Development of Infrared Chip LED with Backside Light Leakage Suppression

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Abstract

Due to the recent trend toward miniaturization of electronic devices, backside light leakage from infrared chip LEDs has become a significant issue. In this development, we successfully suppressed backside light leakage by changing the substrate material of the infrared chip LED to one with lower infrared transmittance. The newly developed infrared chip LED maintains compatibility with existing products in terms of external dimensions and mounting land patterns, eliminating the need for circuit board design changes on the user side. This paper reports on the characteristics and features of the developed LED.

1. Introduction

Our company offers a lineup of infrared LEDs for applications ranging from remote controls to proximity sensors. In recent years, demands for product miniaturization, circuit board downsizing, and power saving have led to reduced spacing between components. As a result, when LEDs and photodetectors are placed in close proximity, light leakage from areas other than the intended receiving section can no longer be ignored as optical noise.

Typically, optical noise is reduced by installing light-shielding covers on both the photodetector and LED sides. However, when the components are closely positioned, the circuit board itself can act as a light guide, making it difficult to achieve sufficient shielding.

In this development, we focused on light leakage from the LED to the circuit board and developed an infrared LED that prevents the circuit board from functioning as a light guide. This paper outlines the development.

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2. Infrared LED with Backside Light Leakage Suppression

2.1 Development Concept

The goal of this development was to suppress light leakage without compromising the usability of existing LEDs. Specifically, we aimed to enable users to replace existing LEDs without modifying the circuit board's mounting pattern or resist layout.

2.2 Structure of Existing Infrared Chip LED

The basic structure of the existing infrared chip LED (hereafter referred to as the "existing LED") is shown in Figure 1 and consists of a BT substrate, LED chip, wire, die attach, and encapsulating resin. The encapsulating

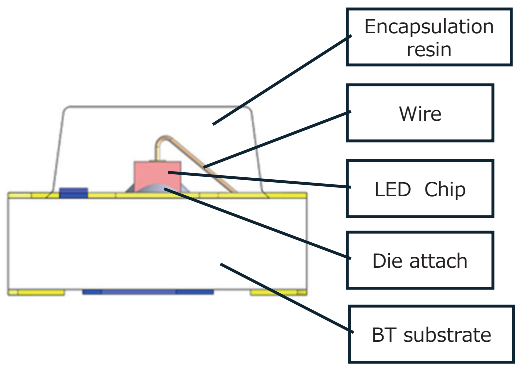

Figure 1. Structure of Existing Infrared Chip LED

resin, which controls light distribution, is a colorless transparent epoxy resin with high transmittance.

The BT substrate is a white board composed of layered glass fibers impregnated with reflective material and BT (bismaleimide-triazine) resin. The BT substrate exhibits a high reflectance of over 90% in the visible to infrared light range. The remaining 10% is absorbed by the substrate, which contributes to backside light leakage.

2.3 Issues with Existing LED

When using the existing LED to detect a target object with a photodetector placed nearby on the same circuit board, the configuration is as shown in Figure 2. In this setup, part of the light emitted from the LED is transmitted as a signal and reflected by the target object, which is then received by the photodetector.

Simultaneously, light that undergoes multiple reflections within the encapsulating resin penetrates the BT substrate and propagates through the circuit board, appearing as optical noise on the photodetector side. While strong reflected light can mask this optical noise, weak reflected light makes the optical noise more prominent.

Therefore, it is necessary to suppress backside light leakage to a level where it can be ignored.

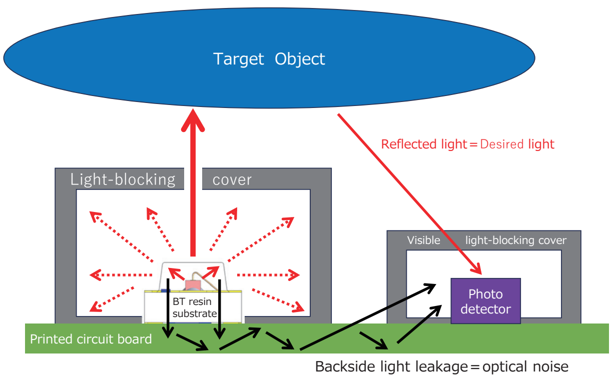

Figure 2. Conceptual Illustration of Backside Light Leakage

2.4 Consideration of Infrared Chip LED with Leakage Suppression

To suppress light leakage to the circuit board, we considered changing the substrate material of the infrared chip LED to one with lower infrared transmittance than the existing BT substrate.

Table 1 shows the evaluation levels. To verify the optical transmittance of each substrate, we used infrared light (λp = 850 nm) and measured the integrated spectral value of light passing through a 2 mm diameter hole, as shown in Figure 3. The condition without any substrate was used as the reference spectrum.

As shown in Table 1 and Figure 4, neither the existing BT substrate nor the Level 1 black substrate achieved a zero reference spectral ratio. Only the Level 2 black substrate, equivalent to FR5, achieved a zero ratio.

Table 1. Substrate Evaluation Levels

	Material	Color	Thickness	Reference spectral ratio
Current model	BT	White	0.5 mm	0.01%
Level 1	BT	Black	0.5 mm	0.15%
Level 2	Equivalent to FR-5 grade	Black	0.5 mm	0.00%

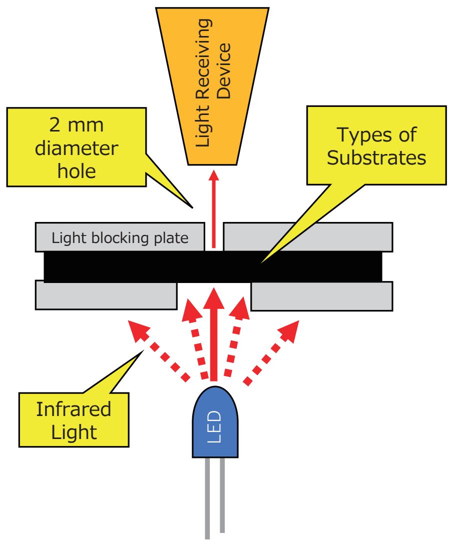

Figure 3. Method of Spectral Transmission Measurement

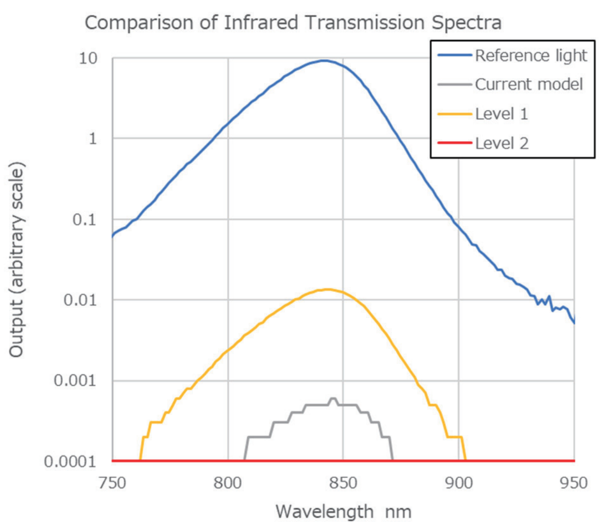

Figure 4. Transmission Spectrum

Although both Level 1 and Level 2 substrates are black, their infrared transmittance differs. The Level 2 substrate is specifically designed to absorb light in the 650 to 1300 nm spectral range.

Based on these results, we adopted the Level 2 substrate for the design of the infrared chip LED.

2.5 Appearance and Emission Characteristics of Infrared Chip LED

Figure 5 shows the appearance of the newly developed chip LED (hereafter referred to as the “developed LED”) on the left and the existing LED on the right. Due to the black substrate material of the developed LED, the contours of the gold-plated pad pattern are clearly visible.

Figure 6 compares the emission states. Light emitted from the top surface of each chip LED undergoes diffusion and multiple reflections within the transparent encapsulating resin, with some light spreading toward the substrate.

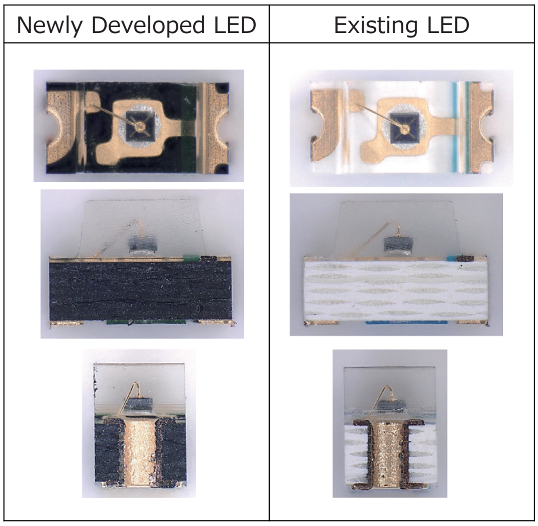

Figure 5. External Appearance Comparison of Chip LEDs

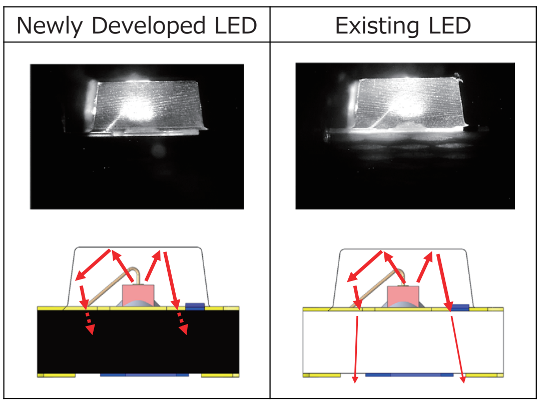

Figure 6. Comparison of Light Emission States of Chip LEDs

In the existing LED, the diffused infrared light penetrates the substrate, and part of it leaks from the substrate side, making the layered structure of glass fibers and BT resin observable.

In contrast, the developed LED shows no visible layered structure of glass fibers and black resin, indicating that the substrate absorbs the infrared light.

2.6 Light Leakage Characteristics of Chip LED

We investigated backside light leakage from each chip LED. The measurement method, shown in Figure 7, involved comparing the light output from the top and bottom sides of five samples each. During backside measurements, only light passing through a 0.4 mm diameter hole was measured to prevent reflection and wraparound from the top side.

The results are shown in Table 2. For the Level 2 substrate, the backside output was below the measurement limit and effectively zero, more than two orders of magnitude lower than the existing LED. This confirms that backside light leakage to the circuit board can be suppressed.

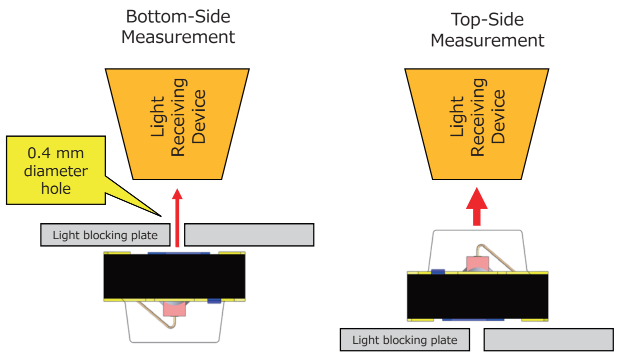

Figure 7. Optical Output Measurement of Chip LEDs

Table 2. Optical Output Comparison of Chip LEDs

	No	Top-Side Light Output mW	Bottom-Side Light Output mW	Top-to-Bottom Light Output Ratio
Existing LED	1	59.7	0.009	0.02%
	2	65.7	0.01	0.02%
	3	60.3	0.007	0.01%
	4	75.1	0.011	0.01%
	5	50.4	0.012	0.02%
	AVG	62.2	0.01	0.02%
Newly Developed LED	1	47.5	0	0.00%
	2	42.2	0	0.00%
	3	40	0	0.00%
	4	48.1	0	0.00%
	5	43.6	0	0.00%
	AVG	43.6	0	0.00%

However, a trade-off of the Level 2 substrate is that it absorbs infrared light, resulting in a reduction of top-side output to approximately 70%.

3. Conclusion

We developed an infrared chip LED with backside light leakage suppression by using an infrared-absorbing substrate. Standard reliability tests have been completed, and the product is expected to be a viable replacement for existing LEDs.

Future work will focus on exploring structures and materials that prevent reduction in top-side output, as well as proposing modules that combine the LED with photo-detectors.