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Giant Micro-Electronics Technology Using Gravure Printing Techniques

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This research investigates the use of printing techniques for industrial use. We examined: (1) the accuracy and alignment accuracy using different ink and different patterns; (2) application to eight-lines/mm line-type thermal printing heads with 1728 heat elements on 60x230mm glazed Al_2O_3 substrate. The results were: (1) within 10μm alignment accuracy; (2) small standard deviation (σ=1.0μm, n=1728) of pattern width at line/space (L/S)=113.5/11.5μm patterns and small resistance dispersion (σ/x=5%, n=1728).

1. Introduction

Gravure printing technique is one of several effective approaches to Giant Micro-Electronics (GME) patterns[1]. The purpose of this research was to apply this technique to GME patterns for industrial use. Printing accuracy was studied, followed by the use of eight lines/mm line-type thermal printing head patterns with 1728 heat elements (115x175μm). 4-6 different thermal printing head patterns were printed on glazed Al_2O_3 substrate (60x230mm size) and resistance dispersion was measured to compare the results of printing with photo processes.

2. Explanation of gravure offset printing

Fig. 1 shows the principles of gravure offset printing. The doctor blade removes the unnecessary ink from the glass intaglio. Then, a silicone rubber roller rotates on the intaglio and transfer, by adhesion, the ink patterns from the intaglio. The ink patterns are transferred again to the substrate to be printed.

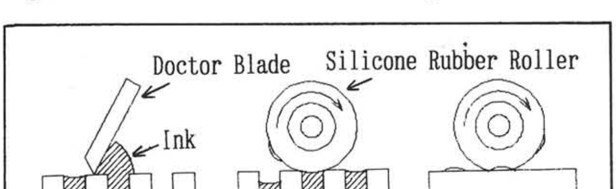

Fig. 1 Principles of Gravure Offset Printing.

3. Printing techniques

3-1 Printing conductive patterns.

Au metallo-organic (MO) ink was directly printed on the glazed Al_2O_3 substrate using this method. After the printing, the printed substrate was placed in a furnace to create Au metal from Au MO ink. Firing conditions of the furnace were 750℃ for 10 minutes.

Fig. 2 shows printed Au MO ink patterns on the glazed Al_2O_3. Printed patterns are L/S=40/10μm (pitch=50μ). Fig.3 shows combined three pictures of representative area from printed Au MO ink patterns on the glazed Al_2O_3. Fig. 3 shows that this technique could print fine patterns all over the 60x230mm substrate.

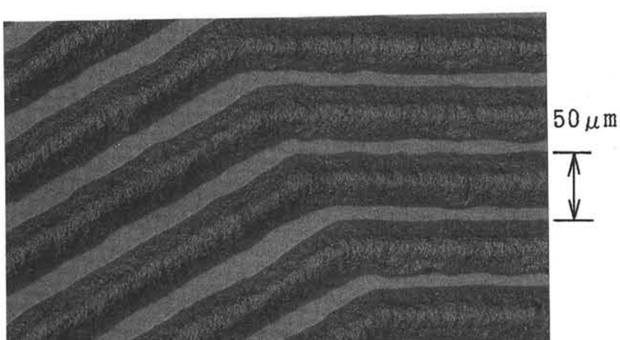

Fig. 2 Printed Au MO patterns. (pitch=50μ)

Fig. 2

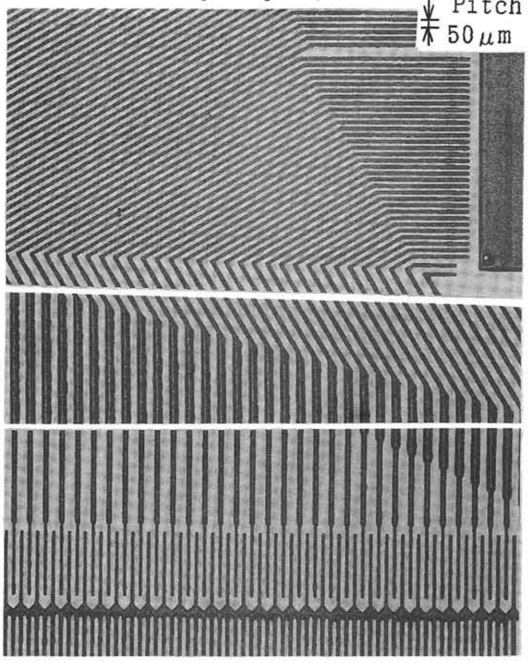

Fig. 3 Representative Example of Printed Au MO Ink Patterns. (minimum: L/S=25/25μm)

3-2 Printing resist patterns

Resist pattern printing is very applicable to industrial processes, too. Carbon ink was used as resist ink. After printing, the resist ink was dried at 150℃ for 60 minutes. The dried resist ink can be used in acid, alkali, and even plasma etching. Firing or organic solvent easily removes the resist patterns.

Ru-Ti-Ox thin films were etched in the plasma etching process. The Ru-Ti-Ox thin films were prepared by firing Ru-Ti-Ox MO ink developed by Saito[2] et al. Stripe patterns (4x230mm size) of the Ru-Ti-Ox MO ink were screen-printed on the glazed Al_2O_3. After the firing of the Ru-Ti-Ox MO ink at 750℃, Ru-Ti-Ox thin film patterns were produced. The resist ink was then gravure-printed on the Ru-Ti-Ox thin films and the Ru-Ti-Ox thin films were patterned using plasma etching. The plasma etching conditions were 13.56MHz, 250W, 0.4Torr with CF_4 gas. After removing the resist ink, 1728 resistances (0.105x0.4mm size) were produced from one Ru-Ti-Ox thin film stripe pattern. The plasma etching process etched not only the Ru-Ti-Ox thin film (0.04 μm thickness) but also the resist ink. A cross section of the printed resist ink patterns was not sharp as photo-resist patterns. Printed ink patterns had thinner edge thickness than their centers. The resist ink patterns should be printed clearly wider since the plasma etching decreased pattern width of the printed resist patterns. We solved the problem by shifting the intaglio. The same patterns were printed twice, sifting one intaglio slightly in the direction of the pattern width. Patterns could be controlled from 90/35 to 115/10μm(L/S). Fig. 4 and 5 show examples of printed resist patterns.

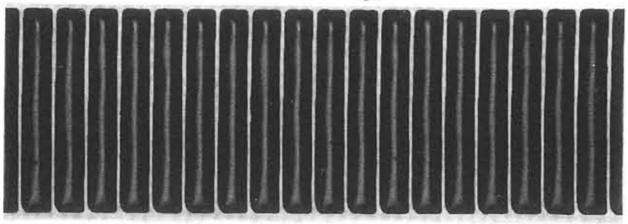

Fig. 4 Example of Printed Resist Patterns. (Carbon Ink, Pitch=125μm)

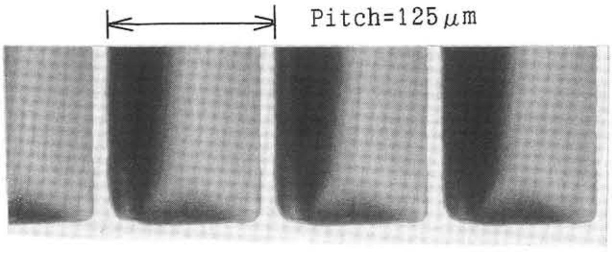

Fig. 5 Enlargement of Fig. 4.

4. Printed Pattern Accuracy

Using the intaglio shifting method, plasma etched Ru-Ti-Ox patterns (125μm pitch) were prepared. Fig. 6 shows a histogram of plasma etched Ru-Ti-Ox patterns (n=1728). The pattern width average (x) was 113.5μm with 1.2μm standard deviation (σ).

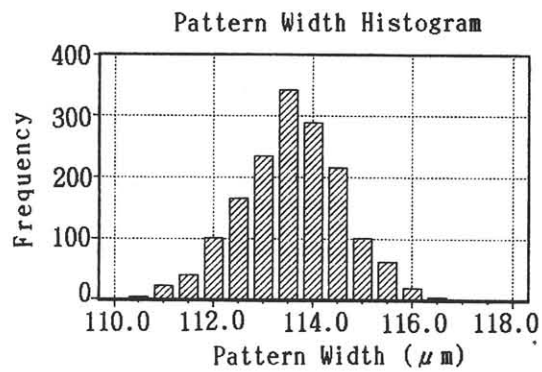

Fig. 6 Pattern Width Histogram.

5. Trial Fabrication of Thermal Printing Head

5-1 Fabrication of Thermal Printing Head.

Prototype thermal printing heads were fabricated using the above described techniques. Fig. 7 and 8 show the results and a structure of print-assisted thermal printing heads. The Ru-Ti-Ox resistances were formed using the resist-printing techniques (Fig. 4, 5). The Au electrodes were formed using the direct-printing techniques (Fig. 2, 3). The patterns could be aligned within 10μm all over the whole substrate. Fig. 9 shows the photo-assisted thermal printing head.

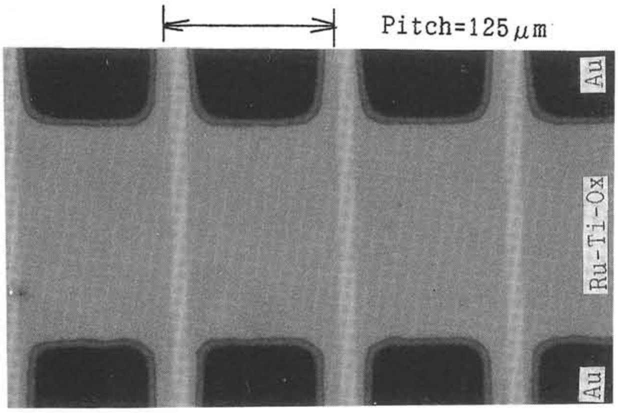

Fig. 7 Print-Assisted Thermal Printing Head. (Heat Element Area, Pitch=125μm)

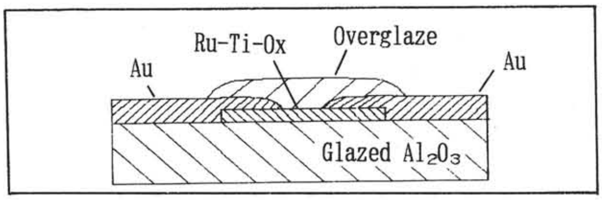

Fig. 8 Structure of Print-Assisted Thermal Printing Head. (Heat Element Area)

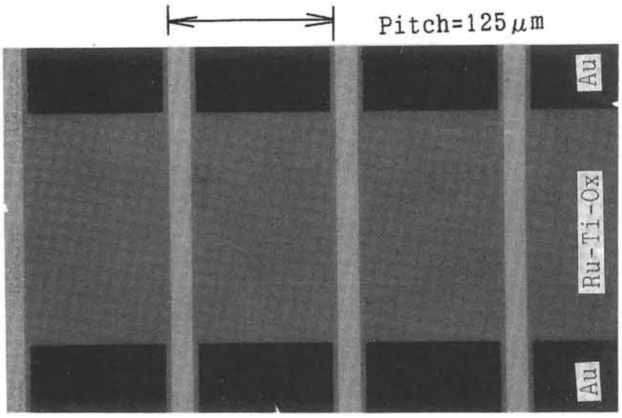

Fig. 9 Photo-Assisted Thermal Printing Head. (Heat Element Area, Pitch=125μm)

5-3 Resistance Dispersion of Print-Assisted and Photo-Assisted Thermal Printing Head.

Fig. 10 shows a resistance histogram. The histogram is specified (average resistance=1) histogram to compare print- with photo- assisted thermal printing head. The resistance dispersion (σ/x) was 5% (n=1728) for print-assisted and 3% (n=1728) for photo-assisted thermal printing head. Fig. 11 shows a thermally-printed picture using the print-assisted thermal printing head. The picture shows the print-assisted thermal printing head is available for such two-gradient thermal printing.

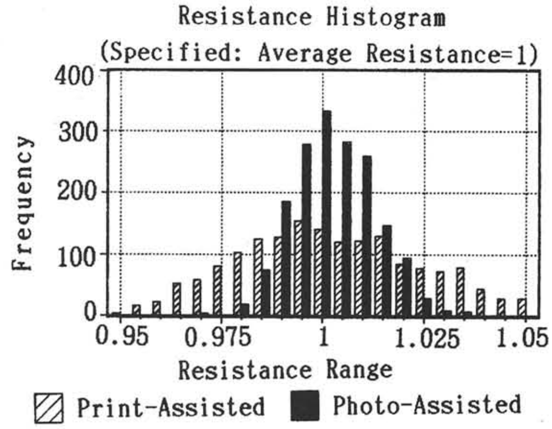

Fig. 10 Resistance Histogram of Photo- and Print-Assisted Thermal Printing Heads.

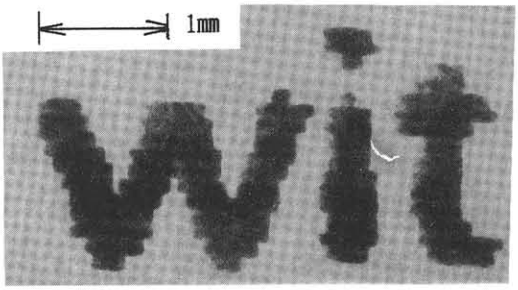

Fig. 11 Thermally-Printed Picture Using the Print-Assisted Thermal Printing Head.

6. Conclusion

The following results were obtained:

(1) Fine patterns for large area (60x230mm) can be printed with different patterns within 10 μm alignment accuracy.

(2) Standard deviation (σ) of pattern was 1.0μm (n=1728) for 113.5μm width patterns.

(3) Resistance dispersion (σ/x) was 5% (n=1728) for print-assisted thermal printing head.

7. Acknowledgements

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8. References

1) M. SHIMADA et al. "Manufacturing of fine-line films by printing technique", IMC 1990 Proc., Tokyo, pp. 581-586.

2) S. SAITO et al. "Formation of The Ru-Ti-O Thin Film Resistors by Thermal Decomposition Technique", No. 3 Micro-electronics Symposium 37 (1991), pp.37-40. (in Japanese)