Covestro Coatings for Optical Fibers

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Investigation on application of biomass raw materials to optical fiber coating agents

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Abstract

We conducted a feasibility study to clarify whether biomass raw materials can be used for optical fiber coatings. In this study, we blended a composition using biomass as part of the raw material and investigated its characteristics. The characteristics are viscosity and Young's modulus, which are the minimum required performance for an optical fiber coatings. Regarding Young's modulus, we set targets for two types of fiber optic coating applications with different hardness: flexible primary applications and high-hardness secondary applications.

As a result of the investigation, the secondary composition using a specific biomass raw material achieved the target viscosity and Young's modulus. For this composition, we calculated the Biobased content indicating the usage ratio of biomass raw materials, compared the mechanical properties and curing rate with existing petrochemicals, and investigated whether there was any difference in performance due to biomass.

Keywords: UV curable coatings; Optical fiber coatings; Biomass

1. Introduction

Most standard tele-communication fibers have a 125 µm cladding diameter and polymer coating that increases the outside diameter to 250 µm. Structure of optical fiber is shown in Figure 1. For this standard size fiber, 75% of the fiber's three-dimensional volume is the polymer coating. The core and cladding glass account for the remaining 25% of the coated fiber's total volume. The polymer coating layer has a two-layer structure, a softer inner coating called the primary and a harder outer coating called the secondary.

In order to achieve high fiber productivity, UV curable coatings are used these layers. Because glass is fragile, the coating must protect it. The bending stresses of the fiber lead to intensity losses for the light transmitted through the fiber. Function of mechanical protection to glass is important.

Optical fibers are laid everywhere in the world, including deserts, ocean, underground, country and urban areas. Therefore, performance that is not affected by various environments is required. Coatings play a key role in helping the fiber meet environmental and mechanical specifications as well as some optical performance requirements.

On the other hand, in recent years, with the goal of reducing the carbon footprint, efforts related to biomass have been made in various fields. Our goal is to promote the use of biomass and renewable raw materials across our industry, making chemical production fit for the future. We believe bio-based products are one important step in permanently reducing our emissions and making the chemical industry a more sustainable place.

Therefore, it can be said that verifying whether biomass raw materials can be used for our UV curable optical fiber coating is an important theme from the perspective of the SDGs. In this paper, the applicability of biomass raw materials to our UV curable optical fiber coating is studied.

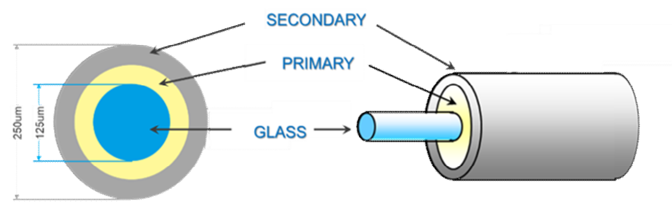

Figure 1. Structure of optical fiber

2. Experiment

2.1 Materials

All samples of primary and secondary coatings consisting of urethane acrylates were prepared in our laboratories. Primary and secondary coatings were designed to perform the high inner cure degree and the high surface cure degree, respectively.

Both coatings were optimized for metal-halide lamp.

2.2 Measurement of Viscosity

The viscosity at 25°C. was measured using a BH8 rotator.

2.3 Preparation of Test Specimens

Liquid UV curable coatings were applied on a glass plate with a certain thickness using an applicator bar. These liquid coatings were cured by UV lamps at a dose of 1 J/cm2 in the air.

The cured coatings were allowed to stand for 12 hours or more at a temperature of 23°C.and a relative humidity of 50%, and subjected to the following tests.

2.4 Measurement of Young's Modulus

Young's modulus at 23°C was measured by using a tensile machine at tensile speed of 1mm/min. Young's modulus was defined by the secant modulus at 2.5 % elongation.

This property was also measured at -40°C and 60°C.

2.5 Measurement of Cure Speed

For the cure speed test, cured films with a thickness of about 250 µm were prepared by irradiating coatings with UV light at a dose of $0.1 J/cm^2$ or $1 J/cm^2$.

The cure speed was determined as a ratio of the Young's modulus of the film cured at $1 J/cm^2$ to the Young's modulus of the film cured at $0.1 J/cm^2$

2.6 Calculation of Biobased content

The Biobased content[1] of the prototype coating agent was calculated by equation (1).

$$BC_{all} = \Sigma W_i \times BC_i \quad (1)$$

BC_{all} : Biobased content of coating

W_i : Weight fraction of raw material *i*

BC_i : Biobased content of raw material *i*

3. Result and Discussion

3.1 Investigation of oligomers using biomass raw materials

Oligomers for fiber coating should be designed with the optimal molecular structure depending on the application and required properties. Therefore, it is important to verify that oligomers can be synthesized using biomass raw materials in the same way as conventional petrochemical raw materials. First, the synthesis of oligomers using biomass raw materials was investigated.

The results of oligomer synthesis are shown in Table.1. Oligomer A and B were designed for primary, a soft material, and for secondary, a hard material respectively.

Table.1 Oligomers using biomass raw materials

	Usage	Handling of Oligomer
Oligomer A	Primary	N.G. *1
Oligomer B	Secondary	Good*2

*1 : Difficult handling

*2 : Easy handling

In the results of this study, it was predicted that the viscosity of oligomer A is very high in its synthesis, and that it is difficult to design the coatings. On the other hand, it was determined that the oligomer B for the secondary has a viscosity suitable for the coating design, and that subsequent resin liquefaction is possible. From the above, the secondary oligomer proceeded with the following test.

3.2 Viscosity and Young's modulus adjustment

Next, the formulation of coatings using oligomers and monomers from biomass raw materials was investigated. In this study, the formulation was adjusted so that the basic properties viscosity and Young's modulus were the target characteristic values among the properties required for fiber coatings.

The reason why viscosity was chosen as the target value is to be able to apply to evaluate the physical properties of the cured films. The target value of viscosity is based on the experience of developing optical fiber coatings conducted so far.

Further, the reason for selecting Young's modulus is to determine whether the composition can be adjusted to the modulus required for the coatings. A standard telecommunications optical fiber has a two-layer structure, a softer inner coating called the primary and a harder outer coating called the secondary. When a pressure is locally applied to an optical fiber side surface, the core of the glass fiber at the portion to which the pressure is applied bends with a small curvature, and as a result, light loss may occur. The primary coating layer is desirably sufficiently flexible from such viewpoints that suppress light loss. On the other hand, the secondary coating layer preferably has a modulus sufficiently high to protect the primary layer. Young's modulus targets for primary and secondary coatings are set based on our know-how to date. In this study, oligomers for secondary coating using biomass raw materials were synthesized as reported in Chapter 3-1, so we tried to adjust the Young's modulus suitable for secondary coating.

Sample A of the bio-based secondary coating composition was prepared using synthesized biomass oligomers and various biomass raw materials. The viscosity and Young's modulus are shown in Table 2. The upper and lower limits of the target values of this study are normalized based on the value of conventional secondary coatings consisting of petrochemical raw materials.

Table.2 Viscosity and Young's Modulus of Sample A

	Target	Sample A
Viscosity	0.7 - 1.3	0.9
Young's Modulus	0.9 – 1.1	0.9

As a result of the examination, sample A having viscosity of 0.9 and Young's modulus of 0.9 which is satisfying the target values was obtained.

3.3 Comparison of Biomass Secondary coating with Conventional Petrochemical coating

In Chapter 3-2, sample A was adjusted for viscosity and Young's modulus for secondary. However, to determine whether sample A is suitable for secondary coating, it is necessary to understand the properties in more detail compared to conventional coatings from petrochemical raw materials. Therefore, characterization was added to understand the performance of sample A. There are three items to be evaluated: mechanical properties, UV curing speed, and Biobased content calculations. Details of mechanical properties were Young's modulus at room temperature, -40 °C, and 60°C. to understand behavior in various temperature environments, tensile strength and elongation at break to understand material strength.

Sample B composed of petrochemicals was used as a comparison target for sample A in this study. It is a composition characterized in that it is close to the 23 °C. Young's modulus of sample A.

The results are shown in Table 3. The characteristic value s of sample A are expressed as relative values with the characteristic value of sample B as 1.0.

Table.3 Properties of Biobased Secondary Coating Sample A

Properties	Condition	Sample A	Sample B
Biobased content (%)		40	0
Young's Modulus	-40°C	1.1	1.0
	23°C	0.8	1.0
	60°C	0.5	1.0
Tensile Strength	23°C	0.8	1.0
Tensile Elongation	60°C	0.8	1.0
Cure Speed	Young's Modulus ratio @ 0.1J/1J	1.0	1.0

Mechanical properties will be described. Compared to Sample B derived from petrochemical raw materials, it was found that Sample A shows Young's modulus at 60°C. was as low as 0.5. From this result, it was indicated that the biomass coating sample A in this study may have lower mechanical properties at high temperatures than sample B of petrochemical products. On the other hand, with respect to the curing rate, the composition had the same level of curing speed as the petrochemical to be compared.

It is necessary to confirm whether the decrease in Young's modulus at high temperatures is a problem. In addition, this study has not sufficiently examined whether mechanical properties including Young's modulus of 60°C. can be adjusted by coating design. Study of coatings using biomass raw materials will continue in the future.

4. Conclusion

In this study, the possibility of utilizing biomass raw materials for optical fiber coating was conducted. This coating was formulated with some biomass materials and designed for secondary use.

The biomass coating was designed to nearly equal to the target viscosity and Young's modulus for conventional petrochemical secondary coating. The biobased content of the biomass secondary coating was 40%.

Biomass Secondary Coating was examined for property comparison with petrochemical coating which has similar characteristic of young’s modulus to 23°C. As a result, characteristic difference was observed at 60°C Young's modulus. But other mechanical properties and curing rates were approximately the same level.

In this study, it has not sufficiently examined whether mechanical properties including Young's modulus of 60°C can be adjusted by coating design. And also it is necessary to confirm whether the decrease in Young's modulus at high temperatures is a problem. Study of coatings using biomass raw materials will continue in the future. Furthermore, it is an urgent subject to search for biomass raw materials for primary coatings. In the presentation, we will also report on the status of consideration of primary coatings.

5. Reference

[1] ISO 16620-1, 4

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