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Split sputter mode: a novel sputtering method for flat-panel display manufacturing

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Advanced static DC magnetron sputtering methods based on the magnet wobbling technique were investigated to achieve highly uniform and homogeneous metallization layers. The novel split sputter mode (SSM) method, wherein the deposition process is divided into two distinct steps, enables the AKT rotary cathode technology to provide excellent layer properties, while keeping a high production throughput. The effectiveness of the SSM technique was demonstrated through copper-coated large-area substrates.

Keywords: static DC magnetron sputtering; rotary cathode array; rotating magnets

1. Introduction

The AKT-PiVot PVD system is driving the FPD manufacturing industry towards the rotating cylindrical (‘rotary’) magnetron technology, which enables higher target utilization, leading to a longer target lifetime (>4×) compared with that of the conventional planar targets; individual control of each magnetron in the array, leading to excellent layer properties; and less redeposition on the targets, resulting in minimized particle generation and, consequently, higher production yield [1]. This paper illustrates a novel deposition method through which highly uniform and homogeneous sputtered layers can be achieved.

The angular distribution $f(\alpha)$ of the atoms sputtered by a rotary magnetron can be described by the following enhanced cosine function (Figure 1):

$$f(\alpha) = \frac{[\cos(\alpha) + a \cdot \cos(\alpha) \cdot (1 - 2\cos^2(\alpha))]}{\pi},$$

where a is a material-dependent fit parameter [2].

Consequently, the layers deposited on a substrate by an array of rotary cathodes (Figure 2), resulting from the superposition of the contribution of each rotary magnetron in the array, are characterized by horizontal thickness periodicity, being thicker in front of cathodes and thinner in between adjacent cathodes [3].

As thickness uniformity and grain structure homogeneity of the sputtered metallization layers are required for the repeatable and reliable manufacture of backplane electrodes [4], advanced static deposition methods for optimizing the layer characteristics must be developed. The ejection direction of the particles from a rotary magnetron depends on the angular position of the magnet yoke installed inside the rotary cathode itself. Thus, magnet wobbling, the periodic oscillation of the movable magnet yokes driven by a dedicated motor driver (Figure 3), is an effective approach for improving the distribution of the sputtered atoms on the substrates [5].

Hence, advanced static DC magnetron sputtering methods based on the magnet wobbling technique were investigated in this study for Cu4N thin films (film thickness = 250 nm) deposited by an array of nine Gen 6 (cathode length = 2 m) rotary cathodes, at a process power of 17.5 kW/m, in an Ar6N atmosphere and by making two magnet yoke ‘moves’ (i.e. two complete oscillations).

2. Experiment

First, the effect of the wobble angle amplitude on the sheet resistance (R_S) uniformity of the sputtered copper films was characterized (herein, the differential uniformity formula $(\text{Max} - \text{min})/(\text{max} + \text{min}) \cdot 100$ was applied). While keeping the magnet yokes continuously oscillating between the outer positions ($t_{\text{Process}} = t_{\text{Sputter}} = t_{\text{Wobble}}$), the total wobble angle was gradually increased. As shown in Figure 4, the maximum sheet resistance uniformity, measured on Gen 2 glass substrates (406 × 355 mm), was achieved for a total wobble angle of 60°.

Then, to improve the sheet resistance uniformity of the sputtered copper films further, the wobble wait time (t_{Wait}) was introduced between the magnet yoke moves. While continuous sputtering occurred ($t_{\text{Process}} = t_{\text{Sputter}} = t_{\text{Wobble}} + t_{\text{Wait}}$), the magnet yokes stayed at the outer posi-

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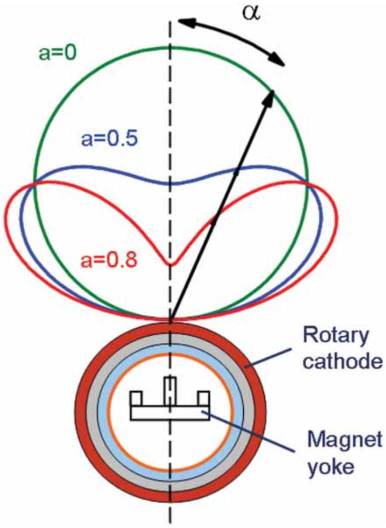

Figure 1. ‘Under cosine’ angular distribution of the atoms ejected by a rotary magnetron.

Figure 2. Typical arrangement of a rotary cathode array.

tions for a given percentage of the total sputter time ($t_{\mathrm{Wait}}/t_{\mathrm{Sputter}}$). As shown in Figure 5, the maximum sheet resistance uniformity, measured on Gen 2 glass substrates, was achieved by sputtering only when the magnet yokes stayed at the outer positions ($t_{\mathrm{Sputter}} = t_{\mathrm{Wait}}$). This novel sputtering method, wherein the deposition process is divided into two distinct steps (as no DC power is applied during the magnet yoke move), is called the ‘split sputter mode’ (SSM).

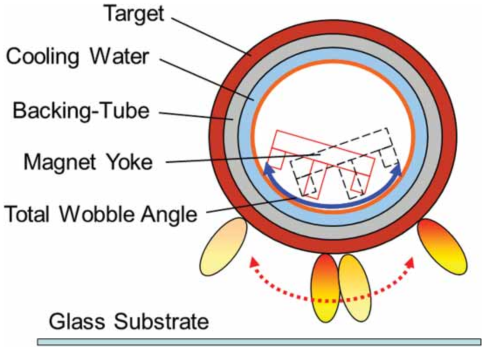

Figure 3. Magnet wobbling operating principle.

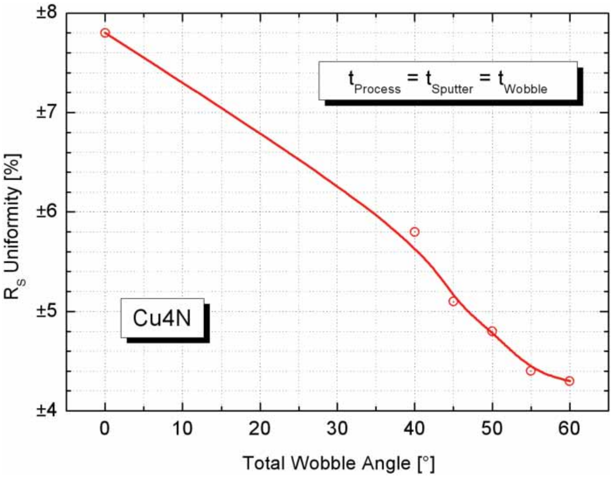

Figure 4. Wobble angle effect on copper film uniformity.

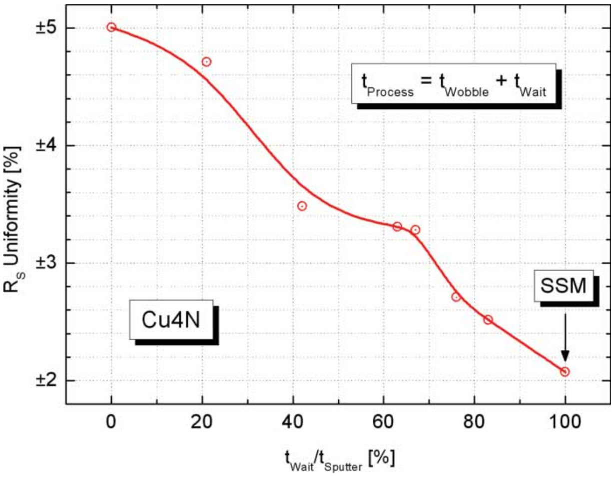

Figure 5. Wait time effect on copper film uniformity.

3. Results and Discussion

Figure 6 shows the copper film R_S distribution and the horizontal profile provided by an array of nine rotary cathodes on a Gen 6 glass substrate (1850 × 1500 mm), obtained without magnet wobbling. The rotary cathode

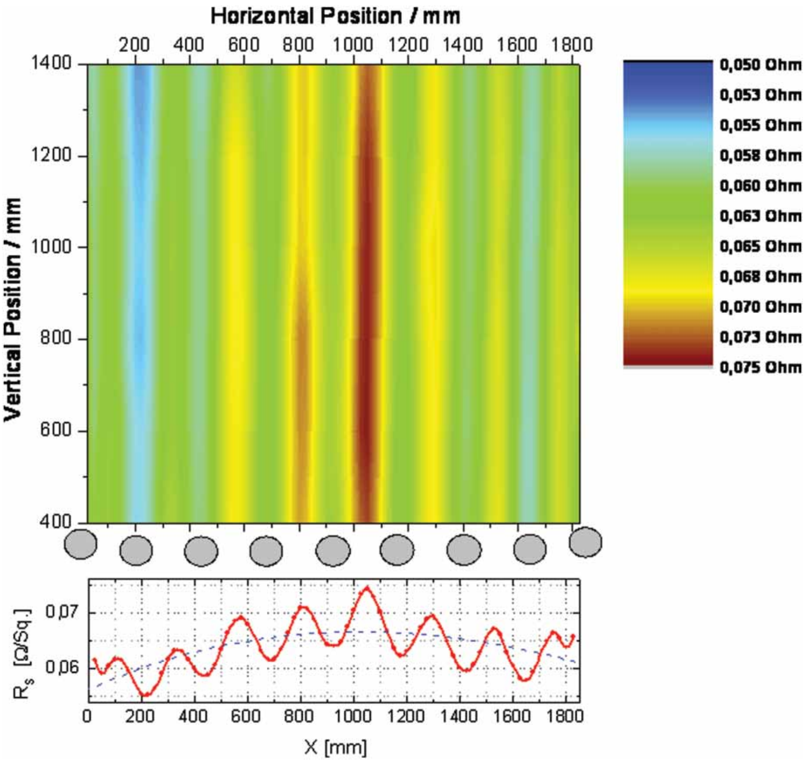

Figure 6. Copper film distribution obtained without magnet wobbling.

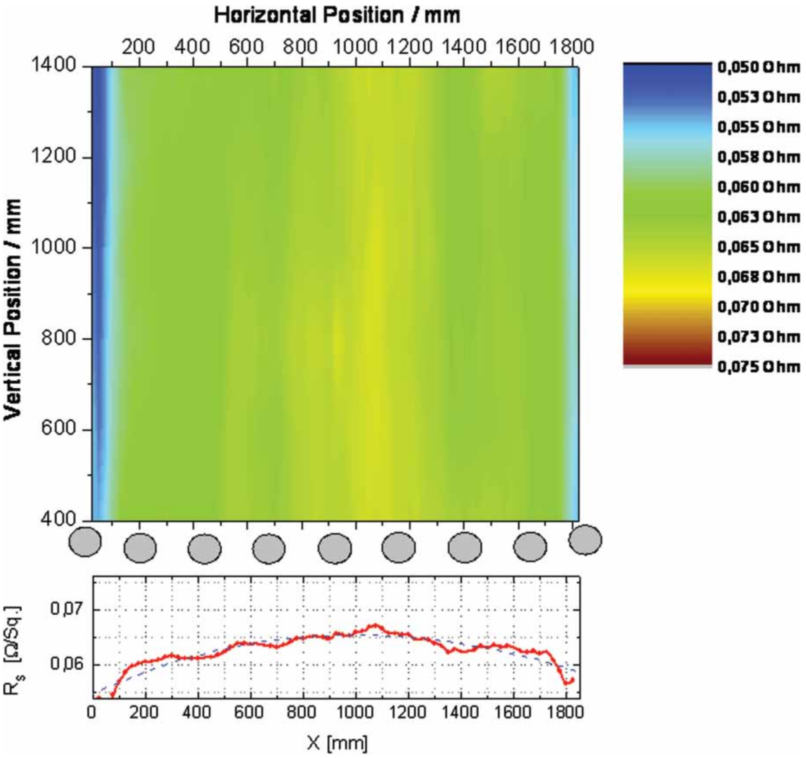

Figure 7. Copper film distribution obtained via the SSM method.

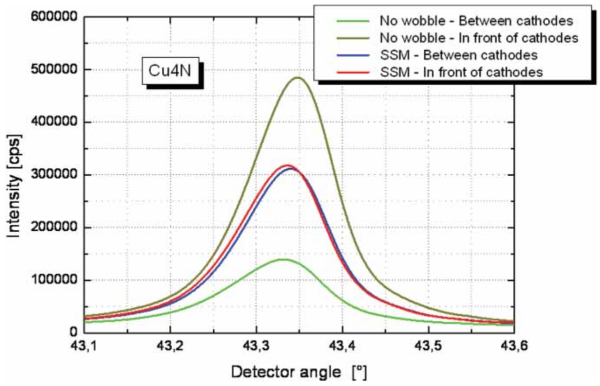

Figure 8. XRD analysis results of the copper films (250 nm) deposited without magnet wobbling, via the SSM method.

Table 1. Estimated crystallographic parameters of the copper films deposited without magnet wobbling, via the SSM method.

	No wobble		SSM	
Cu4N (250 nm)	Between cathodes	In front of cathodes	Between cathodes	In front of cathodes
Grain size (nm)	42.85	46.95	45.32	45.33
Lattice constant (nm)	0.36131	0.36117	0.36123	0.36126

array profile was clearly visible, and the sheet resistance uniformity, calculated considering an edge exclusion of 20 mm, was equal to ±15.8%.

Figure 7 shows the copper film R_S distribution and the horizontal profile provided by an array of nine rotary cathodes on a Gen 6 glass substrate, obtained by employing the SSM method, with a total wobble angle of 60°. When the two complementary film distributions were superposed [6], the rotary cathode array profile was no longer visible, and the sheet resistance uniformity, calculated considering an edge exclusion of 20 mm, improved to ±5.6%. The film thickness measurements showed equal static deposition rates in front and in between the rotary cathodes, resulting in a uniform film thickness all over the substrate, and demonstrating the correlation with the sheet resistance distribution.

As shown by the XRD analysis results in Figure 8, the SSM method, compared with the case without magnet wobbling, also leads to a more homogeneous copper film morphology, resulting in an equal average grain size and lattice constant in front and in between the rotary cathodes (cf. Table 1). Accordingly, the homogeneous film resistivity all over the substrate is achieved.

4. Summary

Advanced static DC magnetron sputtering methods based on the magnet wobbling operating principle were investigated. A novel deposition method based on the superposition of two complementary film distributions was developed and demonstrated, using copper-coated large-area substrates. The newly developed split sputter mode method enables the AKT proprietary rotary cathode technology to achieve highly uniform and homogeneous metallization layers on large-area substrates.

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References

[1] F. Pieralisi and E. Koparal, in *Proc. 36th DFF Working Group Meeting* (2010), Sec. 6.

[2] G.K. Wehner and D. Rosenberg, J. Appl. Phys. **31**, 177 (1960).

[3] A. Lopp, S. Bangert, W. Buschbeck, M. Hanika, M. Koenig, J. Krempel-Hesse, H. Rost, J. Schroeder, and T. Stolley, J. SID **14**, 31 (2005).

[4] W. den Boer, *Active Matrix Liquid Crystal Displays* (Elsevier, Oxford, 2005), Chap. 3.

[5] S. Bangert, Patent EP1594153 B1 (2010).

[6] F. Pieralisi, M. Hanika, E. Scheer, and M. Bender, in *Proc. 17th IDW* (2010), p. 1865.