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# Characteristics of Optical Disc Doped with Organic Fluorescent Material

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In Japan, where commercial compact discs (CDs) were released for the first time in 1982, CDs were an instant success. Now more CDs are sold than LPs. In 1987, the number of CDs produced annually reached 65 million, and it is predicted that 200 million CDs will be sold in 1989. Personal computers and workstations have recently started handling music data and high-resolution images, creating a need for large-capacity files and memories. CD-ROM is being used for this purpose.

Records and magnetic tape record voice and music in analog form. The CD is a digital recording medium. Sound information is stored by the presence or absence of pits on the surface of a transparent plastic substrate. When a laser beam (usually a semiconductor laser with an emission wavelength of 780 nm) is directed onto the opposite side of a pit, it is reflected by a deposited aluminum film. Recorded information is then read according to the intensity of the reflected beam. Information is recorded only on oneside of the CD, so the substrate must have the following qualities: (1) excellent transparency, (2) no birefringence, (3) low absorption of water to prevent warping, (4) excellent heat resistance, (5) high fluidity, (6) high release capability from stamper, and (7) purity. CD-grade polycarbonate (PC) satisfies these requirements and is currently in use.

The most important substrate characteristic is transparency. High beam transparency is required in the reproduced laser-beam wavelength area, so the substrate must be transparent to visible and near-infrared light. The development of PC for CDs has concentrated on establishing a manufactureing process to thoroughly eliminate foreign matter. The presence of foreign matter results in electron transition absorption and Rayleigh scattering.[1,2] Coloring materials in particular cause absorption in the visible radiation area. The effect of absorption appears when the emission wavelength of semiconductor laser is 780 nm. The amount of reflected light is reduced and the S/N ratio is decreased. Colored CDs have therefore been an impossibility.

Fujitsu has already developed a fluorescent fiber from PC doped with perylene organic materials,[3] and confirmed that the minimum transmission loss area of this optical fiber is around 765 nm. The effect of material doping on transmission loss in the near-infrared is very small. This indicates that the organic material is dispersed molecularly in the PC and dose not cause Rayleigh scattering.

This paper deals with perylene organic fluorescent material as a dye for coloring PC resin for CDs. We compared CDs doped with

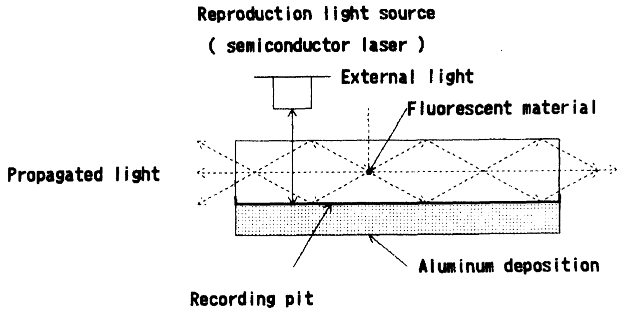



**Figure 1.** Fluorescent CD and light propagation.

this material and normal CDs.

## EXPERIMENTAL

We used commercially available CD-grade PC as a CD substrate. For coloring, we used red, orange, and green fluorescent perylene material.[4] We then produced colored pellets mixed with PC to obtain the specified concentration using an extrusion molding machine. CDs were formed using an injection molding machine in a clean room. The chromaticity of the CDs was measured with a spectral analyzer. Retardation was measured with a birefrigent meter using an elipsometer. Warp was measured with reflected laser light. The eye pattern of reproduced signals was measured with Fujitsu's measuring equipment. The bit error rate was measured with a SONY CDP222ES. Normal CDs were also produced for comparison with CDs doped with fluorescent material.

## RESULTS AND DISCUSSION

*Fluorescent CD Principles*

Figure 1 shows a fluorescent CD. As with a normal CD, the recorded information is read according to differences in reflectivity due to presence or absence of pits, using laser light aimed at the recorded layer. The recorded information is then read from the strong and weak reflected beams. In the fluorescent CD, when external beam (wavelength shorter than

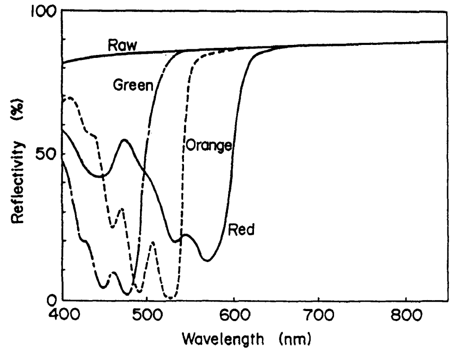



**Figure 2.** Wavelength characteristic of fluorescent CD reflectivity.

fluorescent emission) arrives, it is absorbed by the fluorescent material. The absorbed beam is converted to a fluorescent beam and emitted isotropically. A beam with an incident angle that exceed the critical angle is confined and propagated within the substrate, then finally exits through the end face. A beam with an incident angle within the critical angle, however, passes directly out of the substrate. To human eyes, the beam looks like a color fluorescent beam. In normal CDs, stray light is reflected by the deposited aluminium film and goes out of the CD, so it looks the same as an external beam.

*Reflective Light Spectrum*

Figure 2 shows the intensities of reflected light in fluorescent CDs and normal CDs, at wavelengths from 400 nm to 850 nm. Table I lists the measured values. In the fluorescent

**Table I.** Optical characteristics of fluorescent CD

| Fluorescent Color | Maximum absorption wavelength/nm | Maximum emission wavelength/nm | Reflectivity at wavelength of 780 nm/% |
|---|---|---|---|
| Green | 482 | 532 | 88 |
| Orange | 527 | 580 | 88 |
| Red | 575 | 643 | 88 |
| Normal CD | — | — | 88 |

CDs, the maximum absorption wavelengths of green, orange, and red are 482 nm, and 575 nm. When the semiconductor laser emission wavelength of the reproduction light source is 780 nm, the reflectivity is 88%, which equals the reflectivity of the normal CD. This indicates that in the near-infrared area light is not lost by the fluorescent material. The S/N ratio of the read signal is the same as that of normal CDs, indicating that signals can be read.

*Fluorescent Spectrum*

Figure 3 shows the spectrum of the light that exists through the edge of the fluorescent CD when it is placed under a fluorescent light. The maximum emission wavelengths of green, orange, and red are 532 nm, 580 nm, and 643 nm. The differences from the maximum absorption wavelengths are 50 nm, 53 nm, and 68 nm for green, orange, and red. These wavelengths are equivalent to Stokes shift. This indicates that the perylene material has good fluorescent conversion efficiency.

*Chromaticity*

Table II lists value $L^*$, $a^*$, $b^*$ of fluorescent CD reflected light represented in the CIE-$L^*a^*B^*$ chromaticity diagram. Its color is almost the same as the visual color.

*Warp*

Figure 4 shows the results when warp is measured from the center of a CD toward the circumference. The results show the doping a CD with fluorescent material does not affect warp.

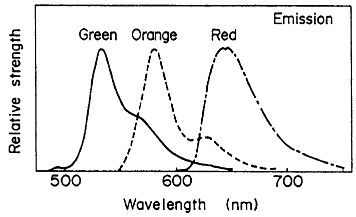



**Figure 3.** Fluorescent CD spectrum.

**Table II.** Values $L^*$, $a^*$, and $b^*$ of reflected light of fluorescent CD

| Color | $L^*$ | $a^*$ | $b^*$ |
|---|---|---|---|
| Green | 88.4 | 19.5 | 56.6 |
| Orange | 75.6 | 32.0 | 34.1 |
| Red | 45.8 | 73.0 | −4.2 |
| Normal CD | 88.2 | −0.4 | 1.7 |

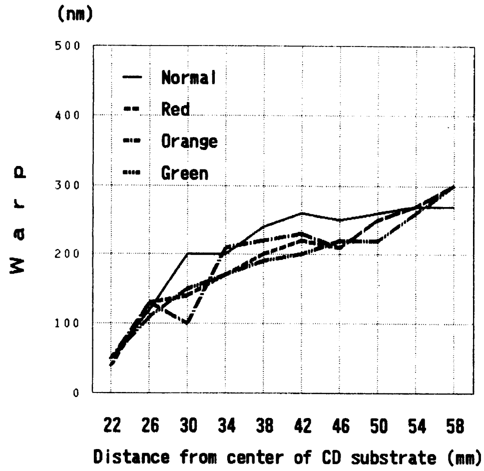



**Figure 4.** Warp in CD substrate.

*Birefringence*

The effect of perylene material, which is a polycyclic organic compound, on birefringence was measured from the center of a PC substrate toward the circumference. Figure 5 shows the results. The highest birefringence occurres at the center on the gate. Birefringence decreases towards the circumference. It increases again at the circumference, which is a general tendency of PC substrates. There is no dif-

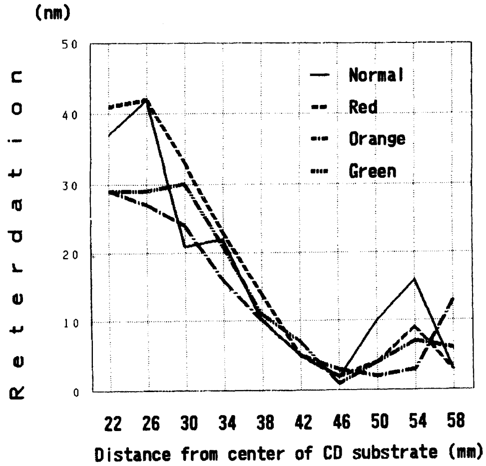



**Figure 5.** Redardation in CD substrate.

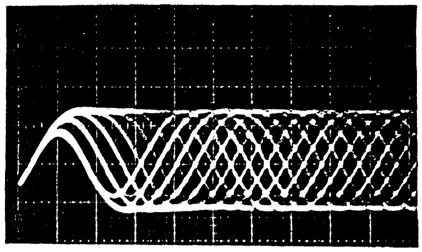
ference between fluorescent CDs and normal CDs. This indicates that perylene material dose not affect birefringence. The requirement that CD birefringence be 100 nm or less is also satisfied.

*Eye Pattern*

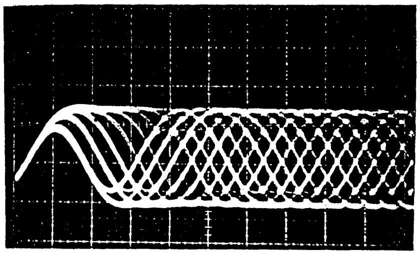
To evaluate the quality of reproduced signals of fluorescent CDs, we measured eye patterns. Figure 6(a) shows signal waveforms of all combinations of green CD record codes observed with an oscilloscope. Figure 6(b) shows the CD eye patterns. From these eye patterns, the aperture ratio each fluorescent CD is calculated. Table III lists the results. Dinamic evaluation of reproduced signals shows that the aperture ratio dose not deteriorated when PC is doped with fluorescent material. A reproduction quality equivalent to that for normal CDs can be expected.

*Bit Error Rate*

The bit error rate of fluorescent CDs was measured and compared with that of normal CDs. Table IV lists the average and maximum values of the bit error rates of all tracks. The average values are relatively large when CDs are doped with fluorescent material, but the maximum values are equal or less. The CD specification of 100 B.E./s is satisfied, so there is no problem in actual use.



(a) Green CD



(b) Normal CD

**Figure 6.** Eye pattern of CD reproduced signal (horizontal axis, 0.5 $\mu$s/div.; vertical axis, 50 mV/div.).

**Table III.** Aperture ratio by eye pattern

| Color | Aperture ratio/% |
|---|---|
| Green | 63 |
| Orange | 62 |
| Red | 61 |
| Normal CD | 61 |

**Table IV.** Bit error rate (B.E./s)

| Color | Average | Maximum |
|---|---|---|
| Green | 6.8 | 61 |
| Orange | 4.5 | 40 |
| Red | 4.2 | 32 |
| Normal | 3.6 | 60 |

## CONCLUSION

More and more CDs will be used for musical recording and as large-capacity information recording media for personal computers and workstations. We need a way to differentiate CD products in the market. Evaluating CD information reproduction quality means searching for a new way to add to the value of CDs. The results of this study show that if perylene material is mixed with PC to make the CD substrate material, the CDs work as well as conventional CDs and look much more exciting. Perylene material is a fluorescent material that fully mixes with PC at the molecular level and is therefore very compatible. The fluorescent CD modulates visible light. We expect that will have new functions in the future. In terms of manufacturing, the release of the fluorescent CD substrate from the stamper of injection molding machine improved and the molding time will be reduced. Because fluorescent material is dispersed throughout the PC, we surmise that the surface of CD substrate is changed.

## REFERENCES


1. T. Kaino, *Jpn. J. Appl. Phys.*, **24**, 12, 1661 (1985).
2. A. Tanaka, H. Sawada, and N. Wakatsuki, *FUJITSU Sci. Tech. J.*, **23**(3), 166 (1987).
3. H. Sawada, A. Tanaka, and N. Wakatsuki, *FUJITSU Sci. Tech. J.*, **25**(2), 163 (1989).
4. FUJITSU, Japan Patent 63-218904.