A Precise Reclaim Fabrication by Nanoscale Removal Processes using a Design of Ellipsoidal Anode

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ABSTRACT

A new design of ellipsoidal anode using micro-electrochemical etching (μ-ECE) as a precise reclaim fabrication by nanoscale removal processes for $In_2O_3SnO_2$ conductive microstructure from a surface of display's color filter surface is presented. Through the design of the ellipsoidal tool electrode, scoring of the display's color filter surface is eliminated, thereby enhancing the feed rate of the workpiece (display's color filter) and reducing production costs. In the current study, a higher current rating with a quicker workpiece feed rate effectively achieves fast promotion of the removal effect. A small major axis of the ellipsoidal anode accompanies with a small gap-width between the cathode and the workpiece surface takes less time for the same amount of $In_2O_3SnO_2$ removal. A small minor axis of the ellipsoidal anode provides larger discharge mobility and better removal effect. A small thickness of the cathode or a small arc radius of the cathode corresponds to a higher removal rate for $In_2O_3SnO_2$. An effective ellipsoidal anode provides larger discharge mobility and better removal effect. It only needs a short period of time to remove the $In_2O_3SnO_2$ easily and cleanly.

Keywords: Nanoscale Processes, Reclaim Fabrication, Ellipsoidal Anode, Micro-Electrochemical Etching, Conductive Microstructure

1 INTRODUCTION

The reproduction of color imagery in TFT displays is achieved through the use of color filters in concert with a backlighting system. The light from the backlight source passes through the liquid crystal and is controlled by the Driver IC to create a grayscale color source. This is then used to illuminate a color filter painted with red, green, and blue color resists. When passed through the color filter, this results in red, green, and blue light that is recombined within the human eye to form a color image [1]. Color filters are the critical component in LCDs, since each TFT array is matched to a color filter of the same size. This means that the quality of the color filter has a decisive effect on the LCD's color reproduction. The future of display technology will be in flat panel monitors, and in this TFT-LCD will play an important role [2]. The development in FPD, especially in TFT-LCD (thin film transistor liquid crystal display), has made the TFT-LCD industry one of the fastest growing industries in the world following the semiconductor industry. Color filters are the critical component in LCDs since each TFT array is matched to a color filter of the same size. This means that the quality of the color filter has a decisive effect on the LCD's color reproduction [3]. When the transparent electrode layer of the transparent conduction oxide ($In_2O_3SnO_2$) layer is applied the procedure is complete. With the push to increase the production capacity of LCD panels, the size of the glass substrate must increase in response to this demand. To achieve this, several large glass substrates with pre-formed color filters are matched to glass substrates with identical pixel electrode arrays. Liquid crystal is then injected to complete the assembly process [4].

Electrochemical machining (ECM) can be applied to electrolytic components (silicon chips, VLSI/ULSI chips). ECM is based on the electrochemical reaction between an electrode and a workpiece. In ECM, good surface quality of the workpiece was obtained through the arrangement of the experimental conditions. The main difficulty lies in the design of tool electrodes considering the complicated process of metal removal [5-6]. Data showed that the gap width between the electrode and workpiece directly influences the current condition and the discharge dreg of the electrolyte [7]. The experimental results of Mileham et al. proved that the quality of the machined surface will be influenced by the main factors including current density, flow rate of electrolyte as well as the gap width in the electrochemical machining [8]. Shen used $NaNO_3$ as the electrolyte to proceed the electropolishing on the die surface. The result showed that the surface roughness of workpieces decreases with increased current density, flow rate, and concentration of the electrolyte [9]. Electropolishing is a surface finish process using PO4-3-P as the electrolyte on brass alloys and zinc alloys. The polishing current is found to increase proportionately with an increase in zinc content in the alloy and with an increase in temperature [10]. Schuster et al. showed that the machining resolution can be shortened to a few micrometers by applying ultra short pulses of nanosecond duration, and micro structures can be machined by ECM [11]. The main difficulty of the electrochemical technique lies in the design of tool electrodes considering the complicated process of metal removal. In addition, workpiece machining through the electrochemical process can improve the precision with the appropriate control of machining conditions or the electrode geometry. End turning electrode was developed for electropolishing [12].

Manufacturers continue reducing production costs, while 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. The primary cause of a decrease in the yield rate for LCD production is "dust". When dust particles become attached to the LCD substrate they impair its function, causing breaks in the circuit, short-circuits or poor performance [13]. Thus, in order to reduce the material cost, constructing a design tool as a tool electrode and a precise etching mechanism as an effective reclamation process is the hottest issue in the optoelectronic semiconductor industry. This study presents a new design modus using electrochemical etching (μ-ECE) as a fabrication process of $In_2O_3SnO_2$ removal from displays' color filter surface. The defective $In_2O_3SnO_2$ thin-films were removed and that the displays' color filters were returned to the production line, the optoelectronic semiconductor industry can effectively reduce the production costs.

2 EXPERIMENTAL SETUP

The experimental setup of the precision recycle process of transparent conduction oxide ($In_2O_3SnO_2$) thin-film removal from displays' color filters is schematically illustrated in Fig. 1. The tool electrodes (including a cylindrical anode and a crossed cathode) are shown in Fig. 2. The workpiece material uses the 5th Generation LCD panel (1300×1100mm; 0.7mm). The electrolyte is $NaNO_3$ of 10%wt and PO4-3-P 10%wt. The temperature of the electrolyte is 65℃. The flow rate of the electrolyte is 25L/min. The amount of the removal reduction from the displays' color filter surface after electrochemical machining for TCO is 150nm. The major axis (S_1) of the ellipsoidal anode is 100mm (gap width 2mm), 98mm (gap width 3mm), 96mm (fap width 4mm), and 94mm (gap width 5mm). The minor axis of the ellipsoidal anode is 20, 30, 40, and 50mm. The thin thickness of the crossed cathode is 20, 30, 40, and 50mm. The current rating is 50, 100, 150, 200A. The thickness of the cathode is 10, 15, 20, and 25mm. The arc radius of the cathode is 2.5, 5, 7.5, and 10mm. The rotational speed of the tool electrodes is 200rpm, 400rpm, 600rpm and 800rpm. The produced $In_2O_3SnO_2$ layer is measured at more than two locations by NanoSpec Film Thickness Measurement System (Nanospec Film Analyzer 3000).

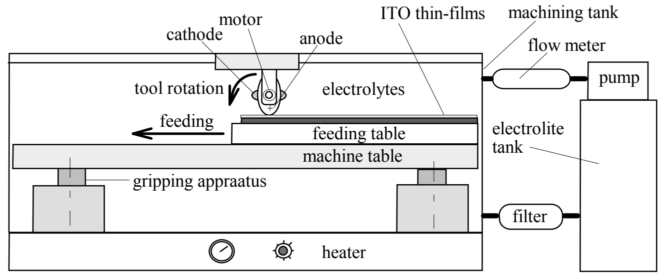
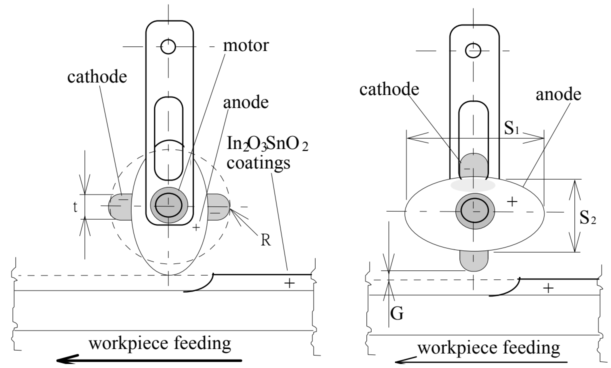


Fig. 1 Experimental setup



S_1: major axis of the ellipsoidal anode
S_2: minor axis of the ellipsoidal anode
t : thickness of the cathode
R : arc radius of the cathode
G : gap-width between the cathode and the workpiece

Fig. 2 Relative position of the electrodes and workpiece

3 RESULTS AND DISCUSSION

Figure 3 shows the effects of different major axis (S_1) of the ellipsoidal anode. The results illustrate that the larger length of the cathode, accompanied by the small gap-width between the cathode and the workpiece (display's color filter), results in less time required for the same amount of $In_2O_3SnO_2$ nanostructure removal since the effect of micro-electrochemical etching (μ-ECE) is easily developed to supply sufficient electrochemical power. However, the discharge of electrolytic depositions from the small gap is difficult, as far as the stable operation of the μ-ECE and dregs discharge is concerned, a small length of the major axis (S_1) of the ellipsoidal anode of 48 mm, accompanied by the small gap-width (2 mm) between the cathode and the workpiece is more effective in the current experiment. Figure 4 demonstrates that a smaller minor axis of the ellipsoidal anode provides more open space for dregs discharge [7, 12], and provides more concentration of the electrical power, which improves the removal effect. The author adopted 20 mm as the minor axis of the ellipsoidal anode in the current study.

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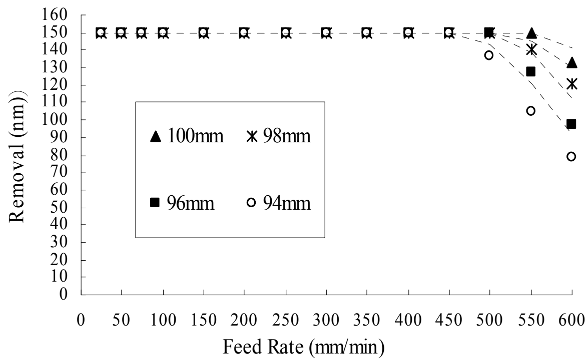

Fig. 3 Removal amount at different major axis (S_1) of the ellipsoidal anode ($NaNO_3$ of 10%wt and PO4-3-P 10%wt, 65℃, 25 L/min, 200A, continuous DC, tool electrodes 800rpm)

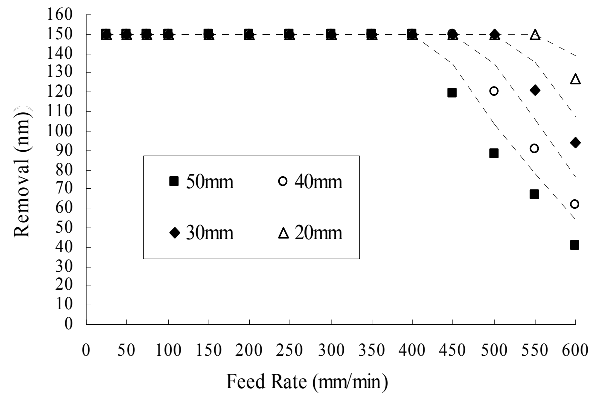

Fig. 5 Removal amount at different thickness (t) of the cathode ($NaNO_3$ of 10%wt and PO4-3-P 10%wt, 65℃, 25 L/min, 200A, continuous DC, tool electrodes 800rpm)

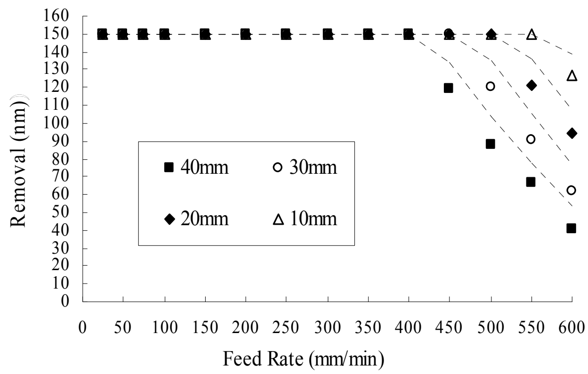

Fig. 4 Removal amount at different minor axis of the ellipsoidal anode ($NaNO_3$ of 10%wt and PO4-3-P 10%wt, 65℃, 25 L/min, 200A, continuous DC, tool electrodes 800rpm)

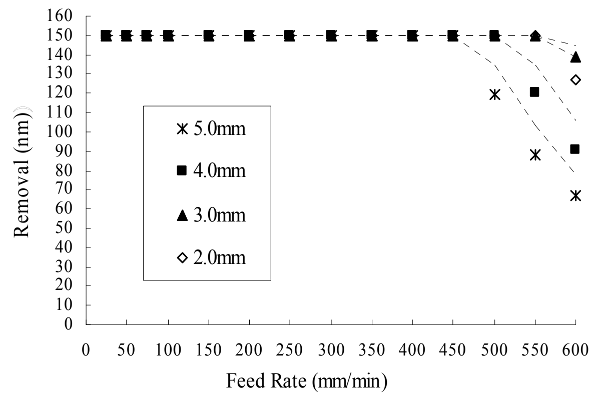

Fig. 6 Removal amount at different arc radius (R) of the cathode ($NaNO_3$ of 10%wt and PO4-3-P 10%wt, 65℃, 25 L/min, 200A, continuous DC, tool electrodes 800rpm)

Figure 5 demonstrates that a smaller thickness (t) of the cathode provides more open space for dregs discharge [7, 12], and accompanies by the concentration of the electrical power, results in less time required for the same amount of $In_2O_3SnO_2$ nanostructure removal since the effect of micro-electrochemical etching (μ-ECE) is easily developed to supply sufficient electrochemical power. Compared with the experimental results, the author adopted 10 mm as the thickness (t) of the cathode in the current study. Figure 6 shows the effects of the arc radius (R) of the cathode. Decreasing the arc radius (R) 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 [7, 12]. Compared with the experimental results, the small arc radius (R) of the cathode of 2.0 mm also provides higher electrical power, which is advantageous for $In_2O_3SnO_2$ removal.

Fig. 7 illustrates that an adequate $In_2O_3SnO_2$ removal is achieved through a combination of current rating and feed rate of the workpiece (displays' color filter) for the process of micro-electrochemical etching (μ-ECE). At a constant current rating, the workpiece has an optimal feed for the best removal rate. Fast feed reduces the power delivered to a unit area of the workpiece surface, and slow feed increases it. The former could not supply sufficient electrochemical power, while the latter could increase the removal time and the cost. In order to reach the same removal amount of $In_2O_3SnO_2$ (the average thickness of TCO film is 150nm in the current study), the following combination of parameter values is suggested: 50A and 250mm/min, 100A and 350mm/min, 150A and 450mm/min, 200A and 550mm/min. Fig. 8 illustrates that high rotational speed of the tool electrodes produces high rotational flow energy and elevates the discharge mobility, improving the etching effect. It is believed that the high rotational speed of the tool electrodes is advantageous when associated with the fast feed rate of the displays' color filter. Compared with the experimental results, the author adopted 800 rpm as the rotational speed of the tool electrodes in the current study.

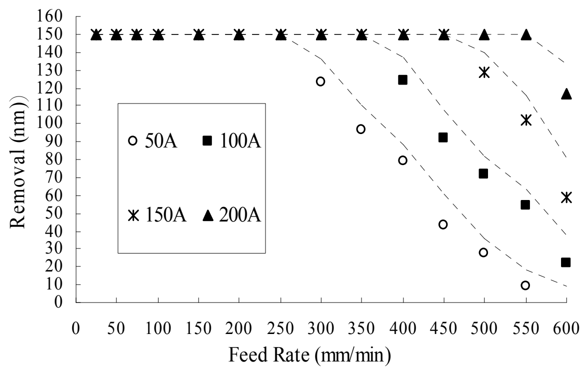

Fig. 7 Removal amount at different feed rate of workpiece using different current rating ($NaNO_3$ of 10%wt and PO4-3-P 10%wt, 65℃, 25 L/min, continuous DC, tool electrodes 800rpm)

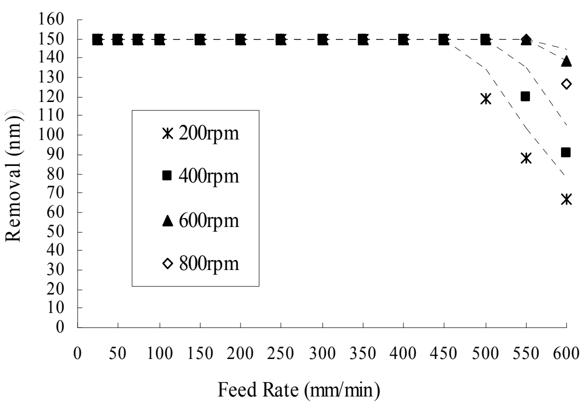

Fig. 8 Removal amount at different rotational speed of the tool electrodes ($NaNO_3$ of 10%wt and PO4-3-P 10%wt, 65℃, 25 L/min, 200A, continuous DC)

4. CONCLUSTIONS

This study creates a new precise reclaim fabrication system for $In_2O_3SnO_2$ nanostructure, reclaims defective display's color filter and reduces production costs. A design system for removing the $In_2O_3SnO_2$ layer through micro-electrochemical etching (μ-ECE) and a design of ellipsoidal tool electrode is the major interest in this current study. For the etching process, a small major axis of the ellipsoidal anode or a small minor axis of the ellipsoidal anode provides an effective removal performance. A displays' color filter with a fast feed rate is combined with enough electric power to provide highly effective removal. A small thickness of the cathode or a small arc radius of the cathode corresponds to a higher removal rate for $In_2O_3SnO_2$. The high rotational speed of the tool electrodes increases the dreg discharge mobility and improves the removal effect.

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