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PD1

The Non-Reflection Optical Interface without Dependence on the Wavelength by Newly Designed Coating

Toshiaki Anzaki*, Kenji Mori, Masahiro Oikawa, Takayuki Toyoshima, Takahiro Asai
Nippon Sheet Glass, Technical Research laboratory
Toukoudai 5-4, Tsukuba city, Ibaragi, Japan
TEL: 0298-47-8681 FAX: 0298-47-7748 e-mail: ToshiakiAnzaki@mail.nsg.co.jp

Abstract

We propose the non-reflection optical interface without dependence on the wavelength by new designing of the interface coating. Thinking the origin of the reflection, we calculated the case of minimum Δn at any position on the light pass, and realized the coating for the whole band of the optical telecommunication. Using this new interface, GRIN-coat, we can integrate many components of the fiber optics, lenses, fibers, wave-guides into "direct contact" with none-reflection in the whole wavelength of WDM.

Proposal

Firstly, we had much interest in the reflection phenomena of a wave, (especially optical wave), by any obstacles, and discussed complete solution of none-reflection-interface with some structure of a physical index.

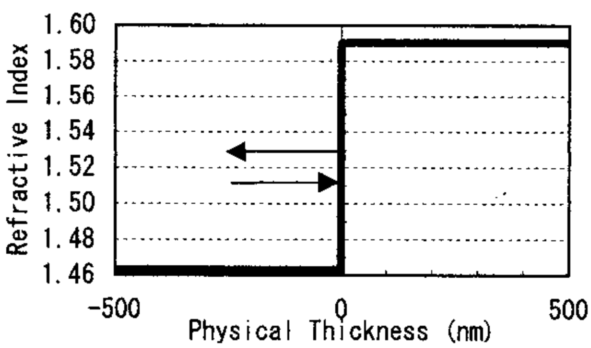

Fig.1. The optical structure in the case of direct step index.

Considering usual cases, we found tetra-pods along the sea breakwater for the protection from wave impact, or kindly slopes on the roadway for the reduction of a wheel shock by the difference in level and many cases. Therefore, the first answer is naturally imagined to the middle index or the simple slope connecting between two different physical indexes.

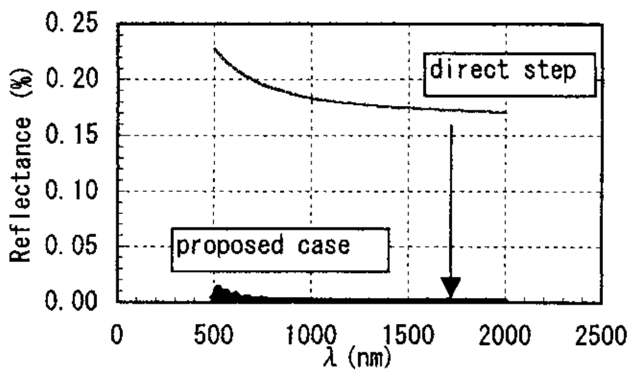

Fig.2 The result of our proposal using Newly designed interface coating. Reflectance is calculated in the incident material.

But, for the optical telecommunication, this simple answer is not enough, and we optimized the solution for this ultimate subject of the none-reflection optical interface for the telecomm by new designing technique. Moreover, it does not use any interference of the wave, so it has the property without dependence on the wavelength (Fig.2).

Designing and Discussion

Before the designing of the none-reflection optical interface without using any interference of the wave, we must consider the essence of the reflection phenomenon at the interface. The equation 1 shows the relation between the reflection at the optical interface and the optical indexes of the both of materials, n_1 and n_2, contacting this interface in the case of none-absorption materials, [1)2)3)4)5)]

$$R = (n_2-n_1)^2/(n_2+n_1)^2 \quad \text{eq.1}$$

and its differecial expression is,

$$= (\Delta n)^2/2n^2 \quad \text{eq.2}$$

Based on eq.2, we must minimize the difference between the each value of index of two materials at any position on the whole light pass. But the value of the difference is usually not so small, and if we contacted such two materials, the reflection becomes very large. Therefore, as the 1st simple answer, we calculated the case of single buffer layer with middle index (Fig.3-1) against the case of direct step.

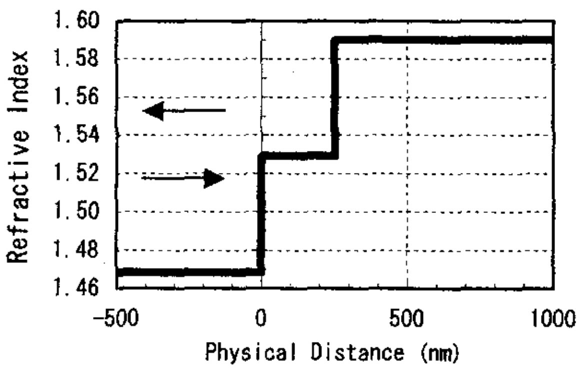

Fig.3-1. The optical structure in the case of single buffer layer with middle index.

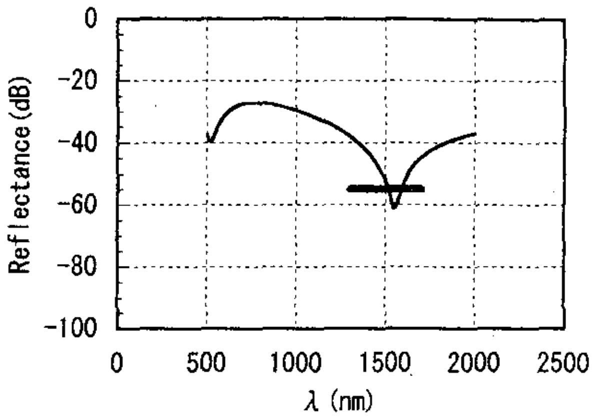

Fig.3-2. The calculated reflectance in the dB scale of the total reflectance from the interface area measured in the incidence material in the case of single buffer layer with middle index

Using this λ/4 thickness of single layer, we can get the anti-reflection effect at only one wavelength λ, but its property has much dependence on the wavelength and immediately increases by missing the λ. In this figure, the short line is a mark of the reflectance of –55dB.

Next, to obtain the property of wavelength dependenceless, we tested a linear changing index as shown in fig.4-1, and acquired a relatively flat and low reflectance in wavelength domain as shown in fig.4-2.

By this design, we can cover partially the WDM wavelength, around 1300nm and 1550nm at the reflectance of –55dB. The small peek valleys are the effect of the interference fringe in the thickness of the interface. From this calculation experiment, we learned also the minimum thickness of the interface required for this property is approximately λ.

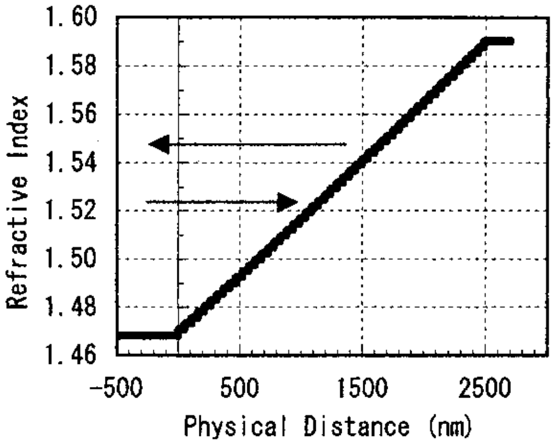

Fig.4-1. The optical structure in the case of the interface with a linear gradient index.

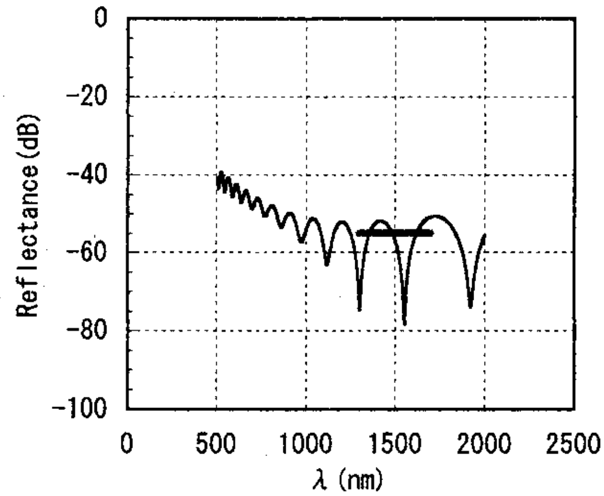

Fig.4-2. The calculated reflectance in the dB scale of the total reflectance from the interface area measured in the incidence material in the case of the interface of a linear gradient index.

Considering the impact for the WDM telecomm, the key wavelength is from 1700nm to 1300nm continuously and 980nm (pump light). Therefore, we investigated the detail of the origin of small reflection in fig.4-2, and guessed the two shoulder of this design are the cause, from thinking the case of the natural reflection phenomena, which we had experienced. Then, many designs are tried to smooth that shoulder, and we obtained several adequate answers.

Fig.5-1 shows one example of such answer and the optical interface with this design results in a spectrum of the reflectance as shown in fig.5-2. The anti-reflection area below the –55dB line is very wide including 980nm and reflectance decreases any wavelength with much reduction of the effect of interference compared with the linear case in fig.4-2.

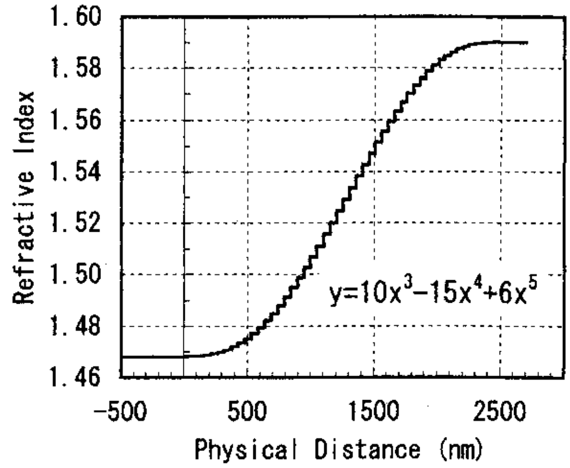

Fig.5-1. The optical structure in the case of the interface with the optimized smooth -gradient index.

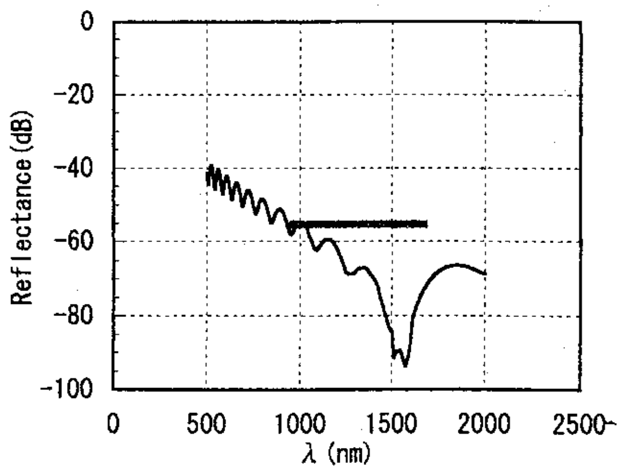

Fig.5-2. The calculated reflectance in the dB scale of the total reflectance from the interface area measured in the incidence material in the case of the interface with the optimized smooth-gradient index.

Moreover, the cause of the big valleys shape is a wavelength dispersion of the high index material, which is Selfoc Micro-Lens, and fitting process using 1550nm wavelength. So using the selection of the fitting point of wavelength, we can adjust the location of this anti-reflection area in the wavelength domain.

Experiment and Results

Using the optimized design of fig.5-1, we fabricated the optical coating sample between the different index 1.47 and 1.59 with the smooth changing of index. The coating deposition is done by special mixing technique, and we obtained the coated substrate with the aimed optical design. Then the coated substrate is connected with a back reflection mater and measured reflection at the first experiment was –37dB, against the value of –32dB in the case of single buffer layer, both includes many other loss factors which is subject from now on.

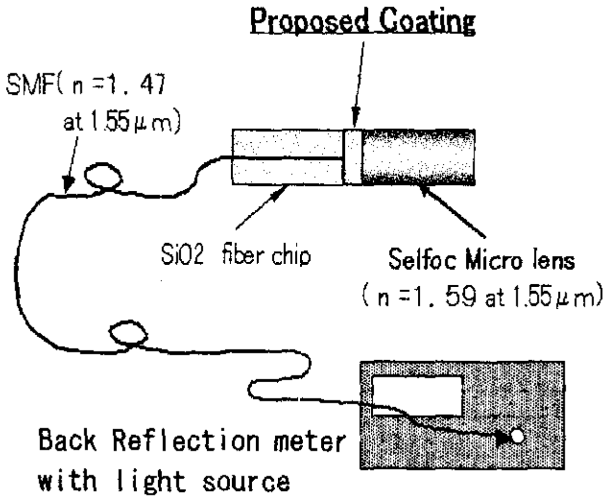

Fig.6. The schematic figure of the measurement of the back reflection from the interface of a Selfoc Micro Lens and fiber chip with proposed coating.

Conclusion

We proposed the none-reflection optical interface without dependence on the wavelength by new designing of the interface coating. Thinking the origin of the reflection, we calculated the case of minimum Δn at any position on the light pass, and realized the coating for the whole band of the optical telecommunication.

By using this new interface, which we call GRIN-coat, we can integrate many components of the fiber optics, lenses, fibers, wave-guides into "direct contact" with none-reflection in the whole wavelength of WDM

Address of thanks

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