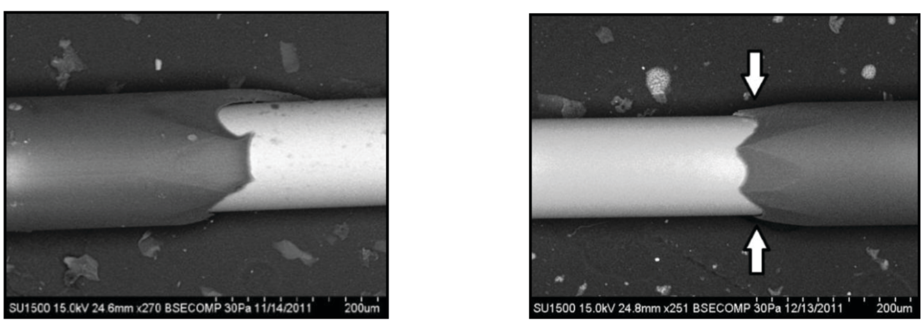

Fig. 2a-b: SEM images of stripped polyimide fibers with uneven (left) and even (right) coating edge faces

The window offset stripping process involves the blade stopping its stripping path at a predetermined distance from the end of the desired strip length. This distance is determined by optimization, varying with fiber type, and is referred to as the window offset. For example, if the desired final product is a 30 mm strip with two evenly beveled coating edges, the parameters would be Strip Length = 30 mm and Window Offset = 4 mm. This would result in the blade path stopping after 26 mm (Fig. 3).

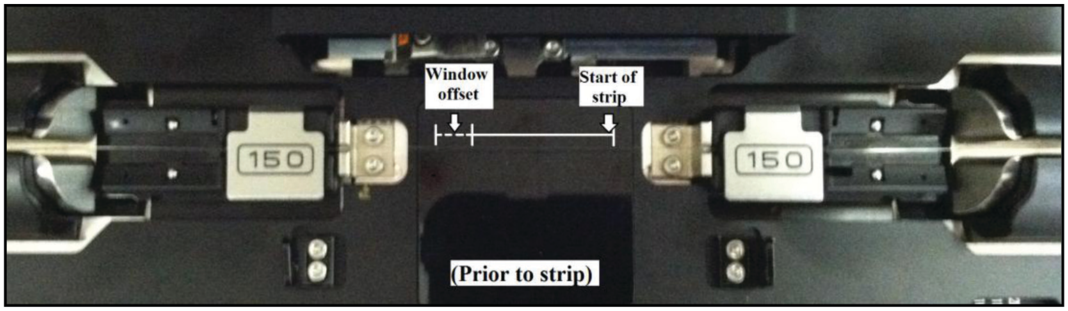

Fig. 3: Window offset: The first step in this process is a strip from right to left, stopping at the predetermined distance referred to as the window offset.

After the fiber has completed the set number of rotations and accompanying strips, the right side coating edge will be evenly stripped and the left side will be uneven. To evenly strip the left coating edge face and end up with the desired final strip length, the fiber holders need to reversed and the process repeated (Fig. 4a-c).

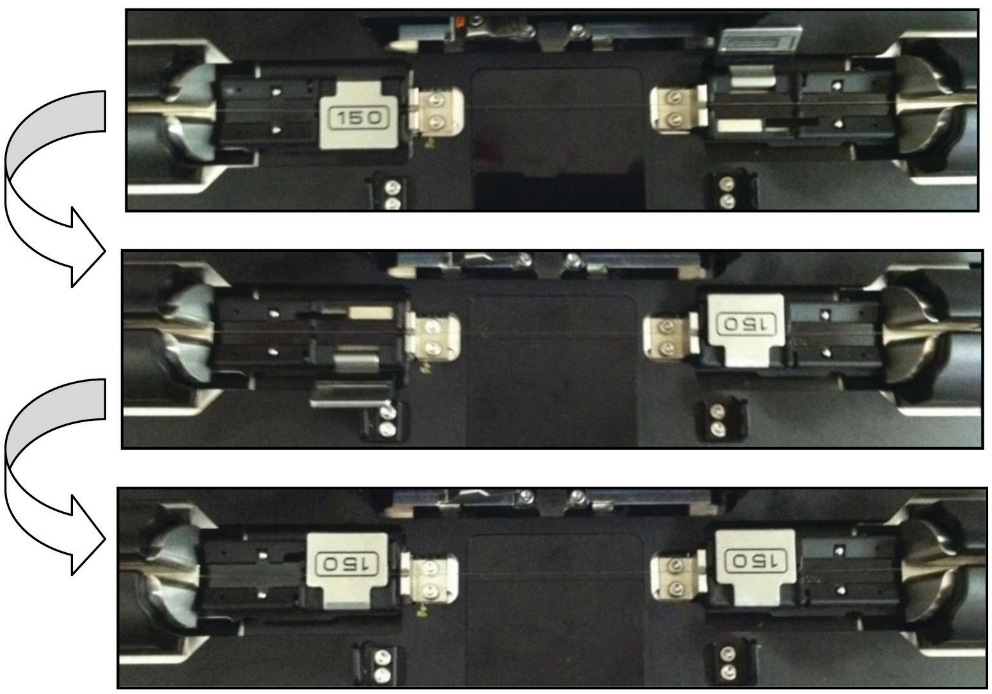

Fig. 4a-c: (from top to bottom) To reverse fiber holder positions (a) Unclamp right fiber holder (b) Lift both fiber holders from stages and switch positions (c) Reclamp left fiber holder

After fiber holder reversal, the stripping process is repeated. This will create an evenly beveled coating edge on the right and stop short of the evenly beveled coating edge created in Fig. 3, prior to fiber holder reversal. The final product will be a stripped length of optical fiber with two evenly beveled coating edges (as seen in Fig. 2b).

2. Coating-specific Stripping Applications

2.1 Polyimide-coated Fibers

As previously mentioned, polyimide coating is utilized for optical fiber applications that require high levels of heat and chemical resistance found throughout the oil/gas and biomedical industries. Due to the highly volatile environments in which these fibers are utilized, it follows that the stripping process must be highly controlled and result in cleanly stripped fibers with even coating edges while still maintaining an acceptable level of tensile strength.

The optical fiber manufacturer Verrillon produces numerous types of harsh environment fibers, with an emphasis on singlemode and multi-mode polyimide-coated optical fibers (Table 2).

FIBER TYPE	CORE/CLAD/COATING (µm)	COATING	TEMPERATURE
VHS300 (SMF-40-P-125-1)	9.2/125/155	Polyimide	-65°C to 300°C
VHM3000 (MMF-50-6-P-125-6)	50/125/155	Polyimide	-65°C to 300°C

Table 2: Selected Fiber Specifications for Verrillon VHS300 and VHM3000

Testing of stripped quality yields numerous data points, such as coating edge images and tensile strength measurements. These two data points serve as indicators of the overall performance of optical fiber stripping equipment.

Coating edge quality is an important aspect in evaluating the efficacy of an optical fiber stripping tool. It is of paramount importance that this interface is even and lacks any debris (see Section 1.2). A variance from these criteria could result in air pocket formation, poor cleave angle, and decreased splice quality. The optical fiber stripping quality of the PCS100 has been extensively tested using Verrillon's VHS300 and VHM3000 polyimide fibers. The stripping parameters utilized for assessing the performance of the PCS100 (Table 3) yielded stripped polyimide coated fibers with high average tensile strength and narrow distribution values (Fig. 5, Table 4).

	VERRILLON VHS300 POLYIMIDE FIBER	VERRILLON VHM3000 POLYIMIDE FIBER
Shaving Number	8	8
Stripping Length	25 mm	25 mm
Coating Diameter	155 µm	155 µm
Cladding Diameter	125 µm	125 µm
Blade Height	0 µm	0 µm

Table 3: Stripping Parameters for VHS300 and VHM3000 Polyimide-coated fibers

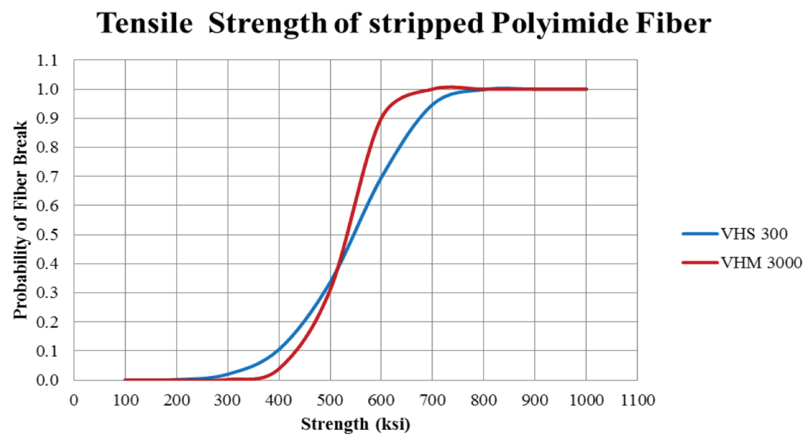

Fig. 5: Tensile Strength for VHS300 and VHM3000 polyimide-coated fibers. Displays probability of fiber breakage at increasing tensile strengths.

	VERRILLON VHS300 POLYIMIDE FIBER	VERRILLON VHM3000 POLYIMIDE FIBER
N =	20	20
MEAN	544.4	527.4
STD	91.1	54.0
MAX	697	609
MIN	417	423

Table 5: Raw tensile strength data analysis of stripped Verrillon polyimide-coated fibers

2.2 Acrylate-coated Fibers

Acrylate-coated fibers are ubiquitous in fiber optic applications. The traditional method for stripping such fibers involves utilizing a tool similar to a wire stripper. While this technique is easily accomplished in a timely manner, it often results in poor coating edge quality (Fig. 6a). When stripping the same fiber with the PCS100, a substantial improvement can be seen in coating edge quality (Fig. 6b).

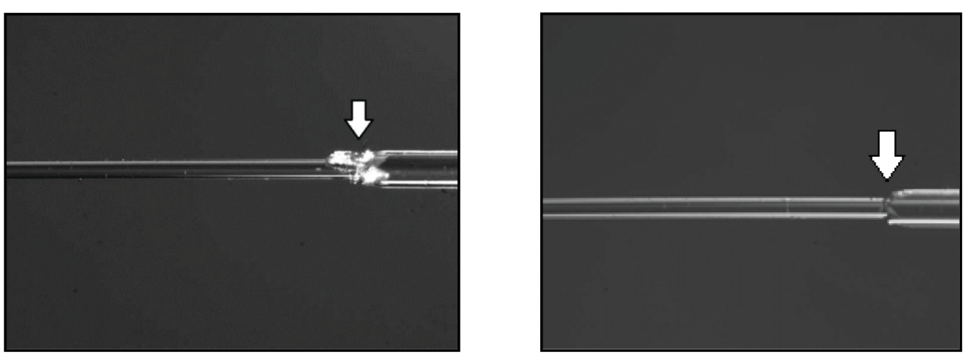

Fig. 6a-b: Light microscopy images of SMF acrylate-coated fiber stripped with a tool similar to a wire stripper (left) and the same fiber stripped with the PCS100 (right). Arrows indicate coating edge.

Tensile strength is another important indicator of optical fiber stripping quality. Any damage to the fiber cladding by the blade would manifest in low tensile strength results. For acrylate-coated fibers, a high average strength and a relatively narrow distribution of strength values was obtained (Fig. 7, Table 5).

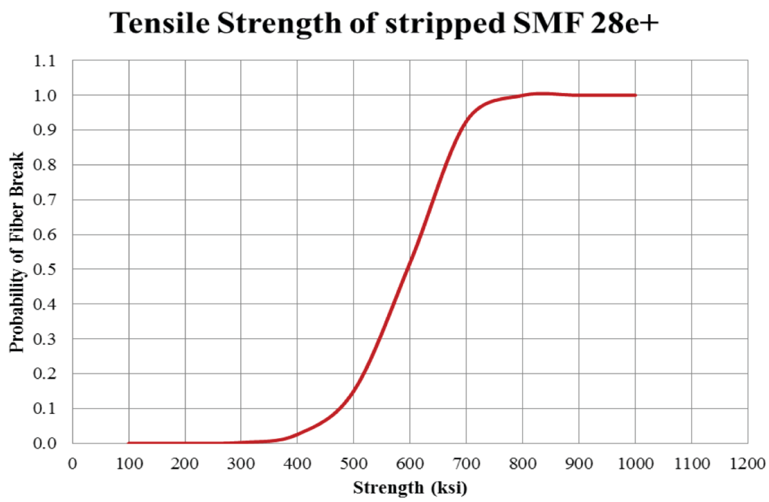

Fig. 7: Tensile Strength of Corning SMF 28e+. Displays probability of fiber breakage at increasing tensile strengths

	CORNING SMF 28E+ ACRYLATE FIBER
N =	20
MEAN	588.6
STD	79.1
MAX	718
MIN	454

Table 4: Raw tensile strength data analysis of stripped Verrillon polyimide-coated fibers

3. Summary

Harsh environment fiber optic applications are widespread throughout multiple industries. The worldwide increase in oil and gas exploration has been a driving force in the use of harsh environment fibers, with a specific emphasis on polyimide-coated fibers. With this trend comes the need for a repeatable and precise methodology for stripping polyimide to allow for splicing onto various temperature and pressure sensing assemblies. The PCS-100 has been shown to produce repeatable polyimide strips of high coating edge quality and tensile strength. Additionally, this equipment can be utilized for numerous acrylate-coated fibers to achieve even, beveled coating edges for recoating applications, making the PCS-100 a versatile fiber optic preparation tool for numerous applications.

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