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Design of Metal-mesh Electrode-based Touch Panel for Preventing Back-surface Touch Error

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We demonstrated a metal-mesh electrode-based touch screen panel that does not have back-surface touch error (BTE) due to panel bending. It was fabricated with a 7-inch double-layer structure by the roll-to-roll process. Samples with various mesh pitch ratios for the sensing (Rx) and driving (Tx) electrodes were prepared and tested. BTE removal was ensured at touch pressures below 650 gf with mesh pitch ratios of less than 0.25 for the Tx/Rx electrodes. The linewidth of the fabricated electrode was 3 μm, and the transmittance was 87.51% at 550 nm. At this time, the mesh pitch of the Tx electrode was set to 220 μm, and that of the Rx electrode was 880 μm.

1. Introduction

The latest trends for connected cars and telematics are prompting more car manufacturers to consider the adoption of projected capacitive touch screen panels (TSPs) that can provide a user experience similar to that offered by the touch displays of smartphones and tablet PCs.(1) The touch interface has become a killer application for consumer electronics devices because it can reduce cognitive burden.(2,3) In recent years, studies have been actively conducted to utilize metal in a sensing electrode, instead of high-resistance indium tin oxide (ITO), to develop large touch panels.(4–6) These touch panels are classified as embedded types and include in-cell/on-cell and add-on types depending on the location of the touch sensor on the display.(7) The typical add-on types used in large panels include an air gap between the panel and the display, and bending occurs when the panel is pressed beyond the limit force. This bending causes a change in the parasitic capacitance (*Cp*) formed between the display and the TSP, distorting the touch position on the front side computed by the IC.(8) This phenomenon is called back-surface touch error (BTE) because it is the same as the error caused by touching the back of the panel. Many studies have been performed on removing this BTE. Typical methods are to use the

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lower layer (close to the display) for the Tx electrodes and the upper layer (far from the display) for the Rx electrodes. In this case, the lower layer of ITO electrodes is made wide and dense to shield the display from interference.[9–11]

However, in order to commercialize an opaque metal layer by applying it in TSPs, it is necessary to form a mesh pattern to prevent recognition. Therefore, the metal electrode is not a solid type like the ITO electrode but a structure with a hole. Electrical interference with the metal-mesh electrodes in the lower layer cannot be avoided. The mesh sensors must be shielded using patterns.

In this study, the metal-mesh pattern design was optimized to prevent BTE due to panel bending. In order to overcome these problems, we applied a bar and bar pattern. On the basis of the results of this study, TSPs with various mesh pattern densities were fabricated and evaluated.

2. Method of Preventing BTE

Figure 1 shows that the touch panel on the display has mutual capacitance (Cm) formed by Tx and Rx electrodes as well as Cp. Given constant voltage V and the same panel position on the display, electric charge stored in Cm and Cp remains constant, as shown by[12]

$$Q = CV. \tag{1}$$

Because the Tx electrode is a mesh that cannot prevent electrical interference, if the panel is warped, an obvious change occurs in Cp.[13] An increase in Cp causes a decrease in the amount of charge transferred from the Tx electrode to the IC through the Rx electrode and is reflected in a change in the signal baseline used by the IC to determine touch occurrence. A reduced charge builds up the (+) difference in the signal baseline, which is used as data for coordinate

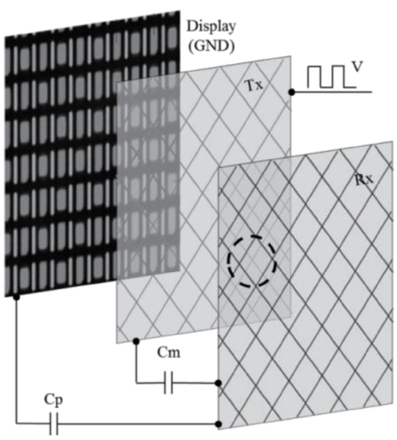

Fig. 1. Metal-mesh-based TSP stack of electrodes and display with Cm and Cp.

calculations. At this time, the amount of change due to bending is added to the amount of change generated by the actual touch. Thus, when the touch coordinates are calculated, they are biased toward the direction in which the bending occurs. As shown in Fig. 2, a BTE generates an error in the calculated touch coordinates.

To prevent the BTE due to bending, the difference in the signal baseline with and without the back-surface touch should be minimized, and it is also necessary to reduce the coupling between the Rx electrode and the display. The strength of coupling can be expressed by *Cp* as shown in Fig. 1 and

$$Cp = \varepsilon \cdot A / d, \tag{2}$$

where A, d, and ε are effective area of overlap between the Rx electrode and LCD, separation, and relative permittivity, respectively. Since the possible range of separation is limited by the panel thickness, the gap distance is not allowed to change over a certain level. In this study, we propose a novel method of reducing the effective contact area by adjusting the mesh pitch of Tx and Rx electrodes. To enable a better understanding, Fig. 3 shows the mesh pitch, electrode, and display layout. However, increasing the mesh density of Tx electrodes has a limitation because it decreases the transmittance. Reducing the Rx mesh density causes an open failure, and it is difficult to ensure the process.

The sensor has different resistance (R) and capacitance (C) components for each channel depending on the ratio Pt/Pr, and they have a direct effect on the drive signal and sense signal. Basically, an increase in the electrode density of the mesh sensor means that the parallel resistance path is increased, which means that R becomes smaller and C becomes larger. In other words, when the electrode density increases, the signal is easily transmitted. Therefore, assuming that the Rx electrode is completely exposed, a higher density for the Rx electrode will result in higher top and back sensitivities. However, it is necessary to consider the shielding

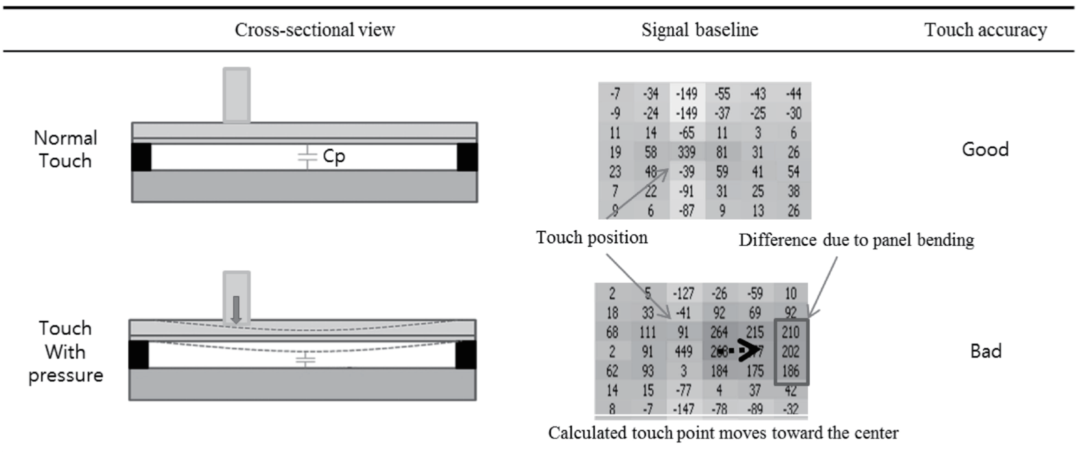

Fig. 2. Variation in signal baseline follows bending of TSP.

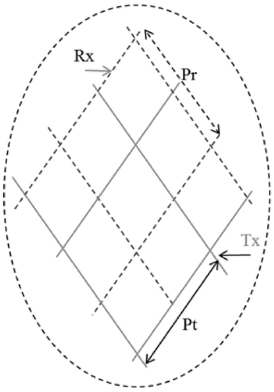

Fig. 3. Design parameters of metal-mesh electrode.

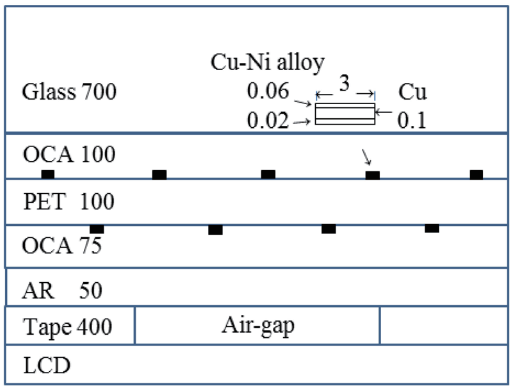

Fig. 4. (Color online) Laminated structure of TSP (unit: μm).

Table 1
Selected mesh pitch ratios of Tx/Rx electrodes.

Ratio		Tx mesh pitch (Pt)		
		440 μm	220 μm	110 μm
Rx mesh pitch (Pr)	880 μm	0.5	0.25	0.125
	440 μm	1	0.5	0.25

effect of the Tx electrode to achieve a high surface sensitivity and low back sensitivity. In other words, it is necessary to control the extent to which the Rx electrode is exposed to the top or back, taking the sensitivity into consideration. Therefore, in this study, we tried to find the optimal sensitivity formation point while controlling the Pt/Pr ratio proportionally, as listed in Table 1.

3. Experimental Details

The touch sensitivity varies depending on the laminate configuration.(14) The sensitivity of the back surface touch, in particular, is proportional to the capacitance formed between the virtual grounded conductor and the Rx electrode. The capacitance is dependent on the dielectric constant of each layer and their thickness. Therefore, in this study, we used the structure shown in Fig. 4. The metal-mesh electrodes are deposited on polyethylene terephthalate (PET) film as passivation/conduction/passivation (PCP) structures and then fabricated by the roll-to-roll process.(15) Then the PET film is laminated with 0.7-mm-thick reinforced glass and 0.05-mm-thick AR film for bonding with the display. For stacking touch panels on the display, 0.4-mm-thick frame-type double-sided tape was used, and 3M OCA was applied where the whole surface was to be bonded.

The BTE was generated by the bending of the module with touch pressure, as previously defined. The corresponding bending of the module is induced in the direction of a narrowing gap between the Rx electrode and the GND (display). As the capacitance is inversely proportional to the gap distance, it is better to apply a panel with bending to significantly increase the initial gap between the TSP and the display. However, because of the contribution to the product thickness by the induced gap, we employed an arch-like shape with less than 100 μm height.

To confirm the occurrence of BTE, an evaluation environment was constructed, as shown in Fig. 5. An IMADA digital push-pull gauge was used to quantify the load applied by a touch. A host board and software were developed to compare the coordinates and mechanical coordinates output by a ZINITICS BT532 IC. A graphical user interface (GUI) was implemented to control a touch robot and display the touch coordinates. In addition, the TSP was attached to a metal plate jig with a common gap between the jig and TSP circuit, making it possible to realize an environment resembling the air gap structure connected to the display (GND). BTE was judged to occur when the difference between the machine coordinate and compute coordinate was ±2 mm with the maximum load of 675 ± 25 gf applied using a 4Φ conductive bar. Equation (3) summarizes the relationship among the BTE occurrence probability, the panel size, and the applied load weight.

$$P(BTE) \propto W \cdot A / T \tag{3}$$

$P(BTE)$, W, A, and T are the probability of BTE occurrence, weight of touch, effective contact area where the LCD and touch panel are overlapped, and the thickness of the panel, respectively. The BTE, therefore, is more prone to occur with increased load weight.

(a) (b)

Fig. 5. Environment developed for evaluating occurrence of BTE: (a) graphical user interface and (b) motorized touch robot.

4. Results

4.1 Electrical properties

As listed in Table 2, the evaluation results confirmed that when the Pt/Pr ratio was set to 0.25 or less, there was no problem in recognizing the 4Φ conductive bar, and the BTE could be prevented. We confirmed the occurrence of BTE in the TSP manufactured using the evaluation system and developed a TSP that does not generate BTE under a touch pressure of 650 gf or less.

4.2 Optical properties

The optical transmittances of the samples were investigated. As listed in Table 3, when the ratio Pr/Pr was 0.125, the minimum transmittance was 84.86% at a wavelength of 550 nm. In addition, Fig. 6 shows the results of panel displacement and coordinate error measurement due to the weight change. Touch counts 1, 2, and 3 are repeated measurements on the same spot. In the absence of BTE, the maximum transmittance was found to be 87.51%.

Table 2
Results of BTE evaluation.

Result		Pt		
		440 μm	220 μm	110 μm
Pr	880 μm	Fail	**Pass**	**Pass**
	440 μm	Fail	Fail	**Pass**

Table 3
Light transmittance at wavelength of 550 nm.

Transmittance (%)		Pt		
		440 μm	220 μm	110 μm
Pr	880 μm	87.84	87.51	84.86
	440 μm	87.16	86.73	84.96

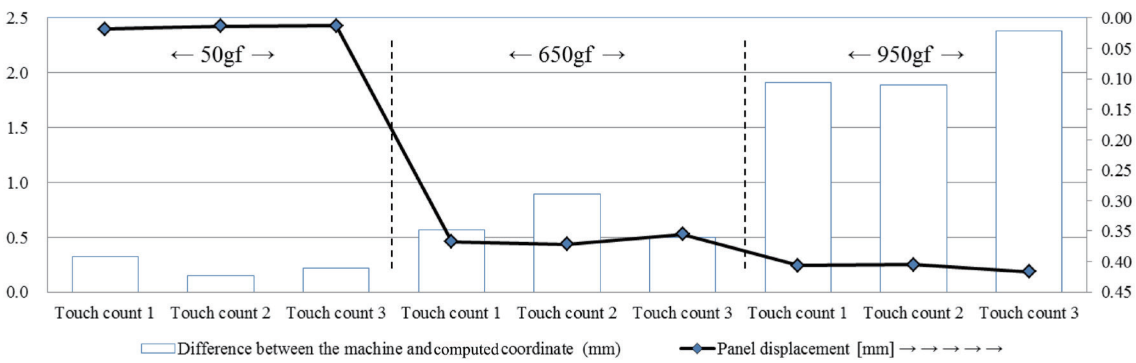

Fig. 6. (Color online) Panel displacement and coordination error due to weight variation.

5. Conclusions

We developed a metal-mesh electrode-based TSP without the BTE caused by panel bending. The criteria for judging the occurrence of BTE were a difference of ±2 mm between the machine coordinate and computed coordinate when the maximum load was 675 ± 25 gf using a 4Φ conductive bar. BTE removal was ensured with a mesh pitch ratio of less than 0.25 for the Tx/Rx electrodes. The linewidth of the fabricated electrode was 3 µm, and the transmittance was 87.51% at 550 nm.

References

1 ITBizNews: http://www.itbiznews.com/news/articleView.html?idxno=2527 (accessed July 2017).
2 K. Phil and T. Nedu: Nikkei Electron. **0602** (2008) 43.
3 G. Walker: Inf. Disp. **23** (2007) 8.
4 H. S. Kim, S. J. Yang, K. J. Noh, and S. E. Lee: J. Korean Inst. Electr. Electron. Mater. Eng. **29** (2016) 414.
5 S. Son, J. E. Park, J. Lee, M. Yang, and B. Kang: Sci. Rep. **6** (2016) 34629.
6 Y. Choi, K. Kim, E. Lee, and T. Lee: SID 14 DIGEST (2014) 197–199.
7 J. H. Yang, S. C. Jung, Y. S. Son, S. T. Ryu, and G. H. Cho: IEEE Trans. Circuits Syst. **60** (2013) 1800.
8 B. Li, T. Wei, and X. Wei: 2014 IEEE 9th Conf. Industrial Electronics and Application (ICIEA) 872–876.
9 J. M. Lee: Comparative Study of Mutual Capacitive Touch Screen Panel Design, Master's Thesis (KAIST, Korea, 2011).
10 Apple Inc.: Double-side Touch-sensitive Panel with Shield and Drive Combined Layer, US7920129.
11 H. W. Klein: Noise Immunity of Touchscreen Devices, Cypress Semiconductor Corp, February 2013.
12 H. Haga, J. Yanase, Y. Kamon, K. Takatori, H. Asada, and S. Kaneko: SID 10 DIGEST (2010) 699–672.
13 J. W. Kim, H. J. Lim, S. H. Han, Y. H. Jung, and S. J. Lee: J. Disp. Technol. **12** (2016) 1623.
14 Fieldscale Corp.: Fieldscale_SENSE_Metal_Mesh_Report, https://www.fieldscale.com (accessed May 2017).
15 K. S. Chae, S. Han, J. Y. Jeong, and T. H. Han: Sens. Mater. **29** (2017) 1285.