UV Curable Upjacketed Optical Fiber Coatings with High Productivity and Superior Strip Performance

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Abstract

As the demand for fiber to the premise continues, there is a need for increased design flexibility and productivity in optical fiber cables. New types of materials that can meet such requirements are certain UV curable upjacketed coatings. The UV curable upjacketed coatings not only offer performance advantages over the traditional thermoplastic materials, including increased processing line speed by 2 to 4 times, easy accommodation to variations in outer diameter of the cable design, and increased fiber strip performance; but also they provide degrees of non-flammability while being halogen free. This allows for flexibility in cable designs to enhance performance and cost saving.

Introduction

Tight buffered cables have been utilized for premise applications for over 20 years. Traditionally the tight buffer design consists of a thermoplastic material that is extruded over a 250µm coated optical fiber resulting in a 900µm upjacketed fiber. The thermoplastic materials include Polyvinylchloride (PVC), Nylon 12, and various grades of Polyethylene. Variations of these materials are utilized to produce cable designs that meet the Telcordia GR-409 cable specification[1] and NEC building code requirements for flame retardancy. However they often pose processing issues such as slow line speeds, high scrap rates, and are limited to 900µm designs.

UV curable resins offer a desirable alternative to traditional thermoplastic materials. The UV curable Bufferlite™ materials designed by DSM Desotech have been formulated for fast line speeds, low scrap rates, offer design flexibility, and result in excellent outer diameter consistency. These types of materials have been used in the optical fiber industry in various cable designs for over 25 years and protective coatings for the glass optical fiber. They are also environmentally friendly; the formulations are halogen and lead free and also produce low fumes and volatiles during processing.

Design flexibility is important as the need for fiber to the home initiative continues to grow. UV curable resins allow varying outer diameter cables to be constructed to 400-500µm resulting in more compact cable designs. This type of cable design has been the current standard in fiber to the home (FTTH) applications in the Japanese marketplace for the last three years. Also new types of designs have been achieved with clear coatings. They include a colored fiber to be upjacketed to varying diameters and use the colored or inked fiber under the buffered layer for identification. The process simplifies production and allows for further fiber identification after stripping.

UV Curable Resin Physical Properties

DSM Desotech has formulated three main product lines to meet the different design demands in the telecommunications marketplace. The first product line is the Bufferlite™ DU-1000 series. These products are used in a dual coating application as a clear softer inner layer coating. These materials are over coated with a harder material from the Bufferlite™ DU-2000, Bufferlite™ 3000 series, or a thermoplastic material. For the thermoplastic applications, this softer layer is utilized to increase the strip performance. However, the performance is limited in comparison with the dual or single coat UV curable solution. This type of design is illustrated in Figure 1.

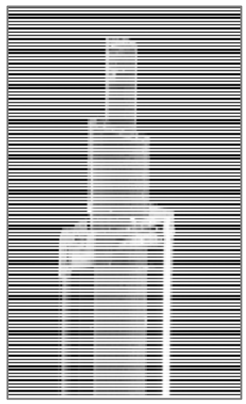

Figure 1. Dual Coat 900µm Upjacketed Fiber with Bufferlite™ DU-1002 as the inner coating and Bufferlite™ DU-2002 as the outer coating.

The Bufferlite™ DU-2000 series is a clear outer layer series with multiple modulus levels for varying applications. The Bufferlite™ 3000 series is composed of two individual pigmented series. Each series contains 12 Munsell colors, which is comparable to the traditional thermoplastic materials utilized in this application. The first series is the Bufferlite™ DU-3007 series. This series is the flame retardant material that is UL94 VTM-0 certified and is utilized for 900µm applications. The flame retardancy and smoke generation have been demonstrated in commercial cables[2]. The second series is the Bufferlite™ DU-3038 series. This series is not fully rated for flame retardancy, but does contain flame retardant additives. Therefore it has some flame retardant characteristics; the 500µm upjacketed fiber with this material passes UL1581 testing. This material has been formulated for 500µm applications with superior stripability. The physical properties for the three product lines can be found in Table 1. The flame retardant and smoke properties for the Bufferlite™ DU-3007 series can be found in Table 2.

What is unique about the Bufferlite™ formulations is they can be used to produce concentric 500µm fiber as shown in Figure 2. This compact fiber design has become utilized in many FTTH applications and has become the standard in Japan. Traditional thermoplastic materials have not been successfully utilized for this design with optimized fiber concentricity.

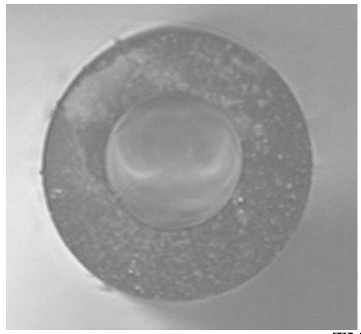

Figure 2. A 500μm Upjacketed Fiber with the Bufferlite™ DU-3038 series a single coat over a standard coated optical fiber .

Table 1. Physical Properties of Bufferlite™ Materials

Properties	**Bufferlite™ DU-1002**	**Bufferlite™ DU-2002**	**Bufferlite™ DU-2008**	**Bufferlite™ DU-3007 Series**	**Bufferlite™ DU- 3038 Series**
Viscosity (mPa*s)	2,500	2,200	1,200	2,000	4,600
Tensile (MPa)	0.5	8	12	9	8-16
Elongation (MPa)	25	20	14	17	8
Secant Modulus (MPa)	4	95	320	140	250-500
DMA properties					
E' @ 1000 MPa (°C)	-55	-5	0	28	30
E' @ 100 MPa (°C)	-47	32	80	63	65
Tan Delta (°C)	-42	40	83	50	50
Equilibrium Modulus (MPa)	3	11	20	38	76

- Tensile, Elongation, and Secant Modulus properties obtained on 3 mil films cured in Nitrogen at 1.0 J/cm^2 using 1 Fusion D lamp. UV dose determined by IL-390 radiometer manufactured by International Light, Inc.
- Tensile, Elongation, and Secant Modulus properties obtained on polyester after 16-24 hours conditioning at 23+/-1°C and 50+/-5RH.

Table 2. Flame Retardant and Smoke Data for Bufferlite™ DU-3007 Series

Properties	**Bufferlite™ DU-3007 Series**
UL 94(1)	VTM-0
UL 1581(2)	Pass
UL 1666(3)	Pass
Flame height (ft)	4
Maximum temperature (°F)	372
UL1685(3)	Pass
Peak smoke release rate (m^2/s)	0.01
Total smoke release (m^2)	0.87
LOI (%)(4)	30
Smoke Testing – ASTM E 662(3)	
Flaming D_m	71
Non-Flaming D_m	85

(1) Tested as 250µm cured flat specimens.
(2) Tested as single 900µm buffered fiber.
(3) Tested in a 12-fiber distribution cable[2].
(4) Tested as a 500µm cured flat specimen.

Processing

Another advantage of UV curable materials is the processing speed as compared to a typical thermoplastic material. Bufferlite™ materials generally process at line speeds greater than 600m/min and can be applied to coated optical fibers using coloring lines that have been modified for upjacketing. Unlike thermoplastic materials which are applied by an extrusion process that requires a much more extensive investment and larger equipment footprint due to the required heating and cooling steps. The typical thermoplastic processing speed is 100-200m/min, depending on the polymer[3]. Also the scrap rate for UV curable materials is less than that of the thermoplastic materials. The scrap rate for the UV curable materials is usually less than 3% in comparison to the thermoplastic materials which is about 10%. The higher scarp rate is based on poor diameter control and shrinkage of the coating after cure.

Typically a coloring line is modified for applying the upjacketing material. All of the materials discussed in this paper were processed on a modified Nextrom OFC-52 coloring machine that is equipped with two Fusion D F10 lamps and processed at varying line speeds with a continuous nitrogen purge of 40L/min. The equipment is modified by utilizing a different die design and software. For a 500µm fiber, a 260-275µm inlet die and a 600-700µm exit die are utilized. For a 900µm fiber, a 260-275µm inlet die and an 1100-1300 µm exit die are utilized. The materials are processed under 2 to 4 bars of pressure and may need to be heated based on the viscosity and if a high processing speed is desired. Processing speeds vary on the number of lamps used, feed line diameter, and the color of the material. Maximum processing speeds with two Fusion D F10 lamps are 600m/min for 500µm fiber and up to 300m/min for 900µm fiber.

For maximum tight buffering productivity, higher capacity pressure vessels and larger diameter feed lines are used. For this type of processing, the pressure ranges from 3 to 5 bars. A die set (three individual dies) allows for optimized fiber concentricity over long processing times. The two die set that is mentioned above can also be used, but the same processing time will be shorter than with the three die design. In order to achieve higher processing speeds, both the pressure vessel and feeding line may need be heated to 50°C. With this type of set-up, as is illustrated in Figure 3, the recommended dies for 500µm fiber are: 270µm entrance, 260µm middle, and 620-700µm exit. The maximum processing speeds are increased over the simple modification due to the higher capacity in the coating delivery system. The maximum processing speed with two Fusion D F10 lamps is 750m/min for the Bufferlite™ 3038 series and 1,000m/min for the Bufferlite™ DU-2008. The recommended dies for 900µm fiber are: 270µm entrance, 260µm middle, and 1100-1300µm exit. The maximum processing speed with two Fusion D F10 lamps is 800 m/min for the Bufferlite™ DU-2008 coating.

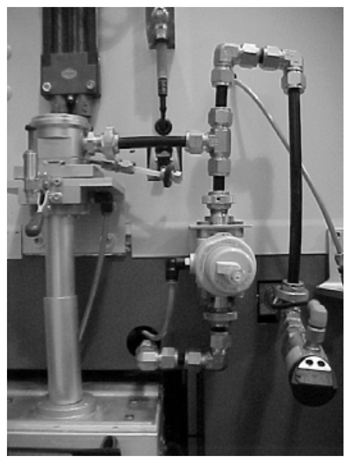

Figure 3. Modified Color Machine for High Capacity Upjacketing Process

Strip Performance Properties

An essential feature of all commercially acceptable tight-buffer coatings is good stripability. In other words during connectorization or installation of a buffered optical fiber, the outer buffer coating must be easily and cleanly removed to expose the natural or color coded inked fiber. A generally accepted criterion of stripability is the ability to cleanly strip 10 cm of buffer from upjacketed fiber with a tool such as Micro Electronics Inc., Micro-Strip. To achieve good stripability in buffer coatings is not a trivial matter, either for opaque pigmented or clear transparent buffers. UV cure coatings for tight-buffer applications are normally quite adherent. This is primarily due to the concentric application of the cylindrical coating and the uniform radial shrinkage during cure which "squeezes" the buffer into very intimate contact with the outer coating layer of the fiber, either the outer primary coating or the color coding ink.

All Bufferlite™ products are specially formulated for good stripability. For some products such as Bufferlite™ 3000 lines, and Bufferlite™ DU-2008, this entails the use of special additives selected to promote stripability while maintaining excellent buffered fiber environmental durability. These special additives are oligomeric or polymeric compounds, but they are not (meth)acrylate functional and so may be classified as polymeric plasticizers.

The use of polymeric plasticizers is well known for thermoplastics and in extruded thermoplastic tight-buffers[4]. A critical issue in the use of plasticizers is the long term permanence and resistance to migration and many studies and publications have dealt with the subject to show that permanence is strongly correlated with molecular weight[5]. It has been shown by Stark, et al., that for PVC membranes, plasticizer resistance to migration in the use environment requires an average plasticizer molecular weight of at least 400 [6]. Concerns about migration and permanence of non-reactive components are the principal reasons that typical plasticizers are not usually found in thermoset coatings. And the issues were of special concern for their use in UV cure tight-buffers where long term service-life and durability are always important.

Because of these concerns the plasticizer-type non-reactive additives selected for use in Bufferlite™ 3000 lines, and Bufferlite™ DU-2008, are significantly higher than 400 in molecular weight. In addition the buffers were thoroughly tested for permanence and durability during the development phase. Table 3 shows the results of a typical cycle of testing used for representative cast films of 152 microns (6 mils). All test specimens were cured under a standard 300 Watt/inch laboratory-web Fusion unit under nitrogen with a dose of 1 Joule/cm^2. The table summarizes the values for numerous developmental, and now commercial formulas; and shows that they are indeed stable and durable.

Table 3. Standard Durability Study for Strippable UV Cure Tight-buffer

	For Bufferlite™ 3000 or DU-2008
Aged Tensile Properties: % Modulus Change	
8 weeks dry-85°C	< +/- 30%
8 weeks dry-125°C	< +/- 40%
2 weeks 85% RH / 85°C	< +/- 20%
Aged DMA: % Change E_0	
8 weeks dry-85°C	< +/- 3%
8 weeks dry-125°C	< +/- 5%
2 weeks 85% RH / 85°C	< +/- 10%
Aged Weight Loss: % Change	
8 weeks dry-85°C	< +/- 2%
8 weeks dry-125°C	< +/- 4%
2 weeks 85% RH / 85°C.	< +/- 2%

Conclusion

The demand for broadband access is continuing to drive the fiber to the home initiative. The telecommunications industry requires the flexibility to produce different designs and products that allow for easy installation. Traditionally thermoplastic materials have filled this role; however as demonstrated by the Bufferlite™ materials in this paper, UV curable solutions allow for the required maximum design flexibility, faster processing, and better fiber stripability. The demand for more compact fiber designs has been illustrated in Japan where the 500µm UV curable design has become the standard over the past 2 years. Also the Bufferlite™ materials provide degrees of non-flammability while being halogen free. This allows for flexibility in cable designs to enhance performance and cost saving.

References

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