Development of Sputtering system "SMD3400" For G10.5 mother glass

Yuusuke MIZUNO[*1], Tatsunori ISOBE[*1], Makoto ARAI[*1], Junya KIYOTA[*1], Kazuya SAITO[*1], Tetsuhiro OONO[*2], Syuhei KYUUJI[*2], Toshio NAKAJIMA[*2], Hiroki OOZORA[*2] and Shigemitsu SATO[*2]

[*1] Institute for Super Material, ULVAC, Inc., 2500 Hagisono, Chigasaki, Kanagawa, 253-8543, Japan
[*2] FPD・PV Division, ULVAC, Inc., 2500 Hagisono, Chigasaki, Kanagawa, 253-8543, Japan

"SMD 3400" is the large-scaled sputtering system, manufactured and developed for use in Generation 10.5 (G10.5), which mother glass size is approximately 3400×3000 mm, for TFT-LCD production line. "SMD 3400" is composed of Loading/Unloading position, Loading/Unloading chamber, heating chamber and 2 sputtering chambers. Planer targets of Cu and ITO are mounted respectively on the sputtering chamber in multi-cathode systems. This sputtering system has improved horizontal wave-formed thickness uniformity problem depends on the cathode arrangement by using new-type deposition method, although conventionally film thickness become thicker right in front of the target and thinner at between the targets. This new-type deposition method has successfully introduced to "SMD2400" so far, which established mass production technology to improve luminance unevenness in display due to horizontal wave-formed thickness uniformity.

We investigated film thickness uniformity, Rs uniformity, reflectance (for Cu), transmittance (for ITO) and film stress in the Cu and ITO process using "SMD3400". We obtained film thickness uniformity less than 10% in both process as we expected by the simulation. We confirmed new-type deposition method improve Rs horizontal distribution. And good Rs uniformity, reflectance, transmittance and film stress were obtained at G10.5 substrate area.

1. Introduction

In a recent strong momentum of capital investment in the flat panel display market, manufacturers have been trying to mass produce large panels typically used for LCD TVs and small-medium sized panels utilized for smartphones, tablets, and other high definition mobile devices. Today's mainstream manufacturing equipment process 8.5-generation (G8.5) mother glass with a size of 2,500×2,000 mm for the production of large panels. The growth in size had stalled after G10 mother glass came out in 2010 until the recent increase in panel size over 70 inches. In pursuit of a greater number of panels obtained from a single sheet of mother glass, panel manufacturers are planning capital investment in equipment to process G8.6 mother glass, which is slightly larger than G8.5, or G10.5 mother glass that is about 3,400 mm on the long side. Meanwhile, to produce small-medium sized panels, the sixth generation (G6) of manufacturing equipment for backplanes (TFT substrates) is now the mainstream. Capital investment in manufacturing equipment for OLED panels is increasing at an accelerating pace, as is additional equipment for producing conventional LCD panels.

ULVAC offers several SMD Series[1-3] products as sputtering systems for panel manufactures to mass produce backplanes (TFT substrates) by forming metal wiring films, transparent conductive films, and oxide semiconductor layers as typified by IGZO.

This article provides an overview of the hardware for the SMD-3400 developed as a sputtering system designed for G10.5 mother glass. Also, the test results for validating the Cu deposition process for making metal wiring films and ITO deposition process for making transparent conductive films is examined.

2. Sputtering system designed for G10.5 mother glass

Figure 1 schematically illustrates the SMD-3400 as a sputtering system designed for G10.5 mother glass which is about 3,000×3,400 mm in size. This vertical in-line deposition system comprises a positioning chamber to remove a substrate from the cassette and attach it to the tray, along with a loading and unloading chamber, heating chamber, and two sputtering chambers. One of the sputtering chamber handles Cu deposition process and the other ITO deposition process. In terms of the type of cathodes, a multi-cathode design was utilized for both Cu and ITO by aligning planar targets.

The new deposition method employed in this system can provide better uniformity in film-thickness, which used to depend on cathode dimension in conventional multi-cathode systems. Conventional multi-cathode deposition on a fixed substrate results in wave-like unevenness in film thickness caused by the different shapes of the cathodes. Such films tend to be thicker just above each target and thinner between targets. The ability of the new deposition method to enhance the uniformity of the film thickness has already been proven by the SMD-2400. Thus, it has been established as a mass production technology for reducing unevenness in panel displays associated with the distribution of film thickness.

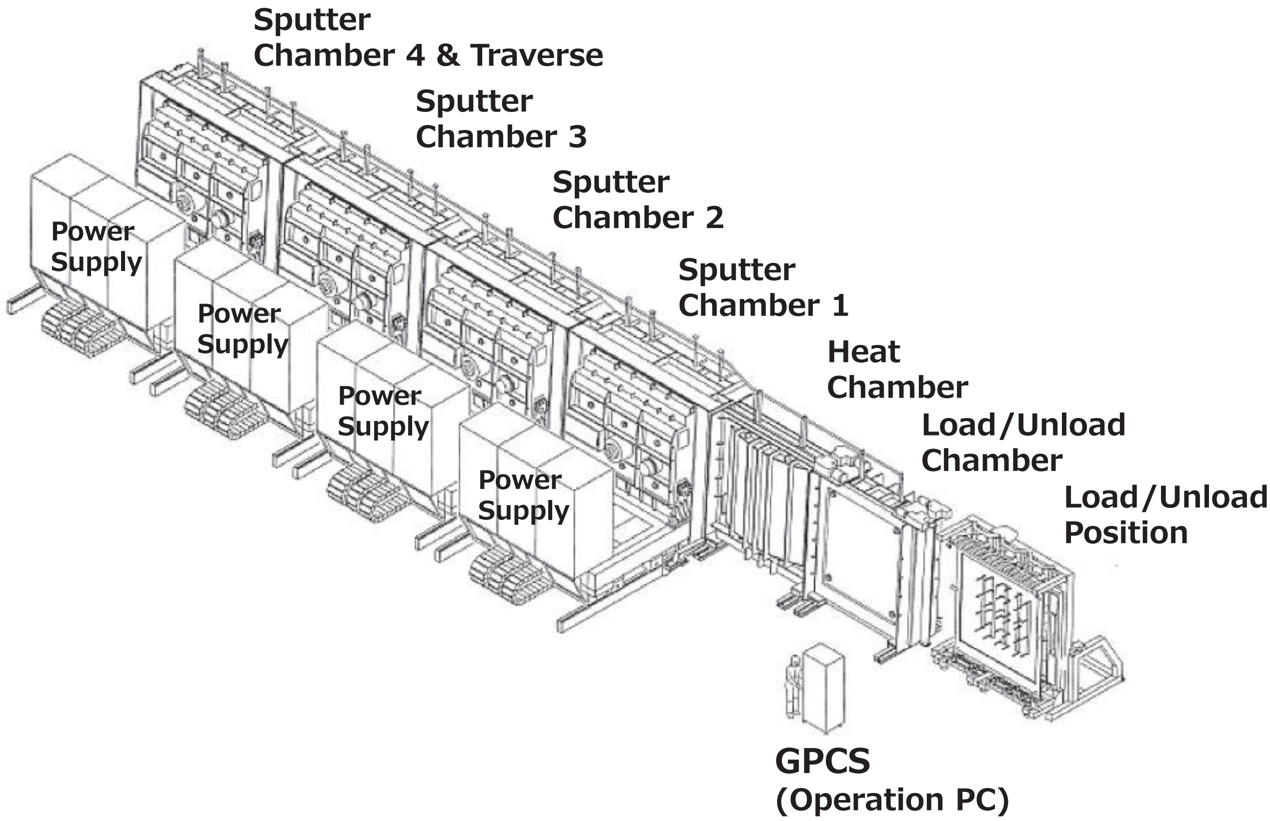

Figure 1 Appearance and diagram of "SMD3400".

3. Testing method

This test used the SMD-3400 to deposit thin-films of Cu and ITO on a glass substrate with respective thicknesses of about 350 nm and 40 nm. These films were examined in terms of their thickness and Rs distributions to check the system's performance in single-film deposition. The thickness was measured with a Dektak3, a step meter. The sheet resistance (Rs) was measured with a 4-point probe measurement device by NAPSON. The reflectance of the Cu film and the transmittance of the ITO film were measured with a SolidSpec-3700 by Shimadzu. The film stress was calculated using elasticity equation with a FLX Scan from Toho Technology.

4. Test results

4.1 Thickness distribution of Cu film

First, the deposition rate and thickness distribution were examined. Deposition was performed under a pressure of 0.3 Pa by using the new deposition method.

The deposition rate was at least 1,000 nm/min, which was estimated with the power density and cathode pitch of the existing SMD-2400. The thickness distribution of the film on the substrate shown in Figure 2 demonstrates

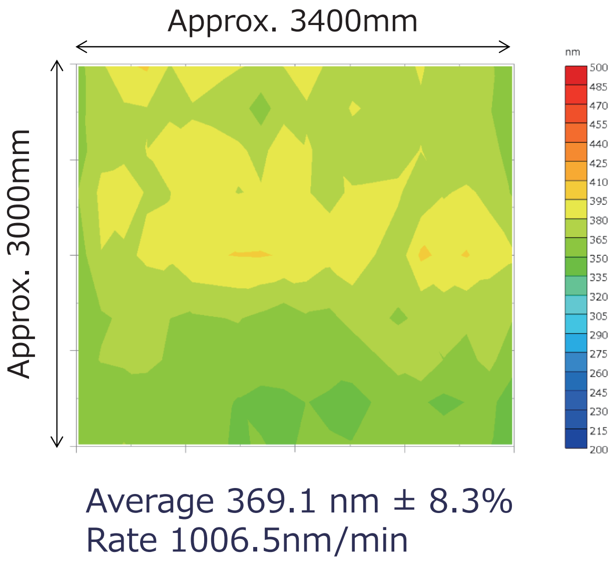

Figure 2 Thickness uniformity of Cu film.

an adequate uniformity of ±8 percent.

4.2 Rs distribution of Cu film

Rs measurement was conducted after forming a Cu film under the same deposition conditions as in the examination of the thickness distribution in the previous section.

The average sheet resistance on the substrate was 0.055 Ω/□. The Rs distribution on the substrate shown in Figure 3 demonstrates an adequate level of ±7 percent.

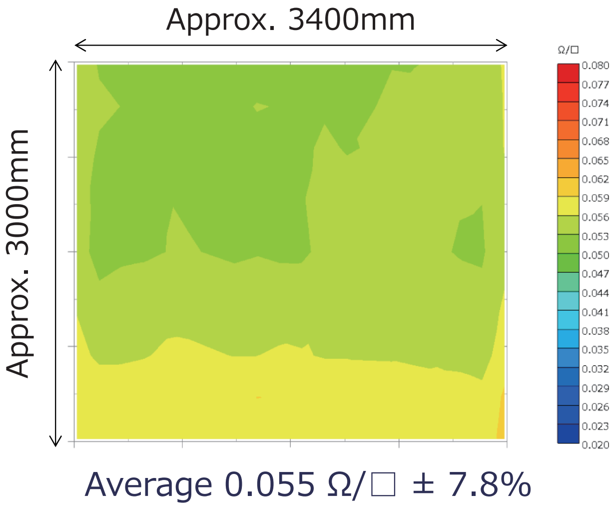

Figure 3　Rs uniformity of Cu film.

4.3　Film stress and reflectance of Cu film

Figure 4 shows the stress and reflectance of the Cu film formed under the same deposition conditions as the previous section. The film stress was calculated after forming a Cu film on the Si wafer substrate. This is the relative reflectance of the Si wafer.

The film stress was even across the substrate with an average level of ＋200 MPa. The reflectance was about 180％R for the wavelength of 550 nm on average.

4.4　Effect of new deposition method

Figure 5 compares the horizontal distribution of the sheet resistance of Cu films formed by the conventional method with a fixed substrate and the new deposition method. The conventional method results in the wave-like Rs distribution in the horizontal direction with a uniformi-

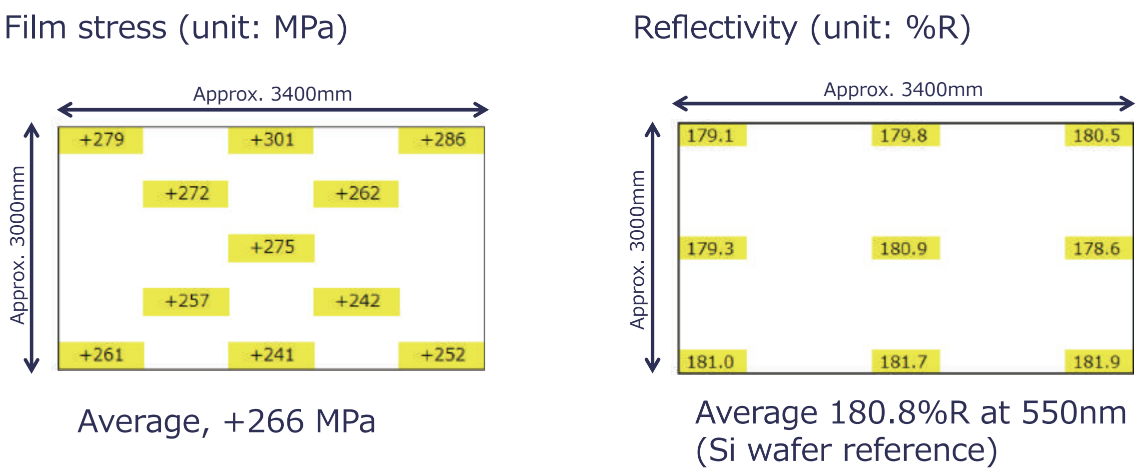

Figure 4　Film stress and reflectance of Cu film.

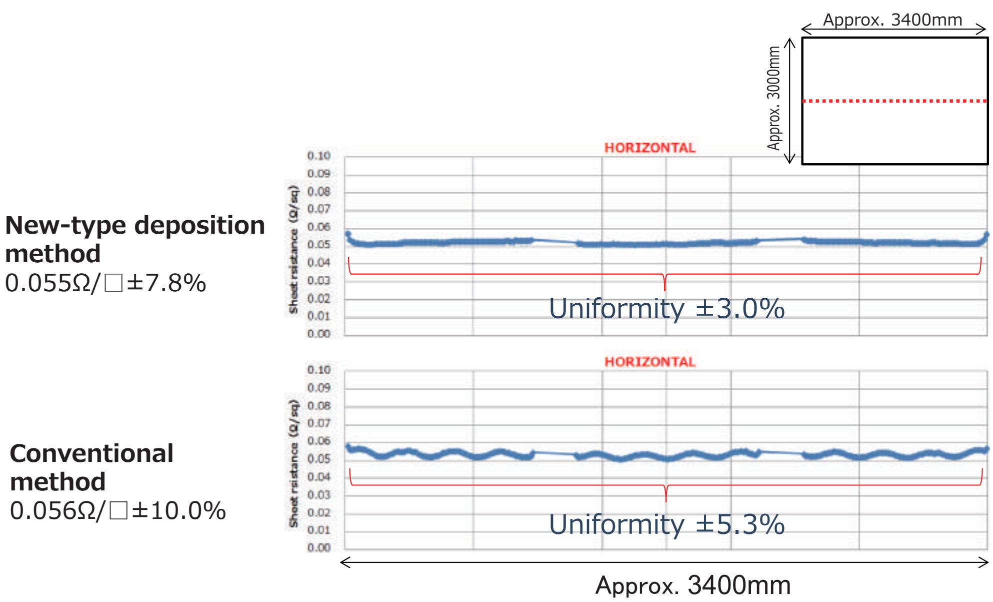

Figure 5　Effect of new-type deposition method. Rs uniformity was improved and Rs horizontal wave form shape became flat with new-type deposition method.

ty of around ±5 percent. The new deposition method eliminates the wave-like distribution and enhances the uniformity to the level of ±3 percent. By the new deposition system, the horizontal distribution of the substrate was improved and no wave distribution appeared. In this example, Cu deposition process was examined to validate the new deposition method. Similar improvements can be achieved with all other kinds of films.

4.5 Thickness distribution of ITO film

The ITO film was deposited under a pressure of 0.67 Pa. The channel for introducing Ar-H_2 gas mixture and O_2 gas was optimized to achieve even gas distribution in the discharge space. The use of Ar-H_2 gas mixture as a process gas is intended to obtain a stable amorphous film in the ITO deposition process. Although the addition of H_2O can deliver the same effect, this test adopted the process involving the addition of H_2[4].

The resulting deposition rate accorded with the estimated rate based on the power density and cathode pitch of the existing SMD-2400. The distribution of film thickness on the substrate shown in Figure 6 demonstrates an adequate uniformity level of ±9 percent.

4.6 Rs distribution of ITO

With the same thickness distribution under the same deposition pressure as the previous section, O_2 gas was introduced as a reaction gas to conduct an O_2 bottom test. Figure 7 presents the O_2 bottom curve after annealing at a temperature of 230℃ for 60 minutes in the atmosphere.

Average Rs was about 66 Ω/□ after annealing by introducing O_2 while optimizing Rs and the Rs distribution.

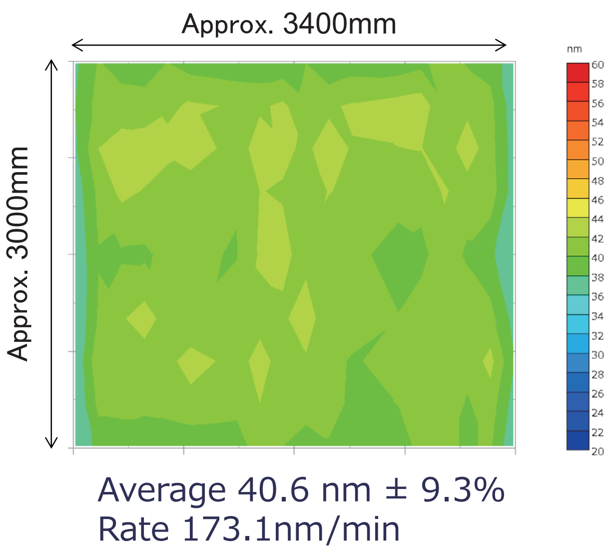

Figure 6 Thickness uniformity of ITO film.

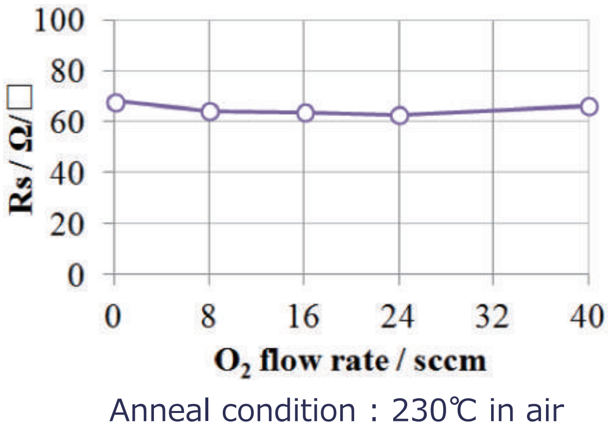

Figure 7 O_2 bottom curve of Rs of ITO after annealing.

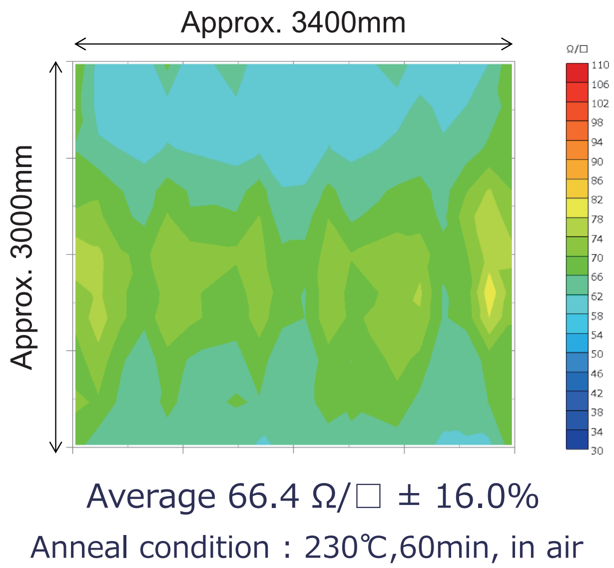

Figure 8 Rs uniformity of ITO film after annealing.

The Rs distribution on the substrate after annealing shown in Figure 8 demonstrates an adequate uniformity of ±16 percent.

4.7 Film stress and transmittance of ITO film

Figure 9 shows the stress and transmittance of the ITO film deposited under the same conditions as the previous section. The film stress was determined by the disc method after forming an ITO film on the Si wafer substrate. The transmittance was the value of the glass reference.

The film stress was even across the substrate with an average level of −160 MPa. The average transmission was around 93%T for the wavelength of 550 nm.

4. Conclusion

This article described the hardware of the SMD-3400 as a sputtering system designed and developed for G10.5 mother glass. Then, it presented the testing results from

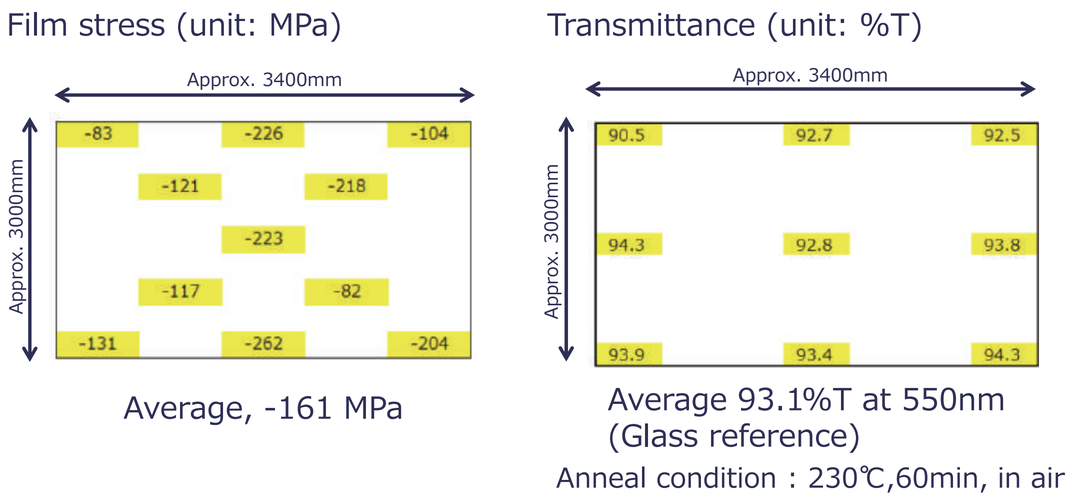

Figure 9　Film stress and transmittance of ITO film.

the deposition process of Cu and ITO films. These films demonstrated comparable performance as that of conventional G8.5 mother glass in terms of thickness distribution, deposition rate, Rs distribution, film stress, reflectance, and transmittance. Accordingly, the system' s good performance was also validated with G10.5 substrates.

A new deposition method was tested to address the wave-like unevenness in the film thickness from the Cu deposition process. It demonstrated enhanced Rs distribution in the horizontal direction of the substrate.

Until the recent spurt in capital investment for larger panels, the growth in the size of mother glass used for producing large panels as typified by LCD TVs had stalled after reaching the substrate size of G10 in 2010. The mainstream manufacturing equipment is therefore now expected to grow in size. ULVAC will continue to launch its new technologies as suppliers of sputtering systems and target materials, and thereby contribute to the development of the flat panel display market.

References

1) M. Matsudai: ULVAC Technical Journal, 43 (1995) 1.
2) Y. Oishi, M. Kobayashi, T. Tatsunori, M. Arai, J. Kiyota, T. Komatsu, S. Ishibashi, K. Saitou, S. Satou, M. Matsudai: ULVAC Technical Journal, 64 (2006) p.23-27.
3) M. Arai: The 57th JSAP Spring Meeting (2010) 17p-TN-3.
4) S. Ishibashi, Y. Higuchi, Y. Ota and K. Nakamura: J. Vac. Sci Technology., A8 (3) (1990) 1399-1403.

ULVAC

ULVAC, Inc. 2500 Hagisono, Chigasaki, Kanagawa, 253-8543 Japan TEL :+81-467-89-2033 www.ulvac.co.jp/en/