Projection Screen Inspired by Human Skin for Use in Pseudo Windows

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Abstract

When we consider viewing the surface of human skin, the skin gives us a sense of natural depth, while, in contrast, the surface of a plastic does not. In our research program, learning from the structure of human skin, we fabricated screens which consist of multilayers made of translucent sheets coated with TiO2 nanoparticles. The feeling of natural depth from the screen can be considered to come from the multiply–observed images produced by phase differences due to the translucent multi layers. Additionally, we think that the feeling of natural depth from our 3D imaging screen comes from the reflection/diffusion differences of light depending on its wavelength as well as human skin. This is because that the spectral distribution measurements of these translucent sheets suggest that blue light with short wavelength is scattered on the surface of the first layer, while red light with long wavelength permeates to the under layers. The screen has a number of potential applications, since it is easy to prepare, low cost, and applicable to a large area. One of promising candidates is, of course, in the application as 3D projection screen. This is because 2D images projected on the screen can be automatically transformed into 3D images with a stereoscopic background. And considering that this system is applicable to not only reflection type but also transmission type, one of interesting candidates is for use in pseudo windows. By connecting an external camera, the screen can be utilized as a pseudo window on a real wall. The pseudo window can be expected to provide an open feeling while keeping high heat insulation, sound insulation, and privacy.

Keywords: Projection Screen, 3D image, Human skin, Pseudo Window

1. Introduction

In general, 3D imaging techniques1-5) require high computing power, specific software, and heavy large–scale hardware. In contrast, we have recently developed a calculation–free 2D-to-3D automatic conversion imaging screen6-8) that uses the nature of specific nanomaterials. We think that the 2D-to-3D transformation is based on the analogous mechanism that we feel the depth when we see human skin as reported in previous paper.7) When we consider viewing the surface of human skin, the skin gives us a sense of natural depth, while, in contrast, the surface of a plastic does not. The real structure of human skin is complicated, but we can simplify the optical structure as shown in Fig.1.

![Fig.1 Optical structure of human skin showing the transmission and reflection depending on color difference](image)

Human skin has a structure of translucent protein that encloses keratin, melanin granule, and blood.
parts. These three parts effect the refraction of light due to changes in their refractive index. Several research groups\(^9\)\(^-\)\(^11\) have indicated that the sense of natural depth of human skin occurs because the incident light reflects and diffuses in a complex manner, not only at the surface of the skin but also in the skin. Therefore, it can be considered that the translucent multilayer structure of human skin is one of the reasons to give us the sense of depth.

Our imaging screens consist of three layers made of two TiO\(_2\) translucent sheets and an aluminum-deposited sheet as shown in Fig.2. These translucent sheets are coated with titanium dioxide (TiO\(_2\)) nanoparticles. Controlling the type and concentration of these nanoparticles, we produced some phase differences in the images between the surface layer and the inner layer behind it. These phase differences can be considered to give us the sense of depth. We think that the feeling of natural depth from our 3D imaging screen comes from the multiply-observed images produced by phase differences due to the translucent multilayers.

We also think that the feeling of natural depth from our 3D imaging screen comes from the reflection/diffusion differences of light depending on its wavelength as well as human skin. Therefore, in this present work, in order to confirm that our screens have the analogous optical mechanism of human skin with particular emphasis on the color dependence, the translucent sheets coated with TiO\(_2\) nanoparticles or TiO2 pigments of our screens have been intensively characterized in terms of their optical properties using a light spectral distribution instrument.

Additionally, in this present work, we introduce one of interesting applications of our 3D screen. It is for use in a pseudo window.

### 2. Experiment

A typical coating liquid (Nano-Ti, 4.0%) was prepared as follows: 0.6 g of 2-propanol was added to a solution mixture of 64.1 g of acrylates/dimethicone copolymer (KP541) containing 40 wt.% of 2-propanol and 30.0 g of decamethyl cyclopentasiloxane. Then, 5.3 g of TiO\(_2\) nanoparticles (Daitopersion Ti-30) was added to the solution mixture above while stirring constantly (total solid content = 4.0 wt.%). The stirred mixture was dispersed for 40 min using an ultrasonic wave instrument with ultrasonic power of 150 W (SUC-200H, SD ULTRA Co., Ltd).

The same procedure was essentially repeated for all coating liquids, although the kinds and/or ratios of the materials were varied, depending on the total solid concentrations required, as summarized in Table 1.

Using the method described in our previous work\(^6\) coating liquids with in the case of Daitopersion Ti-30, 1.0, 2.0, 2.5, 3.0, 4.0 and 5.0 wt.% particle concentrations, or in the case of CR50, only 2.5 and 4.0 wt.% particle concentrations, were coated on 100 \(\mu\)m-thick polyethylene terephthalate sheets using a Baker-type cylindrical applicator with a coating speed of 5 mm/s and a gap of 12.7\(\mu\)m. After the coating process, the sheet was dried at least for 2 days at room

![Fig.2 Structure of our typical screen that consists of translucent sheets](image)

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
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<tbody>
<tr>
<td>Material size</td>
<td>Nanometer</td>
<td>Micron</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material</td>
<td>TiO(_2) Nanoparticles</td>
<td>TiO(_2) Pigments</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solid concentration (%)</td>
<td>1.0</td>
<td>2.0</td>
<td>2.5</td>
<td>3.0</td>
<td>4.0</td>
<td>5.0</td>
<td>2.5</td>
<td>4.0</td>
</tr>
<tr>
<td>Recipe (ratio)</td>
<td>Nano-Ti (30 wt.% slurry)</td>
<td>1.3</td>
<td>2.7</td>
<td>3.3</td>
<td>4.0</td>
<td>5.3</td>
<td>6.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pigment-Ti</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Acrylates/dimethicone copolymer (60% solution)</td>
<td>66.0</td>
<td>65.3</td>
<td>64.8</td>
<td>64.7</td>
<td>64.1</td>
<td>63.3</td>
<td>65.0</td>
</tr>
<tr>
<td></td>
<td>Decamethyl cyclopentasiloxane</td>
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<td>30.0</td>
<td>30.0</td>
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<td>30.0</td>
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<tr>
<td></td>
<td>2-propanol</td>
<td>2.7</td>
<td>2.0</td>
<td>1.8</td>
<td>1.3</td>
<td>0.6</td>
<td>0.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>

### Table 1 Formulation of coating liquids
temperature.

Screens consisting of three layers were made using the coating sheets fabricated as described above. A 3 mm-thick angular backing layer (Takashima Packaging, Japan) made from foamed polyethylene was sandwiched on the perimeter of the front surface between a 10 × 14 cm embossed aluminum-deposited sheet (Shibuta Corp.) and the coating sheets with the 2.5 wt.% particle concentration. The coating sheets with the 4.0 wt.% particle concentrations were then set on the free side of the 2.5 wt.% particle concentration coating sheets. The distance between the 2.5 and 4.0 wt.% coating sheets was controlled to be 6 mm by doubling the 3 mm-thick angular backing layer.

By connecting an external camera and a small projector and using a reflector, one of 3D screens were tried to utilize as a pseudo window on a real wall as shown in Fig.3.

![Fig.3 Schematic diagram showing the structure of a pseudo window using our 3D screen](image)

**3. Results and discussion**

Here we report experimental results for our sheets containing TiO$_2$ nanoparticles and TiO$_2$ particles. Fig.4 shows spectral distributions of a TiO$_2$ nanoparticle and a TiO$_2$ pigment sheets in the visible region. In the case of the TiO$_2$ nanoparticle sheet (sample No.3 in Table 1), as the wavelength increases, the transmittance increases, while with TiO$_2$ pigment sheet (sample No.7 in Table 1), the transmittance remains low, regardless of the wavelength.

The color of light, in other words, the wavelength of light gives us the different information depending on the depth of its permeation into the skin. For example, it is known that the blue light with the short wavelength permeates the depth of 100 μm in human skin while the red light with the long wavelength does the depth of 300 μm. Therefore, the blue light returns to observers with the information of wrinkles on the skin, while the red light does with the information of blood distribution in the skin. The spectral distributions of some of our imaging screens exhibit that, in the visible region, as the wavelength increases, the transmittance increases. Therefore, it can be said that the optical property of our screen with respect to color is similar to that of human skin.

The pseudo window can be expected to provide an open feeling while keeping high heat insulation, sound insulation, and privacy. We think that, since the screen gives us the sense of natural depth, the pseudo window has a potential to be used as a new type of window.

![Fig.4 Spectral distribution showing the transmittance of TiO$_2$ nanoparticle film (sample No.3 in Table 1) and TiO$_2$ pigment film (sample No.7 in Table 1)](image)

**4. Conclusions**

The light spectral distribution of the TiO$_2$ nanoparticle film suggests that the blue light with the short wavelength is scattered on the surface of the first layer, while the red light with the long wavelength permeates to the under layers and is scattered on them. Then, we have confirmed that our screen has the analogous optical mechanism of human skin in terms of the color dependence.

We have succeeded to fabricate 3D screens which consist of multilayers made of translucent sheets coated with TiO$_2$ nanoparticles. The potential of these 3D screens as pseudo windows were explored.

**References**


2) G. E. Favalora, “Volumetric 3D Displays and Application Infrastructure,” Computer, August,