Effective Removal Module by Excimer Irradiation Assistance

P.S. Pa

Department of Digital Content Design, Graduate School of Toy and Game Design
National Taipei University of Education
No.134, Sec. 2, Heping E. Rd., Taipei City 106, Taiwan
myhow@seed.net.tw

ABSTRACT

A new design module using an excimer irradiation to assist in micro-electroremoval process as a precise recycle modus for the digital paper of the touch-panel offers a faster performance in removing the Indium-tin-oxide (TCO) thin-films from the surface of the optical PET-diaphragm (PET) of digital paper was developed. The low yield of the TCO deposition is an important factor in optoelectronic semiconductor production. In the current study, the TCO layers proved difficult to remove, the excimer irradiation can be used to help with its removal. During the digital paper recycle processes the use of a 172nm excimer-lamp can remove the stubborn film residues, effectively improving the TCO removal rate. For executing the removal-process of the fabrication, through the excimer irradiation proposed, the stubborn thin-films were easily broken up from the layer's compositions to the nano-particles and escaped from the PET substrate quickly and cleanly. It is possible to efficiently promote the performance of the designed pillar-form tool striping away the Indium-tin-oxide. The required machining time is shortened by irradiating with an excimer lamp before removal processing TCO layers than that of without the excimer irradiating under similar processing conditions.

Keywords: Nano-Particles, Excimer Irradiation, Digital Paper, Touch-Panel, PET-Diaphragm, Micro-Electroremoval

1. INTRODUCTION

The rewritable digital paper (e-paper) display is an alternative and promising application of technology in informational media [1]. The basic construction of the touch-panel is similar to that of an "Liquid Crystal Display" (LCD) panel, with two substrate coatings of an Indium Tin Oxide (ITO) transparent conductive film. However, the sheet resistance of the ITO transparent conductive film used on the touch-panel is higher than an LCD panel [2-3]. The same image quality should be expected for the display to be easy to read, and the display also needs to be thin and flexible enough to be folded or rolled in a manner similar to printed paper. We are currently developing flexible plastic substrates to replace the active glass substrate of an LCD display. To achieve active digital paper, new techniques for depositing organic semiconductor materials onto plastic (thin film transition (TFT) technology) are currently underway [4]. The largest segment of the LCD market, by both volume and value, remains the Personal Computer (PC) monitor market, which is still growing. Notably, the use of LCD panels in notebook computers has also increased as the market has continued to grow. Panels for mobile phone displays are another product with excellent growth prospects [5]. The primary cause of reduced yield rate in LCD production is "dust." When dust particles attach to the LCD substrate, they impair its function, causing breaks in the circuit, short circuits or poor performance [6-7].

The electrolyte between the workpiece is dissolved and therefore removed through an electrochemical reaction in electrochemical machining (ECM) [8]. The micro-electrochemical machining (μ-ECM) process, also known as the electrochemical micro-machining (EMM) process, has the advantage that during the micro-machining of any metal material, the workpiece will not leave any residual stress remaining on its surface, and the tool electrode will not break. The electric field distribution of the μ-ECM process has great effects on the geometric profile and fabrication precision of micro-holes [9-10]. Data have shown that the gap width between the electrode and workpiece directly influences the current condition and the discharge dreg of the electrolyte in the electrochemical process [11].

An Indium-tin-oxide (TCO) nanostructure is a transparent conducting material that is deposited as a thin film on glass or polymer substrates for use in optoelectronic devices produced using semiconductor techniques. However, the low yield during production is easily seen. Manufacturers continue to reduce production costs, but the material cost related to the component technology is the most obvious part of the total cost. The material cost of most panels of different sizes exceeds 50% of the total cost of the panels; thus, to reduce material costs, constructing a precision recycling mechanism and executing an effective recycling process is important in the semiconductor industry [12]. Low yield during production is easily seen. In the future, the challenges facing the display industry will include how to bring down the production cost even further and improve the yield as much as possible [13].

In this study, a new design module using an excimer irradiation to assist in micro-electroremoval process and a designed pillar-form tool is applied to the nano-scale precision recovery process of the digital paper of the touch-panel to effectively remove the defective TCO nanostructures from the surfaces of the optical PET-diaphragm (PET).

2. EXPERIMENTAL SETUP

The workpiece material was an optical PET diaphragm of digital paper (400 mm width; 0.2 mm thickness). The reduction in the surface thickness of the optical PET diaphragm after micro-electroremoval for the Indium-tin-oxide (TCO) nanostructure was 20 nm. The experimental setup is schematically illustrated in Fig. 1 (including the irradiation system of the 172 nm excimer lamps). The design pillar-form tool is shown in Fig. 2. The electrolyte was $NaNO_3$ (10%wt) and PO4-3-P (10%wt). The flow rates of electrolytes were 20L/min. The temperatures of the electrolytes were 40°C. The rotational speed of pillar-form tool was 600rpm. The irradiation distances of the excimer lamps were 2 to 6mm. The irradiation times of the excimer lamps were 10 to 50 sec. The current ratings ranged from 100 to 200 A. The feed rate of the workpiece (optical PET diaphragm) ranged from 100 to 1500 mm/min. The diameter of the rotation circle of the anode (D) of the pillar-form tool was 60mm. The diameter of the rotation circle of the cathode (D') of the pillar-form tool were 52mm, 54mm, and 56mm. The diameter of the pillar anode (d_a) was 15mm. The diameter of the pillar cathode (d_c) were 10mm, 12.5mm, and 15mm. The tension arc radius (R_t) of the pillar-form tool were 5mm, 10mm, ang 15mm. The produced TCO nanostructure was measured at more than two locations by a NanoSpec Film Thickness Measurement System (Nanospec Film Analyzer 3000). The produced angle of water contact is measured by FTA125 (First Ten Angstroms).

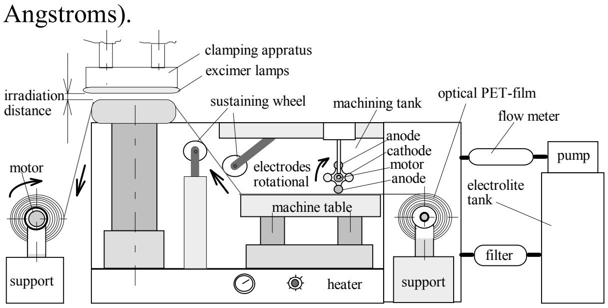

Fig. 1 Experimental setup

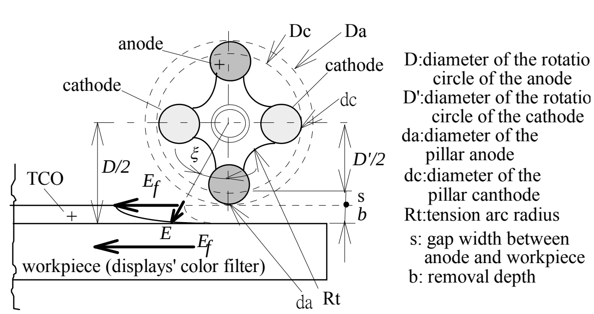

Fig. 2 Geometry of the pillar-form tool

3. RESULTS AND DISCUSSION

Fig. 3 shows the removal amounts of Indium-tin-oxide (TCO) with respect to different excimer irradiation times before micro-electroremoval process. The experimental results demonstrate that the excimer irradiation is possible to efficiently promote the performance of the striping away the TCO nanostructure. It also implies that the longer irradiation time corresponds to a higher removal rate for the TCO layers. As illustrated in Fig. 4, with a fixed irradiation time (30sec), a smaller irradiation distance corresponds to reduction the resistance of striping away the TCO nanostructure, which leads to enhanced removal effect for ITO nanostructure.

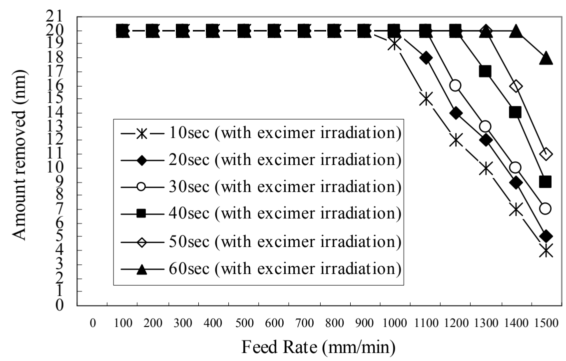

Fig. 3 Amount removed at different feed rates of workpiece using different irradiation time ($NaNO_3$,10%wt; PO4-3-P, 10%wt; 40℃; 20L/min; tool 600rpm; 200A; 172nm excimer)

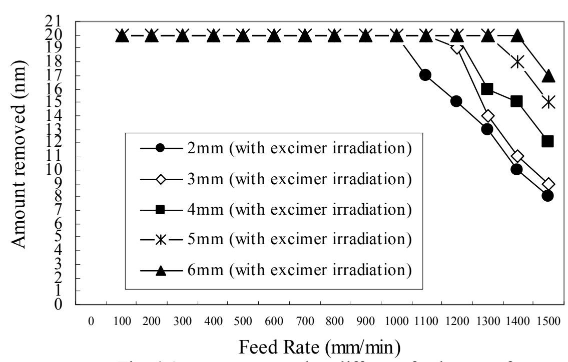

Fig. 4 Amount removed at different feed rates of workpiece using different irradiation distances ($NaNO_3$, 10%wt; PO4-3-P, 10%wt; 40℃; 20L/min; tool 600rpm; 200A; 172nm excimer)

Fig. 5 shows that a larger feed rate of the optical PET diaphragm, when combined with enough electric power, will completely remove the TCO. At a constant current rating, the PET diaphragm has an optimal feed rate for the removal process. In order to reach the same etching of a 20 nm TCO nanostructure, a fast feed reduces the power delivered per unit area of the plane surface, while a slow feed increases the power delivered. The required machining

NSTI-Nanotech 2009, www.nsti.org, ISBN 978-1-4398-1782-7 Vol. 1, 2009

time is shortened by irradiating with an excimer lamp before removal processing TCO layers than that of without the excimer irradiating.

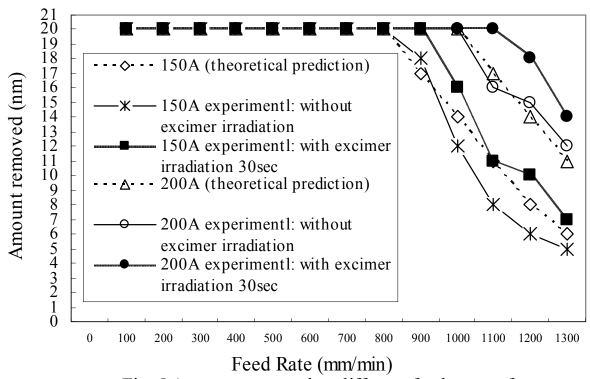

Fig. 5 Amount removed at different feed rates of workpiece using different current ratings ($NaNO_3$, 10%wt; PO4-3-P, 10%wt; 40℃; 20L/min; tool 600rpm)

According to the formula of theoretical removal rate on alloy from Faraday's Law [8]:

$$W = \frac{\eta I t}{F\left(\frac{n_A}{M_A} a_A + \frac{n_B}{M_B} a_B + \dots\right)} \qquad (1)$$

where η is the efficiency of current, I is the current, t is time, F is the Faraday constant, n_i is the atom number, a_i is the proportion of composition, and M_i is the atomic mass.
Let $w=W/At$ and $f=w/\rho$

$$f = \frac{\eta I}{FA\rho\left(\frac{n_A}{M_A} a_A + \frac{n_B}{M_B} a_B + \dots\right)} \qquad (2)$$

where A is the microelectroremoval area, ρ is the workpiece density, f is the removal rate in the longitudinal direction. From the above, the theoretical feed rate of the workpiece during the same material removal rate can be calculated. Where η, I, F, and A are regarded as constant for the material.

From Fig. 2, one assumes:

$$D/2 = D'/2 + s + b \qquad (3)$$

where s is the gap between the anode and workpiece (PET-diaphragm) and b is the removal depth of the microelectroremoval.

$$\cos\xi = \frac{(D/2 - b)}{D/2} = \frac{(D'/2 + s)}{(D'/2 + s + b)} \qquad (4)$$

$$(E_f)\sin\xi = E \qquad (5)$$

squaring and simplifying from equations (4) and (5), one obtains:

$$b = \frac{(D'/2 + s) f^2}{2(f_N^2 - f^2)} \qquad (6)$$

Where E_f is the feeding velocity of the displays' color filters and E is the removal rate in the longitudinal direction. From formula (6), one obtains:

$$b = \frac{(D'/2 + s)\left[\frac{\eta I}{FA\rho\left(\frac{n_A}{M_A} a_A + \frac{n_B}{M_B} a_B + ..\right)}\right]}{2\left\{f_N^2 - \left[\frac{\eta I}{FA\rho\left(\frac{n_A}{M_A} a_A + \frac{n_B}{M_B} a_B + ..\right)}\right]^2\right\}} \qquad (7)$$

From eq. (7), the experimental results agree well with the theoretical prediction (see Fig. 5). Compared with the experimental results, the removal depth b is directly proportional to the current rating I and is the inverse ratio of the feed rate of the workpiece (E_f), which agrees well with the theoretical prediction (see Fig. 5).

Figure 6 shows the effects of different diameter of the rotation circle of the cathode (D') of the pillar-form tool. The results illustrate that the larger diameter of the rotation circle of the cathode (D'), accompanied by the small gap-width between the cathode and the workpiece, results in less time required for the same amount of TCO nanostructure removal since the effect of micro-electroremoval is easily developed to supply sufficient electrochemical power. Figure 6 also demonstrates that the executing feed rate of optical PET-diaphragm is fast by irradiating with an excimer lamp before removal processing TCO layers than that of without the excimer irradiating under similar processing conditions.

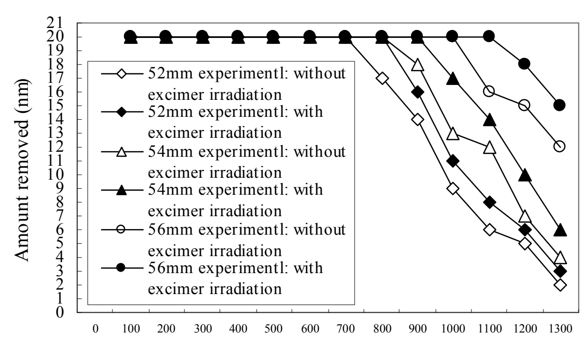

Fig. 6 Amount removed at different feed rates of workpiece using different diameter of the rotation circle of the cathode (D_c) ($NaNO_3$, 10%wt; PO4-3-P, 10%wt; 40℃; 20L/min; tool 1000 rpm; 200A; 172nm excimer; 30sec)

Figure 7 demonstrates that a smaller diameter of the pillar anode (d_a) provides more open space for dregs discharge [11, 14], which improves the micro-electroremoval effect. The author adopted the excimer irradiating before removal processing TCO layers also provides higher feed rate of optical PET-diaphragm, which is advantageous for TCO removal.

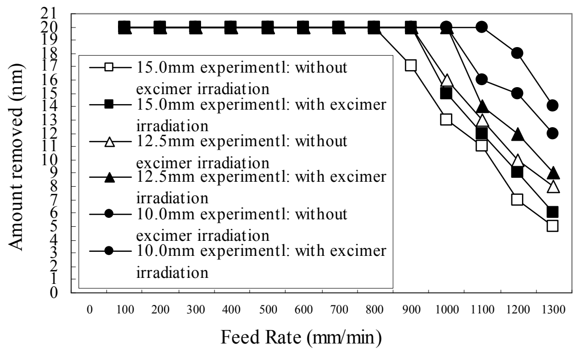

Fig. 7 Amount removed at different feed rates of workpiece using different diameter of the pillar cathode (d_c) ($NaNO_3$, 10%wt; PO4-3-P, 10%wt; 40℃; 20 L/min; 200A; tool 1000 rpm; 172nm excimer, 30sec)

Figure 8 shows the effects of the tension arc radius (R_t) of the pillar-form tool. Decreasing the tension arc radius reduces the resistance of dreg discharge and constructs a more effective flushing path along the features of the cathode. Meanwhile, the electrolytic products (dregs) and heat can be removed more rapidly [11, 14]. Compared with the experimental results, the feed rate of the optical PET-diaphragm is fast with excimer irradiating before micro-electroremoval processing TCO layers.

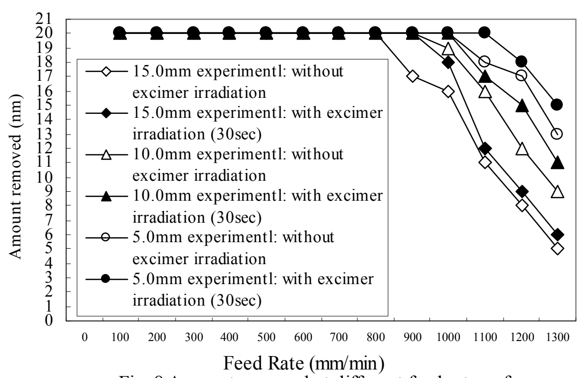

Fig. 8 Amount removed at different feed rates of workpiece using different tension arc radius (R_t) of the pillar-form tool ($NaNO_3$, 10%wt; PO4-3-P, 10%wt; 40℃)

4. CONCLUSTIONS

This study offers a new design module using a 172-nm excimer irradiation to assist in micro-electroremoval process as a precise reuse modus for the digital paper offers a faster performance in removing the TCO thin-films from the surface of the defective optical PET-diaphragm (PET). The experimental results show that through the excimer irradiation proposed, the stubborn thin-films were easily broken up from the layer's compositions to the nano-particles and escaped from the PET substrate quickly and cleanly. A large diameter of the rotation circle of the cathode of the pillar-form tool, a small diameter of the pillar cathode, or a small tension arc radius of the pillar-form tool takes less time for the same amount of TCO removed. Before the micro-electroremoval process, the use of the excimer irradiation can effectively remove the TCO layers and promote the performance of the designed pillar-form tool to strip away the TCO. Lnger excimer irradiation n time or smaller excimer irradiation distance corresponds to a higher removal rate for the TCO layers. The excimer irradiation assistance in micro-electroremoval process promotes the performance of the designed tool only requires a short time easily and cleanly remove the TCO films. The optoelectronic semiconductors industry can effectively reclaim defective products, thereby reducing production costs.

ACKNPWLEDGEMENTS

The current study is supported by National Science Council, contract 96-2622-E-152-001-CC3 and 97-2410-H-152-016.

REFERENCES

[1] R. Cueff, G. Baud, M. Benmalek, J.P. Besse, J.R. Butruille, H.M. Dunlop and M.J. Acquet, Thin Solid Films, 270, 230, 1995.
[2] H. Iwase and A. Murata, IEEE International Conference on Systems, Man and Cybernetics, 1, 252, 2002.
[3] C.C. Lai and C. C. Tsai, Proceedings of the 2004 IEEE International Conference on Control Applications, 2, 1491, 2004.
[4] R. Cueff R, G. Baud, M. Benmalek, J.P. Besse, et al. Appl. Sur. Sci. p. 115, 292, 1997.
[5] E. Avenel and C. Barlet, Journal of Economics and Management Strategy, 9(3), 211, 2000.
[6] P.M. Lee and H.Y. Chen, IEEE Conference Proceeding, 1, 780, 2005.
[7] H.C. Kim, B.H. Kwon and M.R. Choi, Controller IEEE Transactions on Electronics, 2, 47, 2001.
[8] J.A. Mc Geough, "Principles of Electrochemical Machining, " Chapman & Hall, London, 1-10, 1974.
[9] V. Kirchner and. Allongue, Accounts of Chemical Research, 34(5), 371, 2001.
[10] M.S. Park and C.N. Chu, Accounts of Chemical Research, 17, 1451, 2007.
[11] M. Datta and D. Landolt, Elector. Acta, 26, 899, 1981.
[12] K. Daeil and K. Steven, Int'l J. of Surface and Coatings Technology, 154, 204, 2002.
[13] D.M. Tsai, P.C. Lin and C.J. Lu, Pattern Recognition, 39(9), 1679, 2006.
[14] P.S. Pa, Journal of Materials Processing Technology, 195 (1-3), 44, 2008.