Investigations of Temperature Behaviour of 500µm Fibers within the Range of –60°C to +140°C

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Abstract

This paper deals with the investigation results of upcoated fibers with 500µm OD with regard to their temperature behaviour. All tests are based on graded index 50µm core Multimode fibers (fiber type A1a according to IEC 60793-2-10). The purpose of this study was to find out, how different design and material options influence the attenuation of a 500µm fiber within a temperature range of –60°C to +140°C. The results reveal the option to limit the maximum attenuation increase to approximately 0.01dB/km at 1300nm wavelength versus the whole temperature range. Choosing a well adapted upcoating material with a wide Glass Transition Temperature Range or using a thin sliding layer between the original coating and the fiber jacket achieves the desired results.

Keywords: 500µm fiber; upcoating; temperature behaviour

1. Introduction

The study includes tests of offline upcoated fibers with different commercially available UV-curable buffer materials from several suppliers and fibers with originally applied 500µm coating layer during the drawing process. For the analysis all the various upcoated fibers were produced with and without a sliding layer, a UV-curable silicon acrylate layer between the standard fiber and the buffer layer to observe, if there is a difference in temperature behaviour.

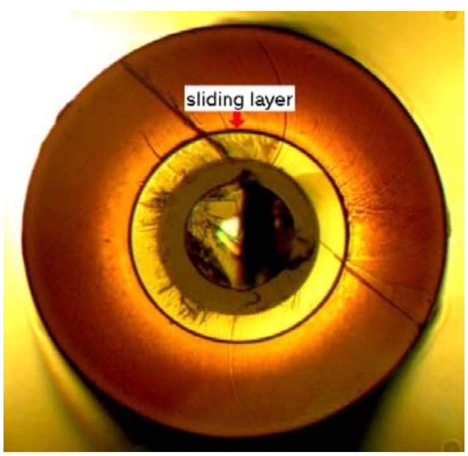

Figure 1. Typical cross section of an upcoated fiber with a thin sliding layer

Figure 1 and Figure 2 show a cross section of an offline upcoated fiber with and without a sliding layer. The thickness of this layer is approximately 3 to 4 µm.

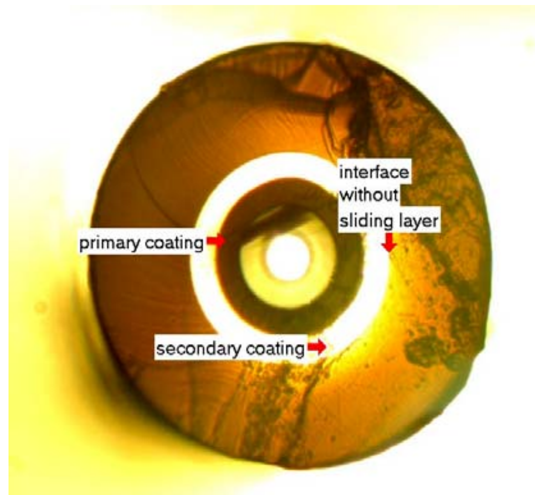

Figure 2. Typical cross section of an upcoated fiber without a sliding layer

Figure 3 shows the cross section of a fiber with originally applied 500µm overall coating diameter during the drawing process. This design only consists of the 125µm glass fiber, a corresponding soft primary layer and a hard secondary layer.

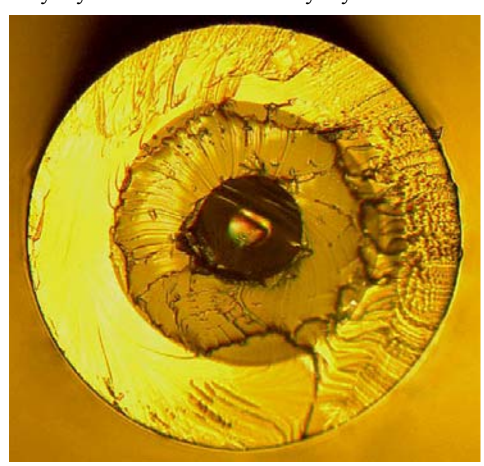

Figure 3. Typical cross section of a 50µm core Multimode fiber with an originally applied 500µm coating

The upcoating process without a sliding layer leads to a strong adhesion between the secondary layer of the original fiber and the upcoated buffer layer. Therefore it is possible to strip off all the coating layers in one step as seen in Figure 4. A very good buffer layer stripability against the original fiber coating can be achieved if an additional sliding layer exists.

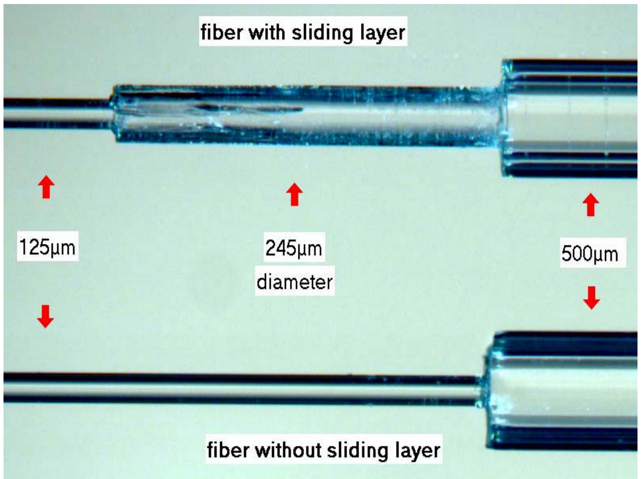

Figure 4. Stripability for different fiber design

2. Sample Preparation

Because of their well known greater sensitivity to microbending compared to the fiber type A1b (graded index 62.5µm core Multimode fibers), four A1a-type fibers were chosen in order to see the largest effects for the purposes of this study.

The fibers were upcoated with different buffer materials. This work was performed by means of a wet in wet coating process on a selfmade coloring/upcoating line.

The upcoated fibers were cut in 1.1km lengths. Four fibers for each buffer material (two of them with sliding layer) were brought into the temperature chamber together with several samples of a non-upcoated A1a type fiber and a 500µm OD fiber from fiber drawing process for reference.

3. Temperature Cycling Test

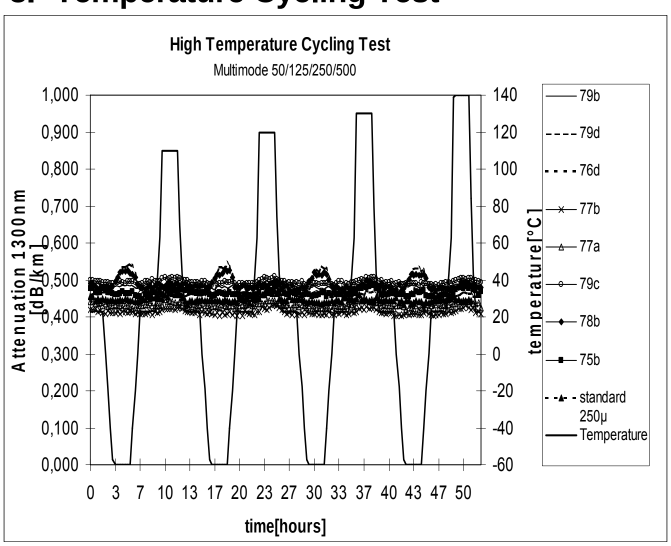

Figure 5. Temperature Cycling graph with extended temperature range

The temperature cycling test was performed according to the IEC 60793-1-52 test procedure, usually carried out between –60°C and +85°C. For this recent investigation the upper temperature range was extended up to 140°C. The test fibers were characterized by OTDR-measurements at 1300nm wavelength with a pulse width of 100ns at an average rate of 30s. The fibers were not subject to mechanical stress in the temperature chamber.

Figure 5 shows the typical temperature cycling characteristics of several upcoated fiber samples. The whole test spans more than 50 hours.

4. Results

4.1 Data Editing and Error Estimation

The attenuation change at various temperatures is represented in the following figures. For this purpose the average for all attenuation values at the same temperature was calculated and related to the average of the measured attenuation values at room temperature at the beginning of the temperature cycling test, provided that the attenuation at the same temperature did not change even after several temperature cycles. This was proven. But as a result of this analysis a small negative attenuation change is superimposing the actual effect, because the high temperature cycles obviously cause a residual stress relaxation with an associated slightly reduced attenuation compared to the initial measured values at room temperature.

Several samples of a standard 250µm fiber were inspected in order to draw conclusions about the variation of attenuation change versus the temperature. The result is shown in Figure 6.

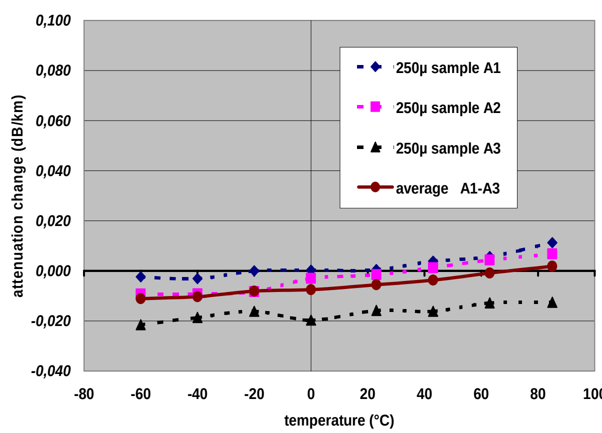

Figure 6. Variation of measured attenuation change for standard 250µm fibers

The variation at each temperature is up to 0.013dB/km. The measured attenuation change is far below the maximum allowed value of 0.2dB/km according to the specification IEC 60793-2-10.

4.2 Interpretation of the Results

The temperature behaviour of the upcoated fibers without and with a sliding layer is shown in Figure 7 and Figure 8 respectively. The individual curves illustrate the mean values of two curves each, representing two fibers with the same upcoated material. Additionally, for comparison purposes the corresponding curve of the standard 250µm fiber and the curve of a standard fiber with originally applied 500µm coating layer during the drawing process are displayed. The last curve is missing in Figure 8, because there is no sliding layer within the 500µm coating design.

The behaviour of the standard 250µm fiber and the standard 500µm fiber at low temperatures is nearly identical, even though the Glass Transition Temperature Tg of the used primary 500µm coating is 13 degrees higher than that of the standard 250µm fiber. Probably the greater thickness of the primary layer can prevent an attenuation increase (without getting delamination effects). Within the high temperature range it seems the standard 500µm fiber is better, but referring to the error estimation exemplified above it is almost the same attenuation change in the order of approximately 0.01dB/km.

The most interesting observations however are the differences of attenuation increases for offline upcoated fibers with different materials at low temperatures. As shown in Figure 7, the attenuation increase at –60°C can be multiples greater in the case of an upcoated unfit material compared to a well adapted material. The question is: What is the right criterion for choosing the best jacket material?

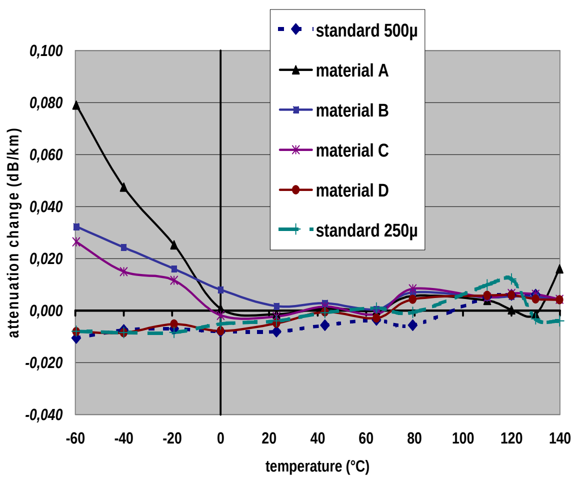

Figure 7. Attenuation change for 500µm fibers with different upcoated materials without sliding layer

Looking at the Secant Modulus at room temperature, we chose four commercially available upcoating materials with quite different properties for this study. As shown in Table 1 we used both soft, rubber-like materials (A and C) and a hard material (B). The Glass Transition Temperatures (Tg), taken from the tan δ-curve of the accompanying DMA-diagram (Dynamic Mechanical Analysis), vary from 30°C to 70°C. The Coefficients of Thermal Expansion (CTE) however are very similar except that of material C.

In order to explain the behaviour of offline upcoated fibers without sliding layers we tried to correlate the various jacket material parameters with the attenuation increase at low temperatures. But neither the Secant Modulus nor the Glass Transition Temperature Tg or the CTE-values exhibit a satisfying correlation. However, if we consider the Glass Transition Temperature Range between the soft (100MPa) and the hard (1000MPa) state of the jacket material we can find a certain kind of correlation. According to this the upcoated material with the widest temperature range Delta T(E') gives the lowest attenuation increase below room temperature (see material D with a temperature range of 62 degrees). On the other hand material A possesses the smallest temperature range of 36 degrees that leads to the highest measured attenuation increase. The two other materials B and C with temperature ranges of 40 degrees and 47 degrees rank in the right order.

Table 1. Selected parameters of the upcoated materials

upcoat. material	T(E') 1000MPa	T(E') 100MPa	Delta T(E')	Tg (max tan δ)	Sec.Mod. (2.5% strain)	CTE below Tg	CTE above Tg
	°C	°C	degree	°C	MPa	mm/m°C	mm/m°C
A	-11	25	**36**	33	60	<0.1	0.45
B	26	66	**40**	70	668	<0.1	0.45
C	-18	29	**47**	30	50	0.05	0.18
D	4	66	**62**	41	281	<0.1	0.45

Figure 8 shows the temperature behaviour of all these jacket materials in combination with a sliding layer between the original fiber coating and the upcoated material. In this case the material features mentioned above don`t play a role in view of

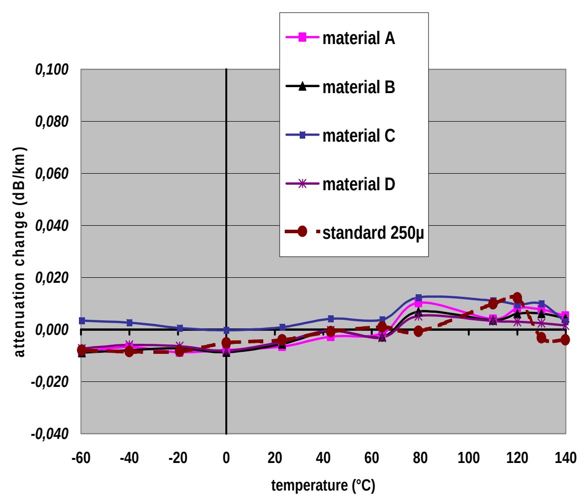

Figure 8. Attenuation change for 500µm fibers with different upcoated materials with sliding layer

the attenuation increase at low temperatures. The sliding layer absorbs all the additional mechanical stress imposed on the original fiber. Referring to the suppliers declaration this UV-curable silicon acrylate layer has a Secant Modulus of 5 MPa at room temperature. The Glass Transition Temperature is not exactly known, but it is smaller than –25°C.

The attenuation increase at high temperatures does not change within the error tolerances. The upcoated fibers show a maximum attenuation increase in the order of 0.01dB/km versus the whole examined high temperature range independent of the existence of a sliding layer.

5. Conclusions

There are three alternatives to limit the maximum attenuation increase of 500µm upcoated A1a type fibers to approximately 0.01dB/km at 1300nm wavelength versus the whole temperature range from –60°C through +140°C.

The first option is the right choice of commercially available UV-curable upcoating materials. The criterion should be the broadness of the glass transition range, not the glass transition temperature itself. The bigger this broadness, the lower the attenuation increases, especially at low temperatures.

The second option is the application of a thin, approximately 4µm thick UV-curable silicon acrylate sliding layer between the original fiber coating and the upcoated material. In this case the excess attenuation at low temperatures will be significantly reduced.

An additional advantage of the sliding layer design may be the easy stripability of the upcoated jacket over several cm or more, without destroying the original fiber coating layers.

Last but not least the third option can be realized by using fibers with originally applied 500µm coating layer during the drawing process. It offers the advantage to strip off the complete 500µm coating layer down to the glass surface in one step.

6. Acknowledgments

The author would like to thank Dipl.-Phys. Andreas Huth for his accurate accomplishment of the Temperature Cycling Tests and Dipl.-Chem. Ines Pautzsch for her assistance in spool preparation.

Author

Manfred Mangold (51) received his Dipl.-Phys. degree from the Friedrich -Schiller-University Jena in 1980. He joined the JENAER GLASWERK “Schott & Gen.” in the same year. At this time he was in charge of the development of measurement engineering and of a laboratory drawing tower for optical fibers. Later on he worked several years as head of fiberdraw at FIBERCORE. Now he is the head of draw technology in J-FIBER GmbH.

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