Active matrix organic light emitting diode (AMOLED) performance and life test results

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ABSTRACT

The US Army and eMagin Corporation established a Cooperative Research and Development Agreement (CRADA) to characterize the ongoing improvements in the lifetime of OLED displays. This CRADA also called for the evaluation of OLED performance as the need arises, especially when new products are developed or when a previously untested parameter needs to be understood. In 2006, eMagin Corporation developed long-life OLED-XL™ devices for use in their AMOLED microdisplays for head-worn applications. Through Research and Development programs from 2007 to 2009 with the US Government, eMagin made additional improvements in OLED life and developed the first SXGA (1280 X 1024 triad pixels) OLED microdisplay. US Army RDECOM CERDEC NVESD conducted life and performance tests on these displays, publishing results at the 2007, 2008, and 2009 SPIE Defense and Security Symposia[1,2,3]. Life and performance tests have continued through 2009, and this data will be presented along with a recap of previous data. This should result in a better understanding of the applicability of AMOLEDs in military and commercial head mounted systems: where good fits are made, and where further development might be desirable.

Keywords: AMOLED, OLED, long-life OLED, lifetime, usable display lifetime, SXGA OLED, display, microdisplay

1. INTRODUCTION

US Army/RDECOM/CERDEC/NVESD and eMagin Corporation have established a CRADA with the goal of evaluating and characterizing new and existing AMOLED microdisplay technology. Under this CRADA, eMagin provides displays, display systems, and display system components to NVESD that eMagin developed under funded or IR&D programs. NVESD evaluates all delivered systems and components for life and performance as applicable. The two organizations then update and modify the Usable Lifetime Model and co-publish the results of the tests on a yearly basis.

The intent of this CRADA is to develop AMOLED microdisplays capable of being fielded in a wide range of US Army applications and to gauge when the display technology is ready for a given application, considering its requirements. The Usable Lifetime Model was established to determine if the performance would be maintained over time at a sufficient level given a certain set of requirements (color, temperature, luminance, video rate, allowed degradation)[4]. The typical test method of driving the display with a full-on (all white) pattern is not an accurate representation of how a display is used but the characteristics of this test are essential in calculating the predicted usable lifetime.

eMagin developed the OLED-XL™ stack in 2006, reporting that the usable life of the panels may be increased significantly over that of the standard white, color, and green materials. In 2008 and 2009, via research contracts managed by RDECOM CERDEC NVESD, eMagin developed further lifetime improvements in their displays, utilizing different materials, including phosphorescent, and modifying different processes for long-life monochrome and color displays. This being an R&D program, not all prototype displays resulted in success, but significant lifetime and efficiency improvements were found in some of the experiments.

The last paper focused heavily on the performance of the recently developed SXGA AMOLED along with the general lifetime characteristics of OLED devices. This paper will cover the lifetime of the SXGA that has a significantly longer lifetime than that of the SVGA displays. The increased lifetime of the SXGA can be attributed to the improved driving characteristics of the SXGA. The constant current aspect of the driving operation provides good luminance stability versus temperature. The SXGA display also features a voltage drive approach, resulting in a significant improvement of the fixed pattern noise over the SVGA+ displays, and that will be discussed as well.

2. LIFE TESTS ON EXPERIMENTAL DEVICES

2.1 Introduction/General Comments

As in the last reporting, the life testing this year concentrated mainly on the deliverables from the aforementioned research programs managed by US Army RDECOM CERDEC NVESD rather than on commercial microdisplays which utilize now well-established production processes. As an R&D program, not all experimental devices were expected to outperform the production OLED-XL™ displays. The intent was to explore the best options available, and determine through testing which devices would have longer life and higher efficiency and should thus be transitioned into production displays.

The 2007 and 2008 papers[2,3] thoroughly detailed the test setup for measuring the accelerated lifetime of the displays. This included the display optimization, calibration, measurement of luminance, and temperature and calibration correction. The displays are driven with a full-on pattern (full screen at drive level 255), to allow for a standard reading of luminance loss over time which in turn allows predictions of display lifetime used for video in real applications.

Each test, generally of five displays, was given a number, with the first two tests (Tests 1 & 2) being covered in the 2007 paper. As more tests were run, the results were published in 2008 (through Test 4) and 2009 (through Test 7). The final results from Test 7 and Test 8 are included here. The details of all tests are shown later in Table 2.

2.2 Test Results

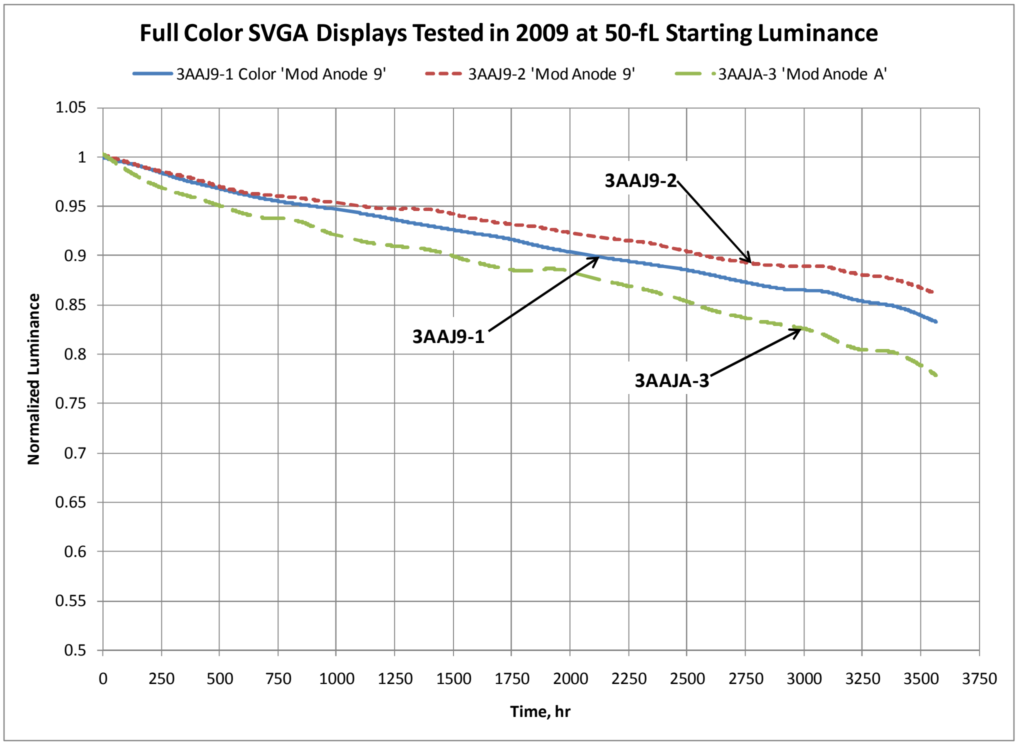


Figure 1. Full Color Experimental displays life tested in 2009 at 50-fL. 3AAJ9 (Mod Anode 9) displays have improved lifetime over production OLED-XL™. 3AAJ9-1 refers to the display serial number and descriptions like 'Mod Anode 9' are arbitrary designations given by NVESD.

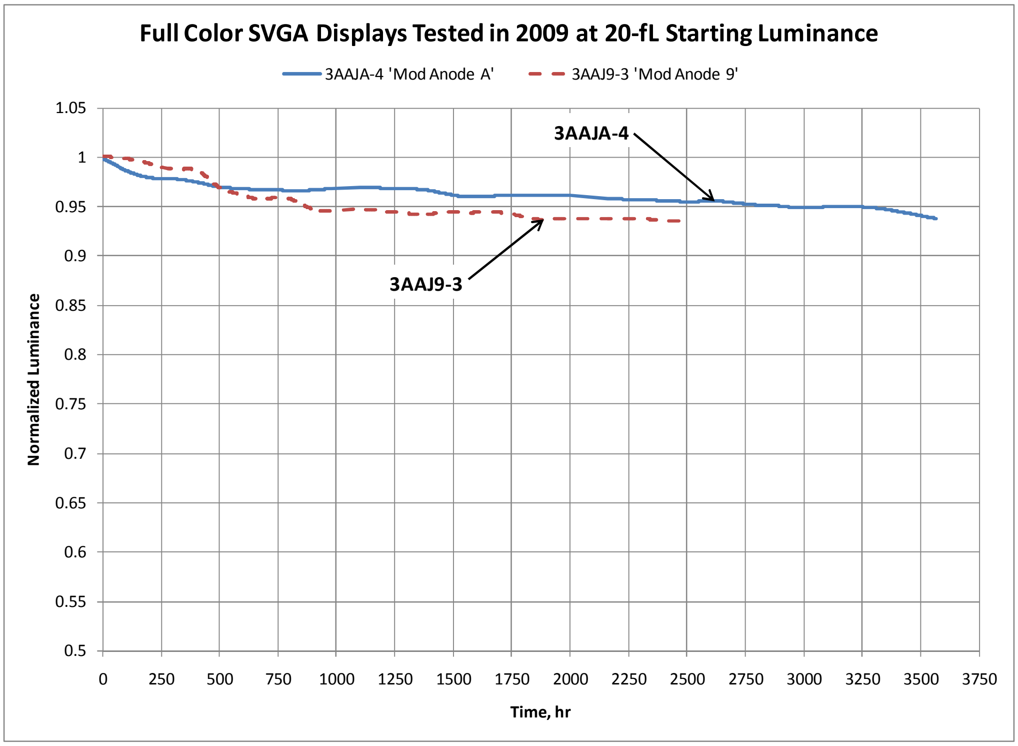


Figure 2. Full Color Experimental displays life tested in 2009 at 20-fL. Both displays did very well at 20-fL.

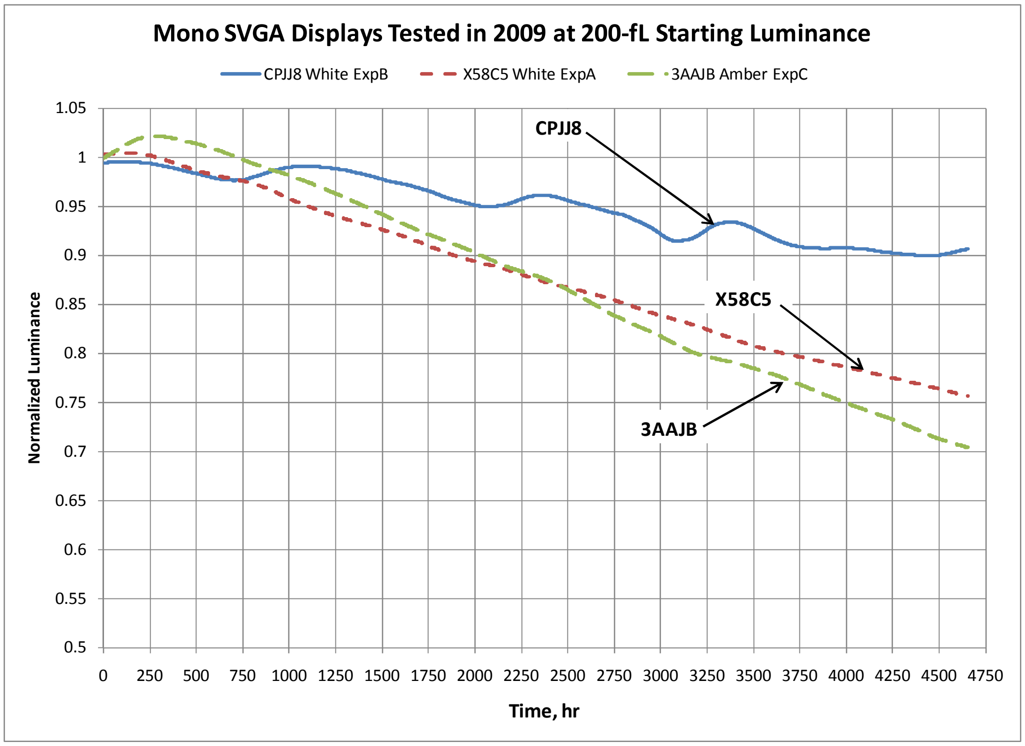


Figure 3. Monochrome (including White) Experimental displays life tested in 2009 at 200-fL. White OLED 'ExpB' has excellent life characteristics, far surpassing the current production OLED-XL™ lifetimes.

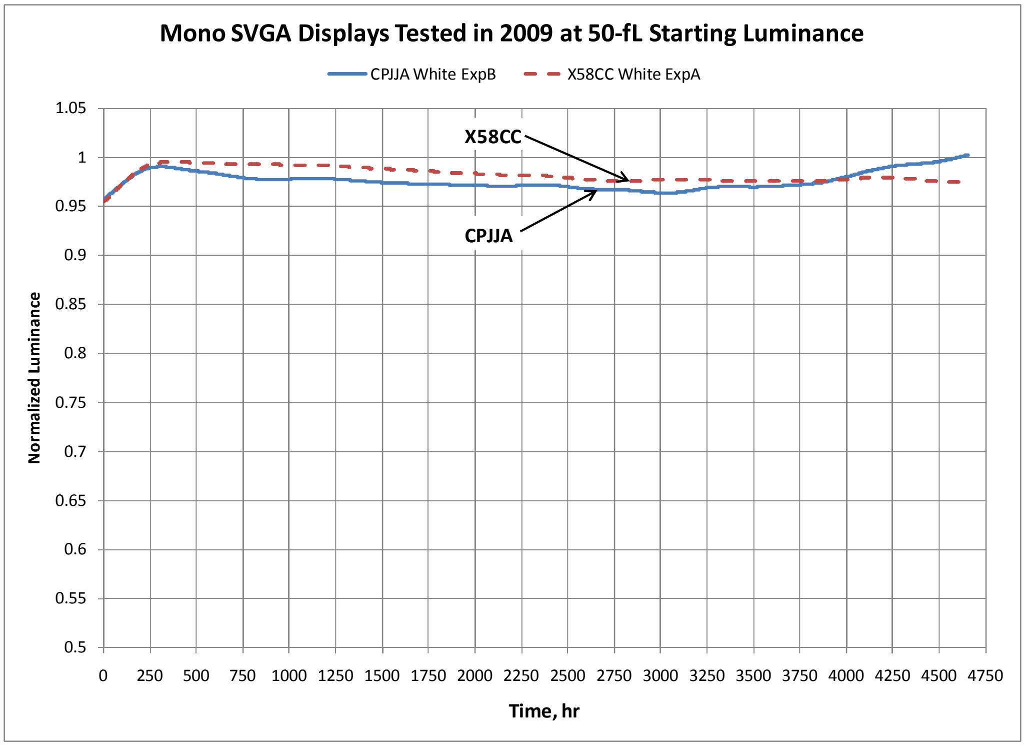


Figure 4. Monochrome (including White) Experimental displays life tested in 2009 at 50-fL. The lifetime of the 'White OLED 'ExpB' display at 50-fL cannot be calculated.

Table 1. Stability of color coordinates during Life Test 8.

Changes in Color Coordinates (CIE 1931) of SVGA Displays from Test 8

Serial #	Description	Luminance	Initial Color (x, y)		Final Color (x, y)		Change (x, y)	
X58C5	White Exp A	200-fL	0.329	0.362	0.328	0.362	-0.001	0.000
X58CC	White ExpA	50-fL	0.334	0.365	0.332	0.362	-0.002	-0.003
CPJJ8	White ExpB	200-fL	0.336	0.356	0.337	0.357	0.001	0.001
CPJJA	White ExpB	50-fL	0.341	0.356	0.341	0.356	0.000	0.000
3AAJB	Amber ExpC	200-fL	0.493	0.463	0.495	0.467	0.002	0.004

Figures 1-4 show the corrected and smoothed (using MathCAD supersmooth function) accelerated life tests of displays evaluated during the past year (Tests 7-8). The displays are labeled by a serial number (e.g. 3AAJB) and a device descriptor that includes the color of the display and an arbitrary designation which may or may not indicate the type of modification made (e.g. Color Mod Anode 9 or Amber ExpC). Test 7 was started in 2008 and interim results were reported last year, but the test was completed in 2009 and the results have been updated. Test 8 was initiated and completed in 2009 and all results from that test are final. The plots are organized by display type (full color or monochrome/white) and starting luminance. Lifetimes of 90%, 75%, and 50% are based on the point when the curve intersects (or would intersect) that level. Actual measured lifetime results are used when available, otherwise straight-line extrapolations are used to estimate the life at a given level. The color stability of the displays in Test 8 is shown in Table 1. Although the color data was not recorded in previous tests, it will be recorded in future evaluations.

The estimated accelerated lifetimes of all CRADA tested displays are shown in Table 2. The first part of the table shows the results from tests 1-4, which were primarily on production displays. The display described as "Full Color HRA" is an exception, being a "Standard" OLED with a highly reflective anode. The second part shows the estimates based on tests of displays that showed promise, having higher efficiency, but were not selected as possible production parts since their lifetimes are not as long as the XL lifetime. The final section shows the life estimates of displays that have longer lifetimes than XL devices and may become production parts due to this and their higher efficiency. In all cases, the times shown are in hours and the boxes are highlighted or shaded if estimated (based on straight line extrapolation).

Table 2. Results of all Accelerated Lifetime Tests (All Pixels Full-On) run under CRADA at RDECOM CERDEC NVESD. Tables include production displays and experimental displays, including displays selected for further investigation and those not. All displays listed were in the SVGA family.

Accelerated Lifetimes (All Pixels Full-On) of Production Displays

Serial #	Test	Hours Tested	Device	Luminance	Temperature	90% Life	75% Life	50% Life
CD5N5	1	2,050	Full Color Std HRA	50	Ambient	740	1,600	3,000
CCR77	1	2,050	Mono White OLED-XL™	50	Ambient	9,000	21,500	42,000
CCLMX	1	2,050	Full Color Std	50	Ambient	440	1,230	2,500
CCLN6	1	2,050	Full Color Std	20	Ambient	1,000	3,700	8,200
CDL18	2	2,250	Full Color OLED-XL™	50	Ambient	1,500	3,700	7,500
CDL0K	2	2,250	Full Color OLED-XL™	50	Ambient	1,350	3,300	6,800
CDL0N	2	2,250	Full Color OLED-XL™	20	Ambient	4,000	9,800	19,600
CDD37	2	2,250	Mono White Std	200	Ambient	425	1,550	3,500
CKK0	2a	950	Mono White OLED-XL™	200	Ambient	1,700	4,700	9,500
X3A2Y	3	2,950	Mono White OLED-XL™	200	50°C	925	2,200	4,200
CHA21	3	2,950	Mono White Std	200	50°C	575	1,450	2,950
X3A3K	3	2,950	Full Color OLED-XL™	50	50°C	525	1,550	3,300
X3A3W	3	2,950	Full Color OLED-XL™	20	50°C	1,800	4,800	9,700
CJJ0W	4	1,300	Mono White Std	200	Ambient	1,000	3,200	6,700
CFSNM	4	1,300	Mono Yellow Std	200	Ambient	700	2,700	5,700
CK1XW	4	1,300	Mono Green Std	200	Ambient	125	475	1,700
X3PSS	4	1,300	Mono Green OLED-XL™	200	Ambient	1,150	3,600	7,800
X3RHK	4	1,300	Full Color OLED-XL™	75	Ambient	300	1,600	4,700

Accelerated Lifetimes (All Pixels Full-On) of Experimental Displays (Not Selected)

Serial #	Test	Hours Tested	Device	Luminance	Temperature	90% Life	75% Life	50% Life
CK28A	5	1,675	Full Color Prototype A	50	Ambient	1,350	2,500	4,500
CK27N	5	1,675	Full Color Prototype A	50	Ambient	1,350	2,600	4,600
CL5YX	5	1,675	Full Color Prototype B	50	Ambient	265	800	2,100
CL5YP	5	1,675	Full Color Prototype B	50	Ambient	215	700	1,700
X3YC0	5	1,675	Full Color Mod Anode X	50	Ambient	1,000	4,200	9,500
CLLZ7	6	2,200	Green Phosphorescent C	200	Ambient	1,080	2,150	4,000
3AAJB	6	2,200	Green Phosphorescent B	200	Ambient	1,580	3,300	6,200
CLLZM	6	2,850	Green Phosphorescent C	50	Ambient	Insufficient data to estimate life		
3AAJA-1	6a	675	Full Color Mod Anode A	50	Ambient	1,200	3,000	6,000
3AAJA-2	6a	675	Full Color Mod Anode A	200	Ambient	130	360	810
3AAJA-3	7	3,600	Full Color Mod Anode A	50	Ambient	1,500	4,100	8,500
3AAJA-4	7	3,600	Full Color Mod Anode A	20	Ambient	7,000	23,000	50,000
X58C5	8	4,600	White ExpA	200	Ambient	1,850	4,800	9,500
X58CC	8	4,600	White ExpA	50	Ambient	20,000	52,000	104,000

Accelerated Lifetimes (All Pixels Full-On) of Experimental Displays Exceeding OLED-XL™ Life at Higher Brightness Levels

Serial #	Test	Hours Tested	Device	Luminance	Temperature	90% Life	75% Life	50% Life
CLLZZ	6	2,850	Green Phosphorescent A	200	Ambient	7,200	18,000	36,000
CLLZR	6	2,850	Green Phosphorescnet A	50	Ambient	17,000	42,500	85,000
3AAJ9-1	7	3,600	Full Color Mod Anode 9	50	Ambient	2,100	5,400	11,000
3AAJ9-2	7	3,600	Full Color Mod Anode 9	50	Ambient	2,600	6,300	12,500
3AAJ9-3	7	2,500	Full Color Mod Anode 9	20	Ambient	6,000	23,000	55,000
3AAJB	8	4,600	Amber ExpC	200	Ambient	2,000	4,000	7,500
CPJJ8	8	4,600	White ExpB	200	Ambient	4,400	11,000	22,000
CPJJA	8	4,600	White ExpB	50	Ambient	Insufficient data to estimate life		

Of the displays tested in 2009 (tests 7-8), White 'ExpB' showed the most promise. The test ran for 4,600 hours, and the display at 200-fL did not reach the 90% point until 4,400 hours. The half-life of 'ExpB' is 22,000 at 200-fL, and it was impossible to determine a decaying trend for the display at 50-fL. This device can be used for white or full color applications with the addition of color filters. Currently the transmission in the color filters is somewhere between 20 and 25%, so a 200-fL White OLED would be similar in lifetime to a 44-fL Full Color OLED.

Both Full Color 'Mod Anode 9' and Amber 'ExpC' displays have improved lifetimes over the best production displays of similar type, but both appear to be eclipsed by newer experimental displays. The White 'ExpB' displays with color filters would likely have longer lifetimes than the color 'Mod Anode 9' devices when set to 50-fL, but it won't be validated until tests are conducted under similar conditions. The Amber 'ExpC' displays have longer life than the similarly colored Yellow standard displays, but further developments in Yellow/Amber devices were recently made that should further increase the lifetime.

Full Color 'Mod Anode A' and White 'ExpA' had some improved characteristics over the production displays, but they did not have longer life at higher luminance levels. Color 'Mod Anode A' has longer life at lower levels (20-fL), but the life is shortened at higher levels (50-fL). The White 'ExpA' displays had much longer life at lower levels (50-fL) and equal life at the higher levels (200-fL), but the White 'ExpB', tested at the same time has significantly better life, relegating the 'ExpA' displays to the "Not Selected" category.

Note that more life data needs to be collected on these experimental displays to establish a good statistical baseline and ensure that the correct lifetime is reported. Further refinements will be made on some of these devices, and a thorough investigation of the lifetime will be completed prior to sending experimental products to production. Both NVESD and eMagin plan on continuing these measurements.

3. SXGA DISPLAYS

3.1 Performance

Along with OLED lifetime evaluation, the previous year's report also detailed the performance of the Rev2 SXGA microdisplay eMagin developed under a research program managed by the US Army Telemedicine and Advanced Technology Research Center (TATRC)[1]. The highlights of those results are shown in Table 3 (R393H and R393F are serial numbers of two full color displays).

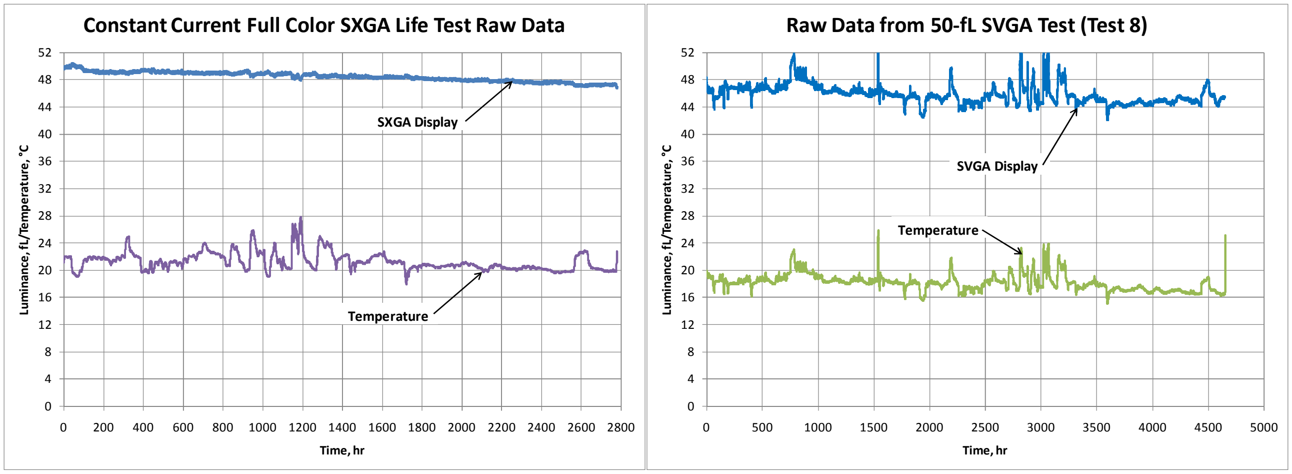
Table 3. Performance results of Rev2 SXGA display evaluated for SPIE DSS 2009.

Highlights From SPIE 2009 SXGA Full Color Rev2 Test Results

	R393H	R393F
Contrast at 50-fL	638,827:1	1,199,232:1
Checkerboard at 50-fL	15,603:1	7,420:1
Contrast at 1-fL	18,670:1	6,810:1
Checkerboard at 1-fL	5,405:1	4,049:1
CTF: Michelson Contrast at 41.7 lp/mm (Nyquist)		
Horizontal	81%	80%
Vertical	88%	90%
Nonuniformity	7.32%	11.72%
Response Time	34.65-µs	

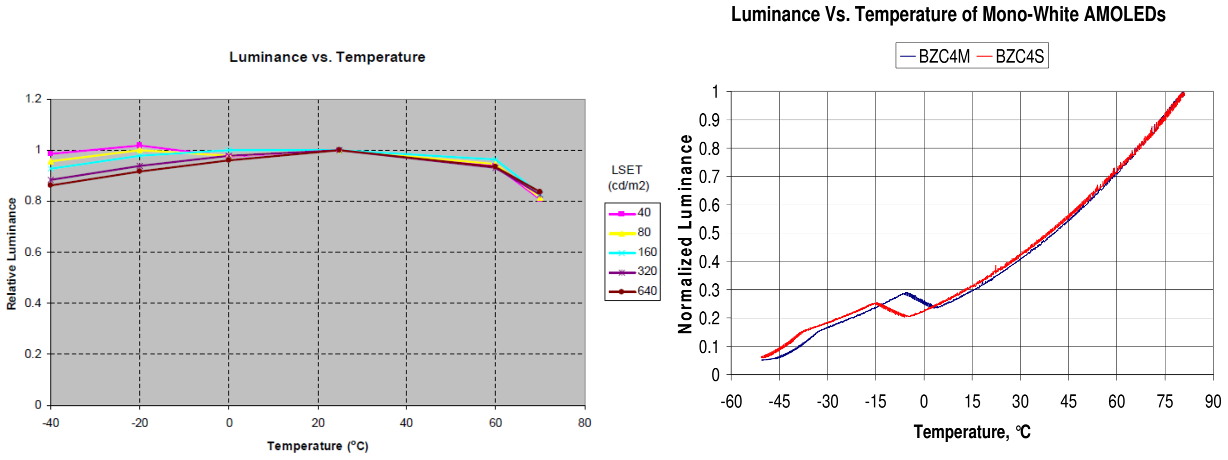
eMagin added temperature stabilization to the Rev3 SXGA. The Rev3 allows the display to be driven with constant current density that keeps the luminance output very stable over the temperature range. From previous reports, it was determined the OLED microdisplays performed well over the -40 to +70°C range, provided the required adjustments were made to the cathode and bias voltages[4,5]. The Rev3 SXGA displays provide fairly consistent luminance over this range and can be set to maintain gamma through the use of lookup tables. Figure 5 compares the stable luminance of an

SXGA display during a life test compared to the temperature sensitive response of an SVGA display during a separate life test. Figure 6 compares the normalized luminance versus temperature of an SVGA[4] to the response of the SXGA over a similar range.



(a) (b)

Figure 5. Raw data from life tests showing luminance stability of Rev3 SXGA (a) display as compared to SVGA display (b)



(a) (b)

Figure 6. Luminance versus temperature for SXGA (a) and for SVGA (b). The plot shown in (a) results from testing done at eMagin. The plot shown in (b) was published at SPIE in 2005 by this author.

3.2 Life Tests

Aside from providing temperature stability, the operation of the SXGA in constant current mode also increases the lifetime of the display beyond that of the SVGA panels tested. As the part ages, the required bias voltage needed to maintain a fixed current density increases, so it was monitored in two of the displays during the life test. Figure 7 shows the smoothed (using MathCAD supersmooth function) accelerated life test of the SXGA displays while Figure 8 shows the change in voltage. The minimal power increase (<7mW over 2,800 hours) is calculated in Table 4. Voltages close to the start and end of the test at the same temperature were chosen. The display current was calculated by multiplying the known current density (20mA/cm^2 at 50-fL) by the active pixel area: 1.888cm^2 (display area) X 0.69 (fill factor) X 20mA/cm^2 = 26.05mA. By increasing the power very slightly, the half-life of the full color SXGA displays at 50-fL is estimated at over 20,000 hours (Table 5).

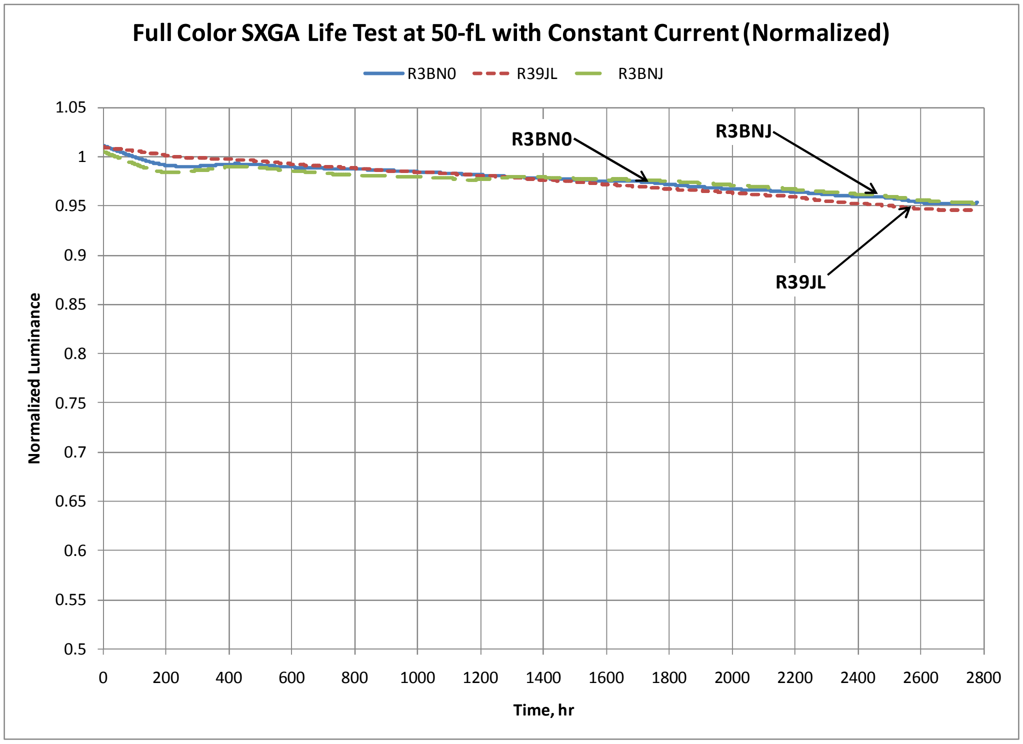


Figure 7. Life test for 3 Full Color SXGA displays operating in the constant current mode.

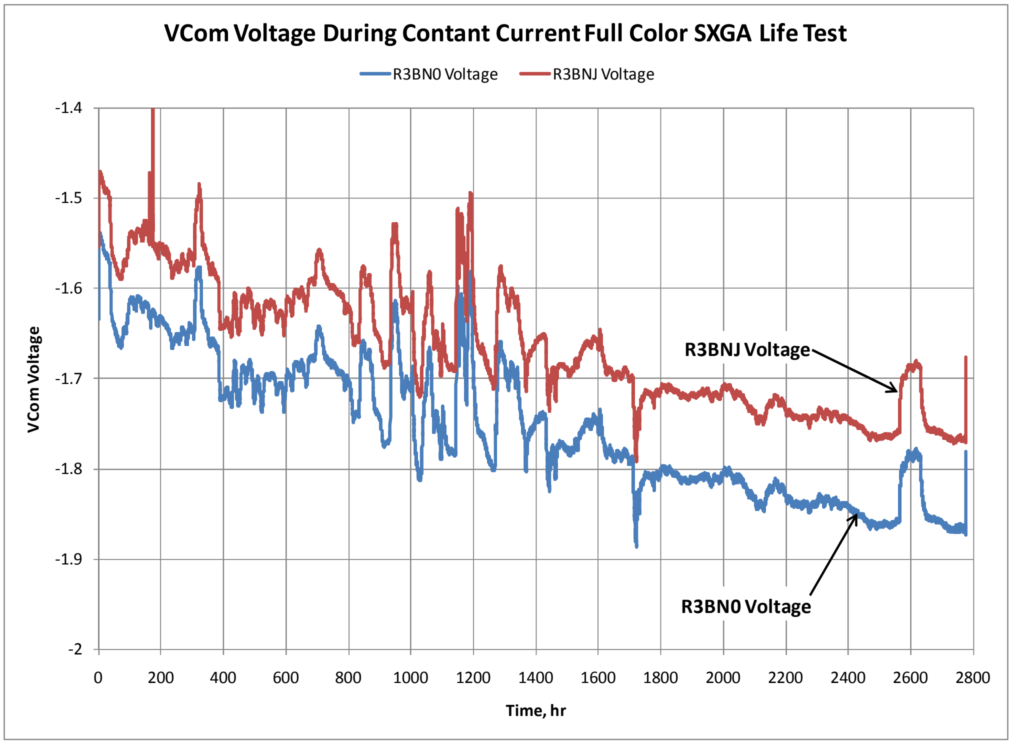


Figure 8. VCom for two displays during SXGA life test. Voltage changes with temperature and over life of display.

Table 4. Increase in power of SXGA display after 2,800-hr at 50-fL as a result of running in constant current mode (achieving 200% improvement in lifetime)

Increase in Power after 2,800-hr Life Test for Constant Current Operation

Display	Starting Voltage	Ending Voltage	Δ Voltage	Display Current, mA	Change in Power (Full On), mW	Change in Power (40% Duty), mW
R3BN0	-1.54	-1.80	0.263	26.05	6.85	2.74
R3BNJ	-1.47	-1.70	0.231	26.05	6.01	2.41

Table 5. Results of SXGA Accelerated Lifetime Test (All Pixels Full-On). Operation in SXGA constant current mode very significantly increased the lifetime of the display.

Accelerated Lifetimes (All Pixels Full-On) of SXGA Displays (Constant Current Mode)

Serial #	Test	Hours Tested	Device	Luminance	Temperature	90% Life	75% Life	50% Life
R3BN0	9	2,800	Color OLED XL™ SXGA	50	Ambient	5,200	11,500	23,000
R39JL	9	2,800	Color OLED XL™ SXGA	50	Ambient	4,700	10,700	21,500
R3BNJ	9	2,800	Color OLED XL™ SXGA	50	Ambient	5,200	11,500	23,000

4. USABLE LIFETIME MODEL

4.1 Explanation of model

The previous SPIE DSS papers[1,2,3,4] have extensively detailed the life model, which is used to more accurately predict how long a particular OLED display would survive in a specific application, based on allowable degradation, color requirements, and luminance and temperature profile. The rules, which have not changed aside from the expansion of #4 (estimating life at lower luminances when only one light level has been tested), are listed below.

Operational Condition Data Rules & Assumptions:

1. The model is currently set up to evaluate the life of a panel that experiences two luminances (e.g. "day mode" and "night mode") and two temperatures at user-entered duty cycles. It can be expanded.
2. The OLED-full-on lifetimes can be found in the database for 90%, 75%, and 50% life (see Table 2).
3. The lifetime value for a luminance not in the database will be calculated using linear interpolation or extrapolation (only for lower luminances).
4. The full-on lifetime of the Full Color SXGA OLED-XL™ at 20-fL (needed for interpolation described in #3) will be calculated by multiplying the ratio of the SVGA Color OLED-XL™ 20-fL to 50-fL lifetimes by the lifetime of the SXGA at 50-fL. The ratio of SVGA White OLED-XL™ 50-fL to 200-fL will be used in a similar manner to calculate the life of the SVGA White 'ExpB' at 50-fL.
5. The video content rate assumption means a certain percent of the pixels are full-on while all other pixels are off – in practice many pixels will be partially on at various gray levels. If the video rate were specified at 50%, the assumption would be that 50 percent of the pixels are full-on.
6. The OLED luminance half-life at 50°C is 40% of that at 20°C.
7. A derating factor of 2 is meant to account for the statistical spread of the OLED-full-on life measurements, and to protect against a possible amplification factor due to how the assumptions combine with each other.

4.2 Improvements in life

Table 6 shows the improvements in accelerated lifetimes of the experimental displays over the best production displays, OLED-XL™. It also shows the improvement in accelerated lifetime achieved with the SXGA in constant current operation as compared to the SVGA. Table 7 then takes the accelerated lifetimes from Table 2 and runs it through the Usable Lifetime Model under three different example conditions. Because no trend of luminance degradation could be determined for the White ‘ExpB’ display at 50-fL, no estimate could be given, but it should last a long time, having run full-on for over 4,500 hours without crossing the 95% mark.

Table 6. Improvements made in display lifetime over OLED-XL™ through developing new devices in R&D program and running displays in constant current mode in SXGA display

Improvements in Display Lifetime Due To Devices Developed Under R&D Programs

Display Type	90% Life	75% Life	50% Life
Green Phosphorescent A over Green OLED-XL™ at 200-fL	526%	400%	362%
Amber ExpC over Mono Yellow (Amber) at 200-fL	186%	48%	32%
Full Color Mod Anode 9 over Full Color OLED-XL™ at 50-fL	65%	67%	64%
Full Color Mod Anode 9 over Full Color OLED-XL™ at 20-fL	50%	135%	181%
White ExpB over White OLED-XL™ at 200-fL	159%	134%	132%
Full Color OLED-XL™ SXGA Constant Current over SVGA	253%	221%	215%

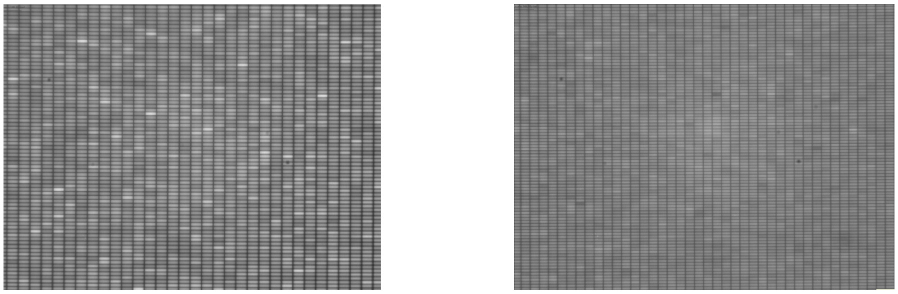
Table 7. Examples of lifetimes of displays for given applications, showing improvements in lifetime of newly developed devices or recently implemented methods. *No trend of luminance degradation could be determined for the White ‘ExpB’ display at 50-fL (See Figure 4).

Comparison of Usable Lifetimes

Color/Mono	Operation Parameters	Display	90% Life	75% Life
Color	50-fL 25% Duty, 10-fL 75% Duty; 20°C 75% Duty, 50°C 75% Duty; 50% Video Content	OLED-XL™	3,400	8,330
		'Mod Anode 9'	5,100	19,550
		SXGA Fixed Current	12,009	26,735
Mono	50-fL 25% Duty, 10-fL 75% Duty; 20°C 75% Duty, 50°C 75% Duty; 50% Video Content	OLED-XL™	8,891	17,561
		Green Phosphorescent A	16,116	35,084
		White ExpB	No Deg Meas at 50-fL*	
Mono	200-fL 25% Duty, 150-fL 75% Duty; 20°C 75% Duty, 50°C 75% Duty; 50% Video Content	OLED-XL™	2,996	7,565
		Green Phosphorescent A	8,203	20,506
		White ExpB	7,755	17,705

5. FIXED PATTERN NOISE

Aside from offering improved life, the SXGA displays also have dramatically more uniform appearance (see Figure 9). The SVGA displays have noticeable spatial noise at the sub-pixel level caused by variability of the sub-threshold slope of the pixel cell current source transistor, which is a silicon issue rather than an OLED issue. The variability is random across the display. Sub-pixels with a steeper slope are brighter and more visible than those with a shallower slope. A minority of sub-pixels outside the normal distribution creates the impression of strong spatial noise. The non-uniformity of the SXGA is related to driving circuitry and is not an OLED issue.



(a) (b)

Figure 9. Photographs from eMagin of (a) SVGA and (b) SXGA displays. The SVGA displays have a greater number of pixels/subpixels significantly outside the range of a normal distribution.

Although the standard deviation of the SVGA tends to be larger than that of the SXGA, the difference is not large enough to account for the improvement in uniformity. As a result, a different metric should be applied to demonstrate the smoother appearance of the SXGA display. Kurtosis, defined below in (1), measures the contribution of outliers to the standard deviation; in a true normal distribution, the kurtosis would be zero. The standard deviation and kurtosis of typical regions measured are shown in Table 8.

$$\left[\frac{m\cdot n\cdot(m\cdot n+1)}{(m\cdot n-1)\cdot(m\cdot n-2)\cdot(m\cdot n-3)}\cdot\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\left(\frac{M_{i,j}-\mathrm{mean}(M)}{\mathrm{Stdev}(M)}\right)^{4}\right]-\frac{3\cdot(m\cdot n-1)^{2}}{(m\cdot n-2)\cdot(m\cdot n-3)} \qquad (1)$$

Table 8. Standard deviation and kurtosis of regions of SVGA and SXGA displays. The standard deviations are comparable but the kurtosis of the SVGA is significantly higher due to the outliers.

Typical Results (In Equivalent Gray Levels)

Display	Standard Deviation	Kurtosis
SVGA	5.37	8.36
SXGA	5.08	0.549

Despite the outliers of the SVGA, a 160/128 (160th gray level bars on 128th gray level background, approximately 11% Michelson Contrast) 1X1 (33 line pairs per mm) 3 bar target could be resolved using a laboratory eyepiece. At lower spatial frequencies, such as 5X5, 132/128 3 bar targets could be resolved. The improvements of the SXGA allow a 152/128 (approximately 8.6% Michelson Contrast) 1X1 (42 line pairs per mm) 3 bar target to be resolved with the same lens. Note that only bar targets with steps of 8 were examined for this test. While the SVGA displays perform well, the spatial noise does have an impact of the low contrast resolution, but the biggest impact of the noise is the qualitative assessment of the display. The SXGA, with its voltage drive approach, has improved performance and a better overall appearance.

6. CONCLUSIONS

The research and development programs conducted by eMagin with oversight from the US Army have produced excellent results: longer lifetime display devices and a display product (SXGA) with significant improvements in performance over the existing lines. The research program for improved lifetime devices has developed displays with major improvements in all colors: white, color, green, and amber/yellow. The research is not finished as of yet, so further progress is expected over the course of the next year. After sufficient laboratory testing has proved the reliability of the new devices, they should move into production.

The previous paper[1] detailed the performance of the SXGA AMOLED displays developed under a research program managed by TATRC. Further evaluation of the SXGA showed dramatically increased lifetimes when run in the constant current mode. The SXGA also exhibits good luminance stability versus temperature, and the voltage drive approach that the SXGA implements results in significantly improved the spatial noise uniformity as compared to the SVGA.

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