Power Optimization of Thermally Actuated Organic Display by Pulse Width Modulation Technique

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Abstract

A power optimization method, pulse width modulation (PWM) technique, is proposed for a thermochromic organic display that consists of a polydiacetylene (PDA) derivative film as the thermally activating material. Heat generation of micro heaters by pulse generator is more efficient in power minimization than by dc voltage supply. The pulse wave of about 30% duty ratio is the most appropriate for power minimization. In addition to the power reduction, pulse wave activation can circumvent the overheating problem.

1. Introduction

Several works in recent years have demonstrated that thermally actuated displays are becoming a promising application of thermochromic organic materials [1]-[3]. Polyvinyl alcohol (PVA) thin film embedded with PDA polymer has thermochromic blue to red color transition property [4]. The color change is effectively realizable to form display images. In addition, micro-patterned functional color images are easily induced using external photomask or embedded mask layer during UV-irradiation [4]-[5]. Moreover, color transition temperature of PDA-PVA composite film is reasonably low, so PDA-PVA film is one of the candidates to be used as an active material of thermochromic display.

Thermochromic display needs relatively high power to be activated because heat generation demands sufficiently large energy. Therefore, power optimization would become important for thermally actuated display. In this work, pulse wave power supply is used to reduce the power consumption and duty ratio control by PWM technique is demonstrated to be an efficient power-saving method. Moreover, the overheating problem by high activation voltage is also suppressed.

2. Experimental

Thermochromic PDA-PVA composite film was prepared using mixture of 3-carboxyphenylpentacosa-10,12-diynamide (PCDA-mBzA) dispersed solution and an aqueous 10% PVA solution, as reported in previous works [2]-[3]. Fabricated thermochromic display device is shown in Fig. 1. A display device consists of a transparent pyrex substrate, micro-heaters, a SU-8 layer, and a PDA-PVA composite polymer film. Pixels were generated using backside UV exposure method as described in [5]. Embedded micro-heaters act as heat sources which convert the color of each display pixel.

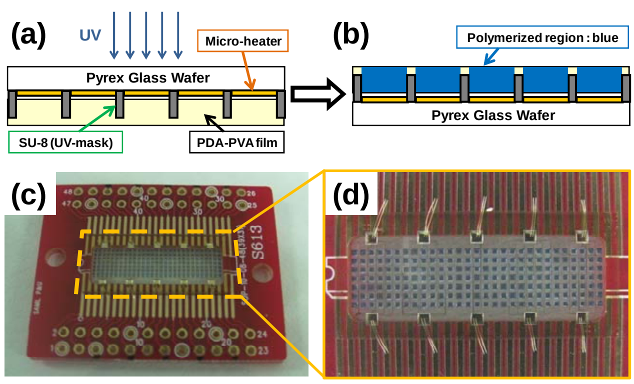

Fig. 1. (a) Self-aligned pixel generation by backside UV exposure with a embedded SU-8 mask. (b) Schematic of the thermally actuated organic display. (c)-(d) Fabricated display device and its close-up view.

The activation of thermochromic display was achieved by applying voltage source. DC voltage supply and pulse generator were both used and compared. The duty ratio of pulse waveform was controlled to verify that PWM technique can decrease power consumption.

3. Results and discussion

Fig. 2 shows the sequential optical images of the letter "I". Clear image of the corresponding letter "I" was shown when the device was activated (Fig. 2 (b)-(d)). Time interval between following images are a few hundred milliseconds. Original state was recovered when the device was turned off (Fig. 2 (e)). If the applied voltage was increased, micro-heaters were overheated resulting image blurring as shown in Fig. 2 (f).

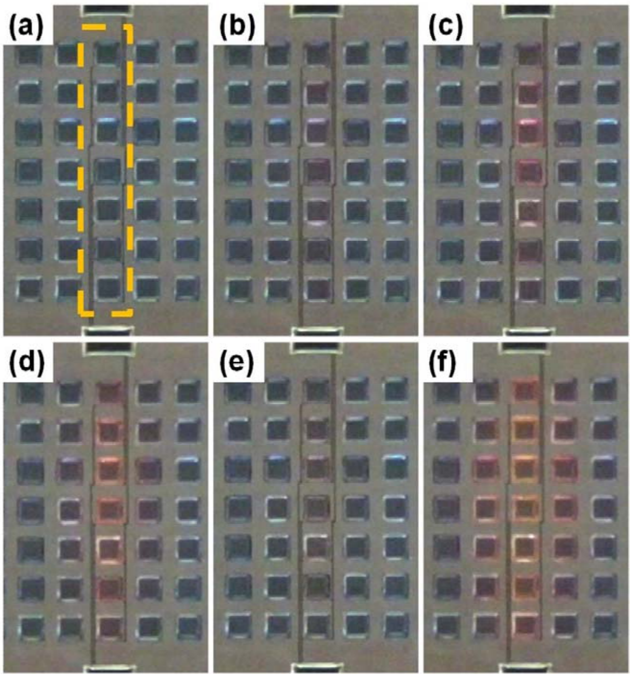

Fig. 2. Optical images of the letter "I"; (a) before display activation, (b)-(c)-(d) sequential images when the device is activated, (e) when the device is deactivated, (f) when the device is over-activated.

Pulse generator was introduced to minimize the overheating problem as well as the power consumption. The frequency of pulse waveform was fixed at 100Hz. Power consumption is simply expressed by

$$P = V_{act}^2 \times (Duty\ Ratio) / R \qquad (1)$$

where V_{act} is activation voltage and R is the measured resistance of driving circuitry including micro-heaters. By adopting PWM technique, the duty ratio (a/T) was controlled, and V_{act} needed to acquire clear display image was investigated. Power consumption was then plotted in Fig. 3 as a function of the duty ratio. Due to difficulty of clear definition of the best display quality, 10 samples with different measured resistance R were investigated and statistically analyzed. All samples showed similar tendency.

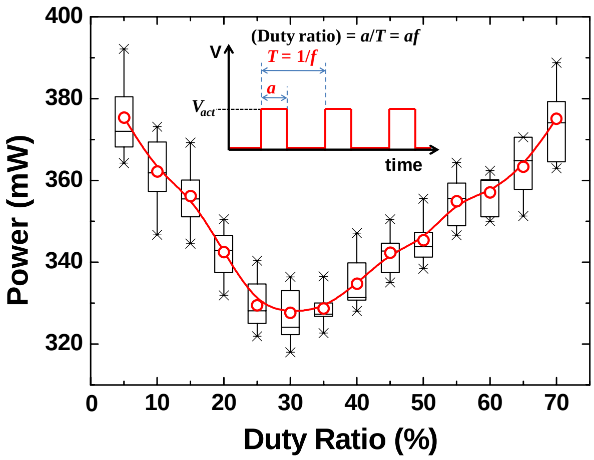

Fig. 3. Power required for good display quality for different duty ratio.

It was evident that demanding activation voltage was increased as the duty ratio was decreased. In terms of power consumption calculated by equation (1), duty ratio of around 30% was identified to be suitable for power-saving.

4. Summary

The pulse width modulation (PWM) technique is introduced to minimize the power consumption of thermochromic organic display. Pulse waveform of about 30% duty ratio is demonstrated to be the effective power source. Image blurring problem by overheating is also suppressed by pulse wave power supply.

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5. References

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