Moiré-less Touch Sensor Film for High-Definition Displays

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Abstract

We have successfully developed a moiré-less touch sensor film for high-definition displays. Both an ultra-fine mesh line width (< 2 µm) and low resistance are achieved by high-aspect-ratio and high-density silver fine-line formation technology. This film is suitable for large-sized and high-definition displays due to its low resistance.

Author Keywords

fine mesh; moiré suppression; display films; photo sensitive materials

1. Objective and Background

A touch panel is used as an input device for notebook PCs and other portable devices by directly touching the screen. It has a touch sensor film sandwiched first between two sheets of transparent adhesive and then between a glass cover and a display (Figure 1 left). The front and back of the touch sensor film have sensor electrodes arranged in the X and Y directions respectively. By applying a voltage between the two facing electrodes, a capacitor is created. With the larger screens of touch panels (> 10 inches), metal mesh sensor films are used to improve pen input and touch performance (Figure 1 right). This is because as the number of capacitance detection points increases on larger touch screens, low-resistance electrodes are required for rapid charge accumulation which enables increase in the scanning speed.

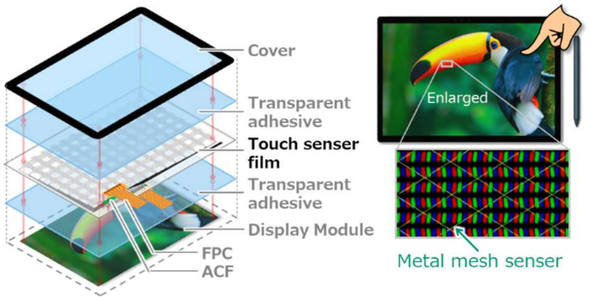

Figure 1. An example of a touch panel module and a touch sensor film (left). An example of a notebook PC and a mesh sensor film (right).

Generally, when the mesh sensor film is placed on the display surface of a panel, moiré patterns may appear. Moiré is a phenomenon where a new pattern is created by overlaying the periodic structure of the pixel array of the screen on the periodic structure of the mesh-like sensor electrodes. This reduces the visibility of the display [1-2]. In LCD panels, since the shape and size of the RGB pixels are often the same, it is possible to suppress moiré by adjusting the pattern of the mesh sensor electrodes [1-2]. On the other hand, in OLED panels, since the shape and size of the RGB pixels are different [3] and there are multiple periodic pixel structures, it is impossible to suppress moiré by adjusting the pattern of the mesh sensor electrodes.

To eliminate moiré patterns, use of fine line mesh sensors in addition to adjusting the pattern of the mesh sensor electrodes have been proposed [1]. The interference with the periodic structure of the pixel array is reduced by thinning the mesh line. Figure 2 shows simulation of moiré formed by thinning the mesh line. We compared the occurrence of moiré by simulating the cases where metal mesh sensors with line widths of 3.5/2.5/2.0 µm are superimposed on two panels with different RGB pixel arrangements. In this simulation, the moiré pattern is more visible on complex panels where the pixel arrangements of RG and B differ, and less visible when the mesh line width is thinner. We posited that it would be possible to lower the visibility of moiré patterns with complex pixel arrangements by thinning the mesh line width to 2 µm or less.

In this study, we present new touch sensor films with a fine mesh line width of 2 µm or less, made by silver mesh precision patterning technology. We tested its moiré pattern suppression in the cases of OLED panels with different pixel patterns.

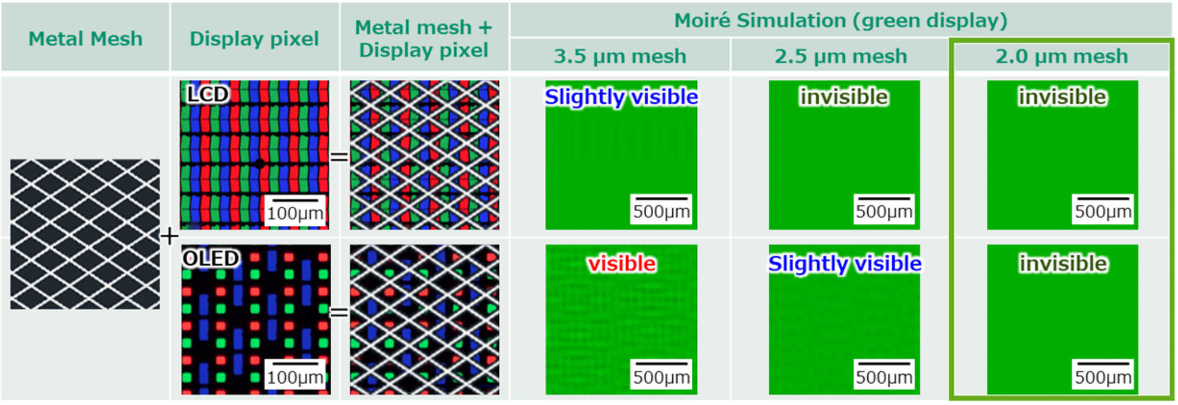

Figure 2. Simulations of moiré formed when a metal mesh sensor film and display are superimposed.

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2. Results

2-1. Processing of metal mesh sensor films

In 2017, we reported a metal mesh sensor film made using silver halide photographic technology [6]. It can form highly conductive silver lines with a precisely adjustable pattern through exposure of a photosensitive silver material.

Figure 3 shows the steps of this silver mesh patterning process, including exposing portions of photosensitive material containing silver halide to UV light to form metallic silver, and dissolving the remaining silver halide with developing solution [6]. A photosensitive material containing silver halide particles of 200 nm with a gelatin binder is coated onto a transparent substrate (Figure 4). Next, UV light exposure through a pattern mask forms silver nuclei in the silver halide [7]. Then, silver nuclei are reduced to silver by the reducing agent in the developing fluid. Finally, undeveloped particles are dissolved in water and removed from the film, to make a mesh sensor with a silver mesh pattern.

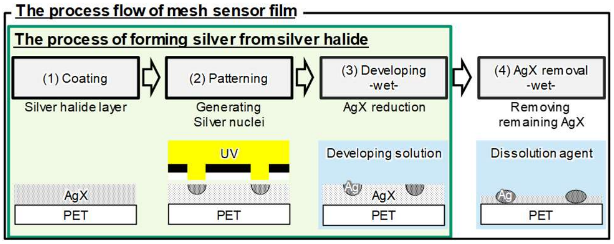

Figure 3. Method of fabricating a silver sensor film with a mesh pattern.

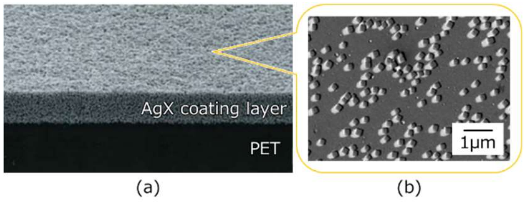

Figure 4. (a) Cross-section of the silver halide coating layer. (b) The silver halide grains.

2-2. Fine silver mesh pattern formation technology

The mesh line width is affected by the light scattering, as shown in Figure 5. Light through the mask is exposed to the photosensitive material, and silver nuclei are formed, but the mesh line becomes wider than the mask aperture due to light diffusion in the photosensitive material layer. The silver halide that has absorbed light is converted to silver by the development process, and the silver mesh pattern is formed.

Figure 6 shows the relationship between the mesh line width and resistance in relation to UV exposure dose. The dark circles plot line width against exposure dose. The white squares plot electric resistance of the line against exposure dose. The higher the exposure dose, the lower the resistance and the wider the mesh line width (becoming progressively wider than the mask aperture width). This is because when the silver halide particles in the photosensitive material are exposed, the light that is not absorbed by the silver halide particles inside the material scatters, diffusing the light, and the surrounding silver halide absorbs the light (Figure 5). Reducing exposure will make the mesh lines thinner, but the resistance will increase, and it will become impossible to form a highly conductive silver mesh pattern.

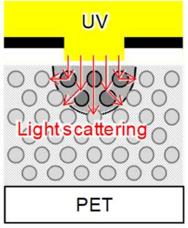

Figure 5. Light scattering during pattern exposure in this process.

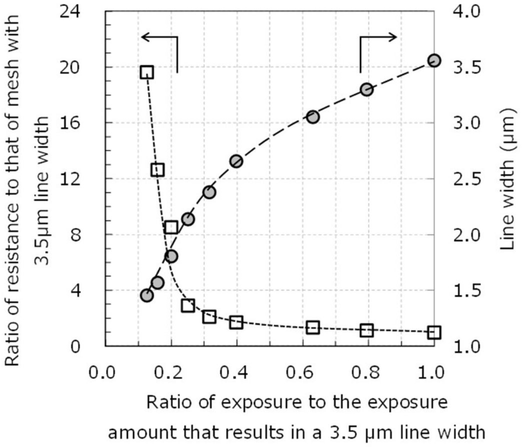

Figure 6. Relationship between exposure dose, line width and resistance (mask aperture width 1.2 μm)

One the other hand, the reduction process by physical development is known as the method of increasing the density of silver [7]. It is known that silver grows isotropically with high-density through this method (Figure 7). Silver ions and electrons provided by the reducing agent react near existing silver, upon whose surface additional silver is deposited.

To achieve both high conductivity and fine line widths, it is necessary to increase both the total amount of silver and the silver density. We thought it would be possible to form a fine silver mesh pattern with high silver density by: i) suppressing the scattering of the exposure light in the photosensitive layer and increasing the depth of silver halide that is photo-exposed ii) reduction of silver particle surfaces, which increases silver density (Figure 8).

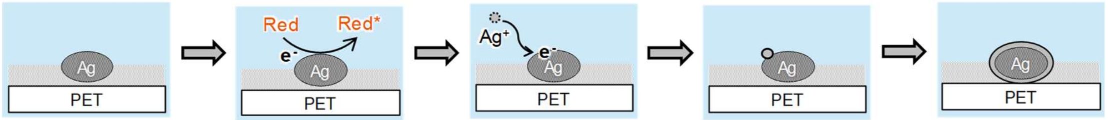

Figure 7. A reduction process using physical development. “Red” is reducing agent.

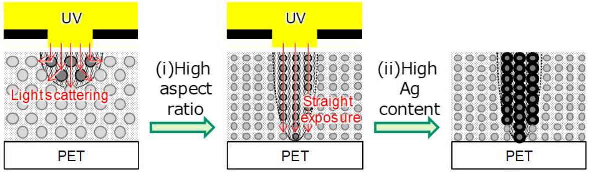

Figure 8. Method of fine mesh sensor film fabrication for high silver content and density.

2-3. Effect of silver halide particle size on the depth of pattern photoexposure

The light scattering of silver halide in the photosensitive layer depends on the particle size. To analyze this dependence, we calculated the intensity distribution of light irradiated on silver halide photosensitive materials using the FDTD (Finite-difference time-domain) method. Figure 9 shows the cross-sectional area of the portion of the material where light intensity is sufficient to reduce the silver halide, calculated with various silver halide particle sizes. In this simulation, the photo-exposure was adjusted so that the mesh line width was 2 µm. It was found that the cross-sectional area of silver halide photosensitivity could be increased by reducing the particle size of silver halide to 100 nm. Figures 10(a-1) and 10(a-2) show the simulated intensity distributions of light within photosensitive materials with silver halide particles of 200 nm and 100 nm in diameter. The cross-sectional area of the portion sufficiently exposed for reduction increased with reduction in the size of the silver halide particles. We believe the depth of silver halide that is reduced by light increases due to reduction in light scattering within this layer. Figure 10(b-1) and Figure 10(b-2) show cross-sections of actual samples after pattern exposure and development. They agree well with the simulated distribution of the light exposure. It was confirmed that by being made finer, the distribution of the silver halide particles converted to silver deepened, for a high aspect ratio. Therefore, by making the silver halide particles finer, light scattering was suppressed and the cross-sectional area of the silver halide that becomes silver upon exposure to light was increased.

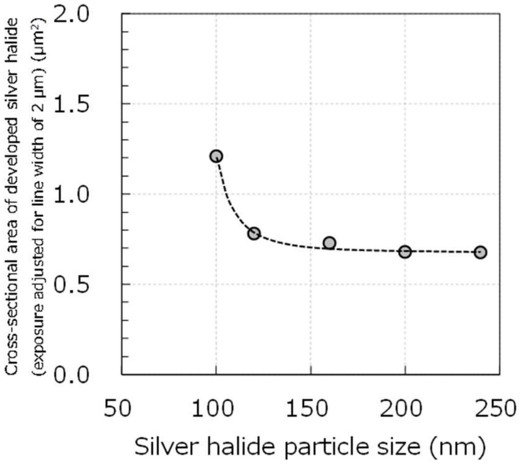

Figure 9. The particle size dependence of the cross-sectional area of the silver halide sensitized material when the exposure dose is adjusted to achieve a line width of 2 µm.

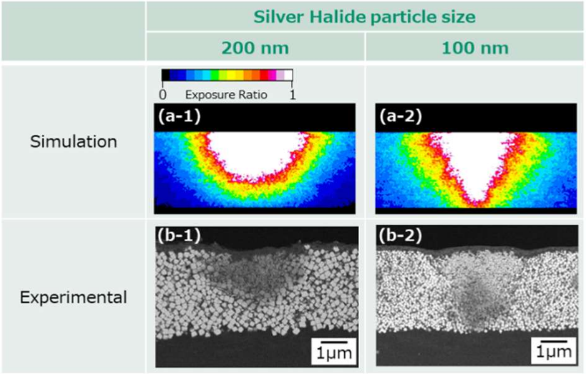

Figure 10. FDTD-simulated distributions of exposure light intensity and actual morphological photos

2-4. Increasing silver density by reduction treatment

Figure 11 shows the test results of high-density silver achieved by reduction treatment. We confirmed that new silver particles formed and adhered around existing silver particles to form a high-density silver mesh. Further, there was almost no increase in the width of the silver mesh. Figure 12 shows the resistance after the reduction treatment (the line widths of the gray dots in Figure 6 are plotted here on the horizontal axis). By reducing the size of the silver halide particles and carrying out a reduction process, it was possible to reduce the resistance ratio of a sample with a line width of 1.6 µm to that of width 3.5µm to less than 1; samples made with the previous development process had a resistance ratio of 12. It is thought that this is because the silver particles formed after exposure are smaller due to the silver halide being made into fine particles, and as the result of the increased surface area, the number of silver particles inside the silver line increases, increasing the density inside the silver. Thus, increase in mesh line width is suppressed. From these results, we discovered that reducing the size of silver halide particles minimizes light scattering, enabling the use of silver halide in photosensitive materials. We also found that reducing the size of silver halide particles decreases the resistance of the developed silver without increasing the mesh line width. By applying this technology, we successfully developed a low-resistance touch sensor film with a mesh line width of 1.7 µm.

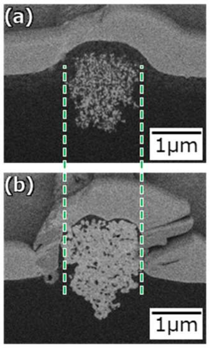

Figure 11. Cross-sectional morphology of mesh silver before (a) and after (b) the physical development process.

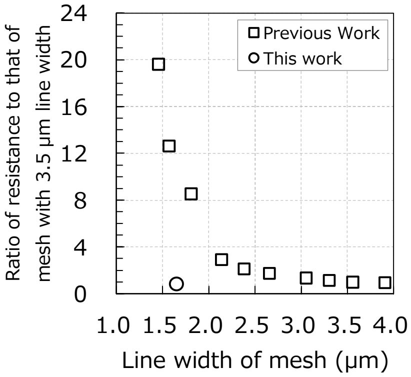

Figure 12. Line width dependence of resistance (square: previous work; circle: this work.)

2-5. Verification of moiré suppression in OLED panels using a fine mesh pattern

Figure 13 shows the dependence of the line width of the touch sensor film on the sensory evaluation of moiré when OLED panels with different pixel patterns are superimposed on the touch sensor film. Moiré appeared due to interference between these OLED panels and the mesh sensor film with the mesh line width of 3.5 µm. On the other hand, when the mesh line width was 1.7 µm, moiré was almost invisible, as the simulation results showed. It is suggested that if the mesh line width is 1.7 µm, it is possible to suppress moiré generation by superimposing the same mesh pattern on various pixel arrangements.

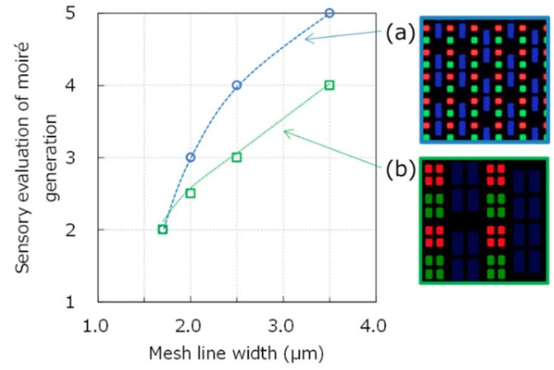

Figure 13. Dependence of visibility of moiré on mesh line width when mesh sensor film and OLED panel are superimposed (Displayed image color: G, Observation distance: 30cm, Evaluation levels of moiré: 5; visible, 4; slightly visible, 3; weakly visible, 2; almost invisible, 1; invisible).

3. Conclusion

We have developed a technology for controlling fine lines by applying silver halide technology. By controlling the scattering de on the size of silver halide particles and applying reduction technology, we have succeeded in developing a touch sensor film with a line mesh of fineness which was previously thought difficult to achieve. It is now possible to eliminate moiré from high-definition OLED panels with complex pixel arrangements. Furthermore, because this mesh has low resistance, it can also be applied to OLEDs for large IT devices, which are difficult to make with ITO due to insufficient conductivity.

4. Acknowledgements

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5. References

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