# A Study of Characteristics Comparison with Polyimide in LCOS Microdisplay

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**Abstract**

*We studied characteristics of polyimide (PI) about Liquid Crystal on Silicon (LCOS) microdisplay. In order to compare two kinds of PI and choose one PI, we measured some items. First, we measured thermal imidization of SE-7492, SE-5291 (Nissan) PI using FT-IR. The results of thermal imidization are same 85% for SE-7492 and 86% for SE-5291. The second, we measured voltage-holding ratio (VHR) of LCOS imager using two kinds PI and one liquid crystal (LC) that is a mixture developed by Merck. The third, we measured contrast ratio (C/R) of LCOS imager using function generator from 0V to 4V. The results of VHR and C/R are higher LCOS imager using SE-7492 than LCOS imager using SE-5291. And last we measured response time and the result is same two types LCOS Imagers. So, we choose PI of LCOS imager and concluded that LC is much better matched of PI using SE-7492.*

## 1. Introduction

Liquid Crystal on Silicon (LCOS) is reflective display equipment composed of less than 2" Imager and optical systems (LCOS engine). [1] And there are some advantages of silicon-chip-based light valves. High-performance peripheral circuits and be built in. a high aperture ratio (>90%) can be realized for a small pixel pitch (<20㎛) because of the reflective pixel structure. Efficient cooling can be achieved by radiating heat from the entire back. [2] That is used a projection monitor, a projection TV over 40" and projector. LCOS Imager is made with Liquid Crystal (LC) like Liquid Crystal Display (LCD) and also process is almost identical. Many of researchers are studied characteristics of PI align capability. [3.4.5] Especially, the controlled process and characteristics of PI is very important to display characteristics in LCOS microdisplay.

In this report, we report the difference for two kinds of PI having different property.

## 2. Experiments

We used two kinds of polyimide (PI) having different property, SE-7492 and SE-5291 (Nissan). PI precursor films were prepared by spin coating the poly (amic acid) solutions on indium-thin-oxide (ITO) coated glass substrates. The PI films were pre-baked at 80℃ for 10min and imidized at 230℃ for 90min. And in order to compare imidization of PI, the PI films were fully imidization at 300℃ at 60min. The degree of imidization were measured FT-IR (Nicolet nexus). The PI thickness was about 500Å. The PI films were rubbed using a rubbing machine JE-2121-ATC (Joyo Engineering Co. Ltd) with a cotton cloth (YA-25C, Yoshigawa Chemical Co. Ltd). We made a transmittance LC cell using LC that is a mixture developed by Merck. The LC cell was assembled with anti-parallel rubbed surface using same rubbing strength. [6] All the cells had a thickness of 4.2± 0.5㎛. In order to determine the polar anchoring energy, we used the "high electric-field technique". [5.7] In order to measure the polar anchoring energy, we measured the capacitance (C) and the optical retardation (R) as a function of applied voltage (V).

Under the high electric field ($V>>6V_{th}$), the extrapolation length $d_e$ was derived from: [5.7]

$$\frac{R}{R_0} = \frac{I_0}{CV} - \frac{2d_e}{d}, \text{ when } V>>6V_{th} \quad (1)$$

Where $I_0$ is a proportionality constant that depends on the LC materials; V and d stand for the applied voltage and the LC medium thickness, respectively.

We determined the polar anchoring energy A from

$$A = \frac{K}{d_e} \quad (2)$$

Where K is the elastic constant which is given by $K=K_1\cos^2\Theta_0+K_3\sin^2\Theta_0$, where $K_1$, $K_3$, and $\Theta_0$ stand for the elastic constants of splay, bend deformation, and the pretilt angle, respectively. We measured elastic constants in this work.

We made LCOS imager using two kinds PI and LC as same process. And voltage-holding ratio (VHR) was measured using Model 6254 (Japan, Toyo Corporation). Model 6254 amplifiers is a role impedance exchanger with sample and hold amplifier

and that is illustrated Figure 1(a). Either Sw1 or Sw2 was connected to the circuit during the nonselected to the circuit during the selected periods, while neither Sw1 nor Sw2 was connected during the nonselected periods. The VHR was obtained by measuring the profiles of the voltages, which was applied to the LCOS imagers in selected periods, during nonselected periods. The schematic waveform applied to the LCOS imagers and the definition of the VHR obtained by the relaxation of the LCOS imagers during nonselected periods are given in figure 1(b). The VHR was defined as the ratio $V/V_0$, of the initially applied voltage ($V_0$) and the finally obtained voltage when relaxed during the nonselected period (V). [8]

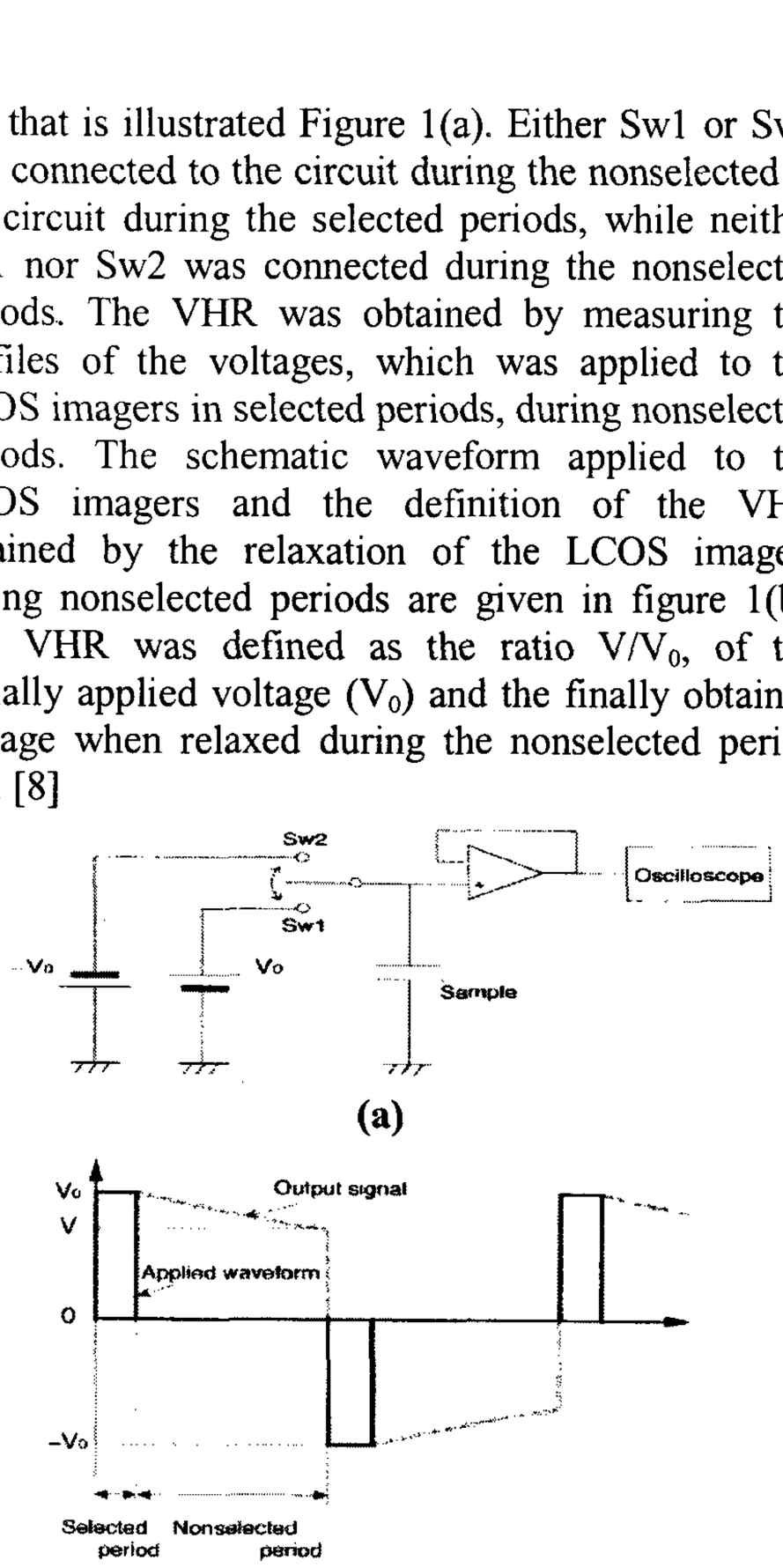


**Figure 1. (a) Circuit diagram of the measurement system for VHR characteristics. (b) Schematic waveform applied to LCOS imagers and corresponding output signal for the measurements of VHR characteristics.**

We measured white to black contrast ratio (C/R) using chroma meter CS-100 (Japan, Minolta Co.,Ltd.) and LCOS engine that is comprised of light source (metal halide lamp), and infrared (IR) filter, fly's eye integrator arrays, polarizing beam splitter (PBS) array, polarizer, half wave plate, PBS and dichroic cubes (prisms), reflecting mirrors, etc. [1]

Figure 2 illustrates response time measurement system that was measured from their optical signals triggered by switching a waveform generator on and off. The signals from the LCOS imagers were observed with a digital oscilloscope (Hewlett-Packard) the switching on and off times ($\tau_{rise}$ and $\tau_{decay}$) were defined as the times from the moment of the field on and off to that at which a 90% optical change from the off state to the on state or vice versa is achieved.

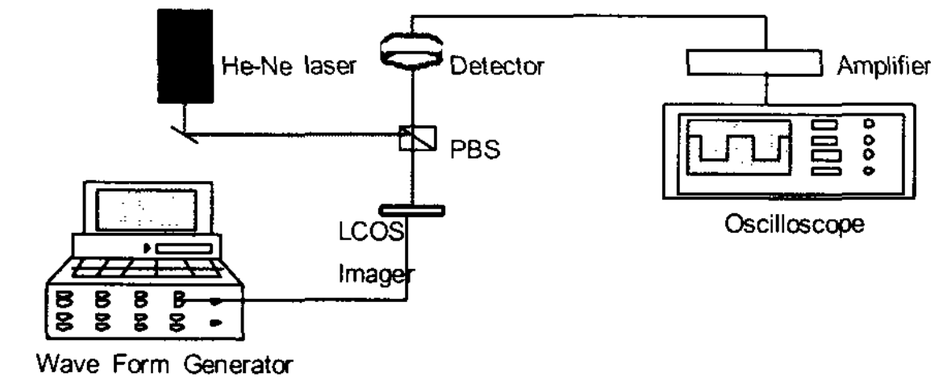


**Figure 2. Measurement system of response time.**

## 3. Results and Discussion

Table 1 is a result of imidization and anchoring energy of LC cell using two kinds of PI. The peak at 1515cm$^{-1}$ corresponds to the C-C stretching of para-substitued benzene and the peak at 1378cm$^{-1}$ is attributed to the C-N stretching of the imide group. [3] The degree of imidization is determined by referencing $A_{1378}/A_{1515}$ to the ratio obtained at fully imidized temperature of 300℃ that is compared with imidization at 350℃ at 60min.

**Degree of imidization (%)**

$$= \frac{(A_{1378}/A_{1515})_{sample}}{(A_{1378}/A_{1515})_{fully-imidization}} * 100 \quad (3)$$

The degree of imidization for SE-7492 is 85% and for SE-5291 is 86%. The results of two kinds of PI have same imidization values.

**Table 1. The results of imidization ratio and anchoring energy for SE-7492 and SE-5291.**

| | Cure Temp | 1378cm$^{-1}$ | 1515cm$^{-1}$ | Ratio | Degree of imidization | Anchoring energy (x10$^{-2}$ J/m$^2$) |
|---|---|---|---|---|---|---|
| SE-7492 | 230℃ 90min | 0.0397 | 0.0243 | 1.642 | **85%** | **2.73** |
| | 300℃ 60min | 0.0159 | 0.0827 | 1.924 | 100% | |
| SE-5291 | 230℃ 90min | 0.0610 | 0.0515 | 1.185 | **86%** | **2.14** |
| | 300℃ 60min | 0.0207 | 0.0151 | 1.370 | 100% | |

The anchoring energy is higher for SE-7492 than SE-5291. So, the anchoring energy of PI for SE-7492 is strongly attributed to the surface ordering due to the increase of LC aligning capability. [4]

Figure 3 shows VHR result of LCOS imagers using two kinds of PI. That is measured 480Hz because LCOS imager operating frequency is 480Hz but 120Hz and 240Hz measurement result is very similar. The difference in the VHR characteristics between SE-7492 and SE-5291 was the degree of sensitivity to the resistivity of the PI. An explanation of this mechanism must be closely related to the electrically working components involved in each LCOS imager structure. [8]

LCOS imager using SE-7492 have uniform VHR values at each cell above 95% (at average 97%) but LCOS imager using SE-5291 have lower VHR value at average 93%.

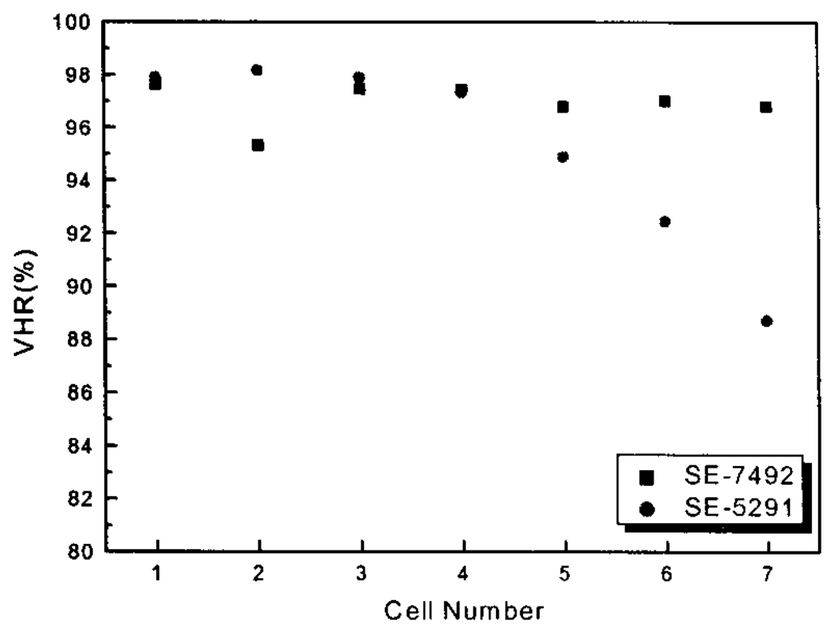


**Figure 3. VHR values of LCOS imager using two kinds of PI. Square dot is LCOS imagers using SE-7492. Round dot is LCOS imagers using SE-5291. VHR value is higher SE-7492 imagers than SE-7492 imagers.**

Figure 4 shows white to black C/R ratios of LCOS imagers using two kinds of PI and that is not used compensating film between PBS and LCOS imager. When we use the film, the C/R of LCOS imagers have higher value because of compensating for light passing the PBS and LCOS imager. [9] That is showed VHR values related C/R in LCOS imagers. [10] The corresponding requirements of LCOS imagers are high VHR for better contrast. The C/R is calculated at 610nm by obtaining the reflectance of the LCOS imager (normally white mode) at V=0 and at V=4V. It is simply the ratio of the two reflectance, the actual contrast will surely be difference if white light or a different voltage is used. The C/R is higher LCOS imager using SE-7492 than LCOS imager using SE-5291 (about 11%). LCOS imager using SE-7492 have higher VHR (figure 4) and C/R that is more matched LC that is a mixture developed by Merck.

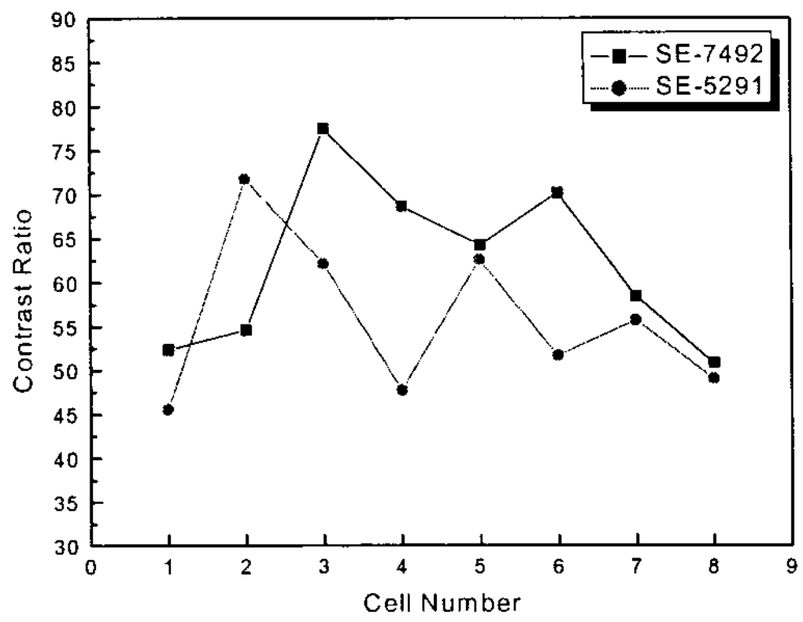


**Figure 4. Contrast ratio of LCOS imagers using two kinds of PI. Square dot is LCOS imagers using SE-7492. Round dot is LCOS imagers using SE-5291.**

Figure 5 shows the experimental reflectance-voltage (R-V) curve of LCOS imagers using two kinds of PI under light illumination. We can find that there is good dark state at 4V. And the R-V curves have same curve in LCOS imagers using two types of PI. There is also a slight decrease in the reflectance at 1~1.3V. The operating voltage for the dark state is only 4V, which is well suited for back plane CMOS operating voltage. So white reflectance voltage is 1V and dark reflectance voltage is 4V. [2] We confirmed that LCOS imager using SE-7492 have higher C/R because of lower dark reflectance value at 4V that is shown in figure 5.

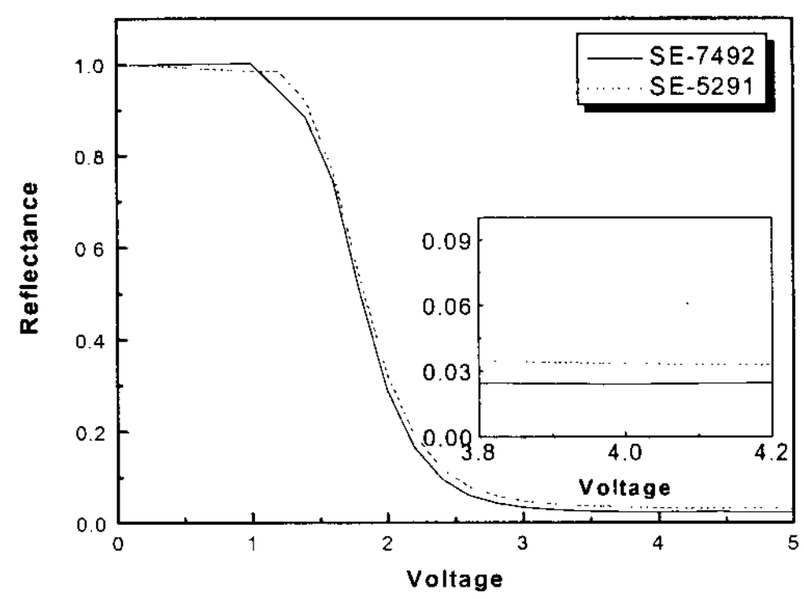


**Figure 5. Reflectance-voltage curves of LCOS imagers using two kinds of PI. Solid line is LCOS imager using SE-7492. Dash line is LCOS imager using SE-5291.**

Figure 6 shows response time of LCOS imagers using two kinds of PI. The response time of LCOS imager is related to the applied voltage, cell gap, rotational viscosity, elastic constant, threshold voltage and bias voltage. In a displayed gray scale image, each pixel may have a different response time, depending driving voltage and bias voltages. Normally, the LC rise time is faster than the decay time owing to the driving voltage factor. The fast response of less than 8ms is due to the relatively thin LCOS imager. The result of two types of LCOS imagers have same response that is 4~5ms (at average 4.3ms for SE-7492 and at average 4.2ms for SE-5291).

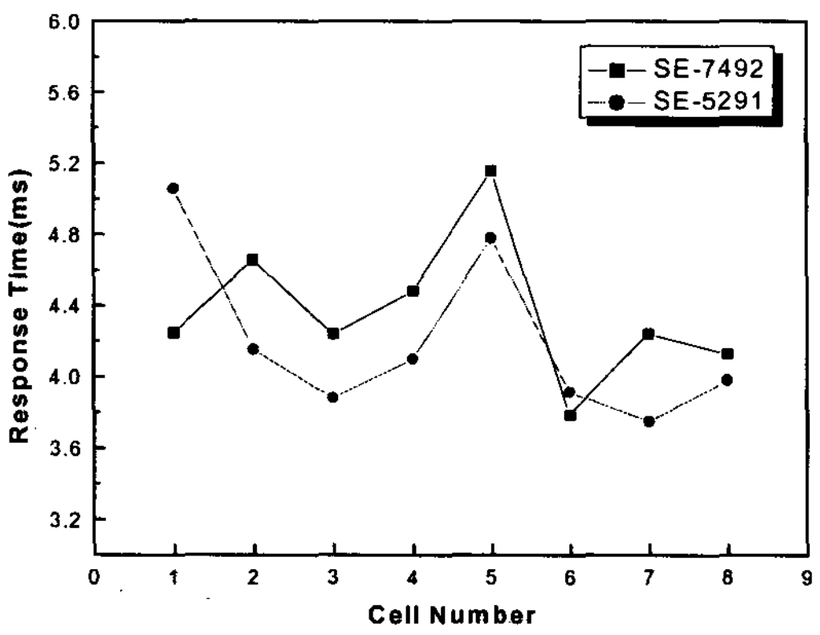


**Figure 6. Response time of LCOS imagers using two kinds of PI. Square dot is LCOS imagers using SE-7492. Round dot is LCOS imagers using SE-5291. Two types of LCOS imagers have same response that is 4~5ms.**

## 4. Conclusions

The PI is very important role in LCOS imager because PI is related at VHR and C/R. In order to compare PI, we measured FT-IR, VHR, C/R and response time. When imidization ratio is same at two kinds of PI for SE-7492 and SE-5291, VHR and C/R is higher LCOS imager using SE-7492 than LCOS imager using SE-5291. So, we choose PI of LCOS imager and concluded that LC is much better matched of PI using SE-7492.

## 5. Acknowledgements

The author wishes to thank Merck and Nissan for supply materials and acknowledges the support of technical process group members in Samsung SDI CRD 4 Team.

## 6. References

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