Commercialization of an Ultra-Thin, Bendable, High Efficacy OLED Light Engine

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PROJECT OPPORTUNITY

1. Efficacy gap with LED. Best bendable OLED panels only 63 lm/W.
2. Too few lumens per panel and too high $/klm compared to LED.
3. Limited options for form factors and sizes compared to LED.
4. Driver costs too high compared to LED.
5. OLED too complicated for creative small companies.

PROJECT OBJECTIVES

1. Increase bendable OLED lighting panel efficacy to >90 lm/W and lifetime to >100,000 hr.
2. Decrease $/klm by increasing yield for > 150 cm2 OLED lighting panels.
3. Develop a one-time bendable ultra-thin OLED panel frame sub-assembly.
4. Develop one or more low cost drivers for controlling one or more OLED lighting panels.
5. Combine above technologies to develop a commercially viable ultra-thin, bendable, high efficacy OLED light engine.

APPROACH

1. Evaluate printable, bendable Internal Light Extraction Layer (ILEL) combined with bendable Willow™ glass, patterned ITO and patterned isolation layer.
2. Test new phosphorescent blue emitters and hosts in an all phosphorescent white OLED formulation.
3. Test new methods for preventing or reducing the frequency of "Hot Spots" (see Penn State DOE project).
4. Design and test metal and/or plastic sub-assemblies
5. Test linear constant current drivers instead of switching constant current drivers for lower cost.
6. Combine optimal results from above approaches to create ultra-thin, bendable, high efficacy OLED light engine.

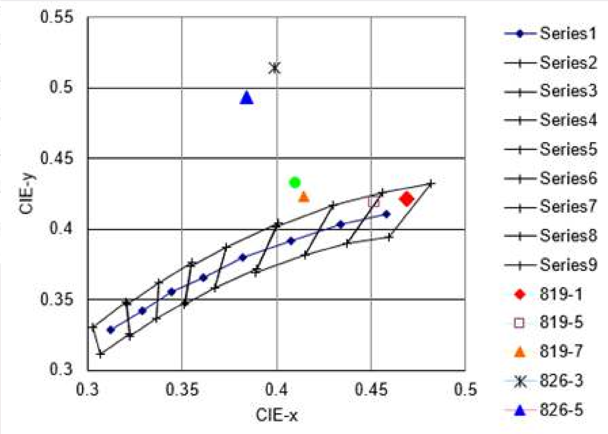
CURRENT RESULTS

2 Stack Phosphorescent White Development

1. Difficult to meet color point target (Duv target between -0.004 to -0.001 and CCT target 3000K).
2. For most devices, voltage is too high for high efficacy.
3. Lifetime at 3000 cd/m² too low due to poor phosphorescent blue lifetime.
4. All phosphorescent OLED not currently viable for commercial products. Need improved phosphorescent blue

Device	V	cd/A	lm/W	CIE x	CIE y	Peak, nm	EQE,%	cd/m2	CCT,K	Duv	CRI_Ra	LT70, hrs*
819-1	6.8	166.2	77.3	0.4685	0.4213	614	85.2	2975	2665	0.0032	79	6000
819-5	7.1	118.8	52.5	0.4521	0.4185	615	63.9	2993	2875	0.0037	75	2000
819-7	10.5	161.3	48.5	0.4146	0.4232	616	86.1	2985	3548	0.0116	68	2000
826-3	6.5	250.3	120.3	0.3989	0.514	546	84.1	2979	4264	0.0479	53	7000
826-5	9.8	296.5	94.8	0.3842	0.4937	546	109	2995	4456	0.0452	61	5252
826-10	10.2	233.8	72.1	0.4105	0.4325	614	115	2992	3684	0.0162	76	2590

All data at 3000 cd/m², including LT70



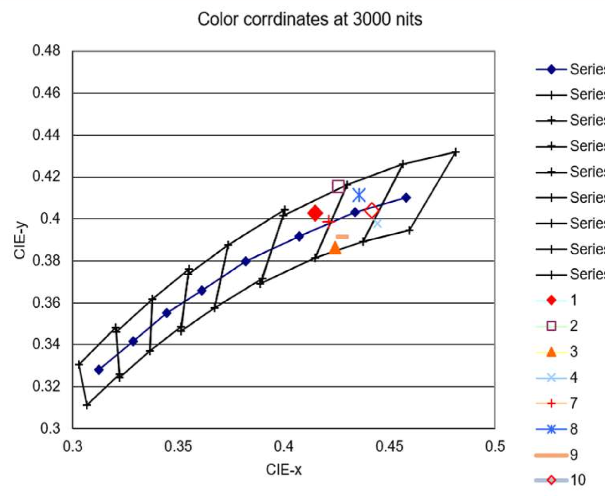
3 Stack Hybrid (Fluorescent Blue/Phosphorescent Red & Green) White Development

1. Very close to target efficacy (90 lm/W) with good CCT and Duv.
2. Some trade-offs between efficacy, CRI and lifetime.
3. Further optimization and lifetime improvement is needed, but very close to meeting objective.
4. Hybrid OLED known to be viable for commercial products.

OLED	V	cd/A	lm/W	CIE x	CIE y	EQE,%	CCT	Duv	CRI	LT70, hrs *	LT70, hrs**
1	9.1	254.4	88.2	0.4147	0.4029	113	3402	0.0033	83	632	30,000
2	9.3	252.8	85.8	0.4257	0.4156	111	3289	0.0064	83	145	
3	9.4	230.9	77.4	0.4241	0.3865	113	3083	-0.0054	92	545	21,000
4	8.4	232.2	87.0	0.4442	0.398	115	2832	-0.0033	93	230	
7	8.9	252.0	88.5	0.4214	0.3988	112	3240	0.0003	84	576	25,000
8	9.1	250.8	86.8	0.4357	0.4114	111	3081	0.0031	84	105	
9	8.9	241.2	85.2	0.4276	0.3915	112	3062	-0.0038	88	630	25,200
10	8.8	242.7	86.5	0.4416	0.4038	111	2922	-0.0007	87	535	

*at 10 mA/cm2 ** at 3000 cd/m2

All data at 3000 cd/m², except 10mA/cm² LT70 column



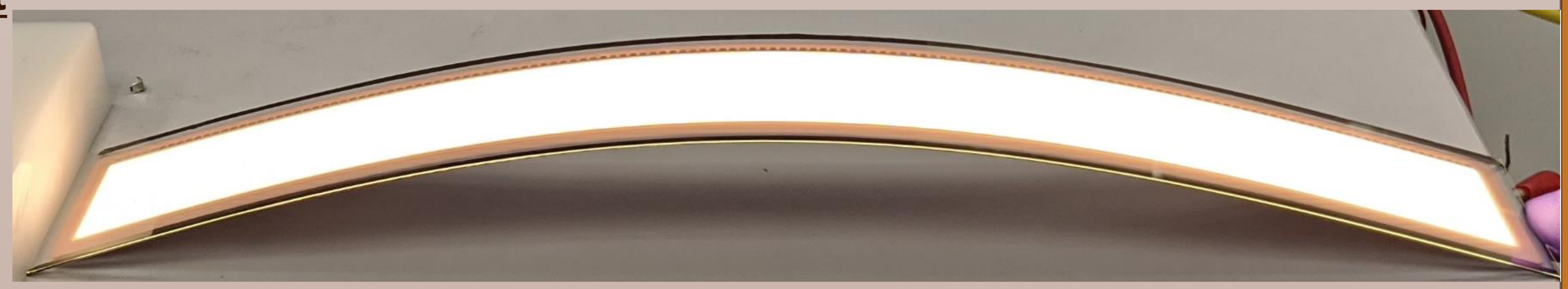
Internal Light Extraction Development

1. Tested two bendable IEL types (found baking conditions to remove water before OLED coating).
2. Performance at 3000 cd/m² gave 2.3-2.4x light extraction.
3. Up to 2.5x light extraction has been demonstrated in a separate project.
4. Gen2 and Gen2.5 substrates coated and tested in Rochester and Aachen production facilities.

	No External Light Extraction							With External Light Extraction						
IEL Type	Voltage	cd/amp	Lm/watt	CIE x	CIE y	EQE	Voltage	cd/amp	Lm/watt	CIE x	CIE y	EQE
A	8.6	225	82.0	0.430	0.420	99.2	8.6	221	80.7	0.431	0.421	97.8
B	8.8	187	66.9	0.428	0.398	86.4	8.6	230	83.7	0.424	0.410	103
None	8.7	73.5	26.4	0.447	0.335	44.4	8.7	156	56.3	0.428	0.38	75

Large Panel Development

1. 376mm x 80mm panel
2. Hot spot reduction process developed and demonstrated to increase yield of large panels.



One-time Bendable Sub-assembly Development

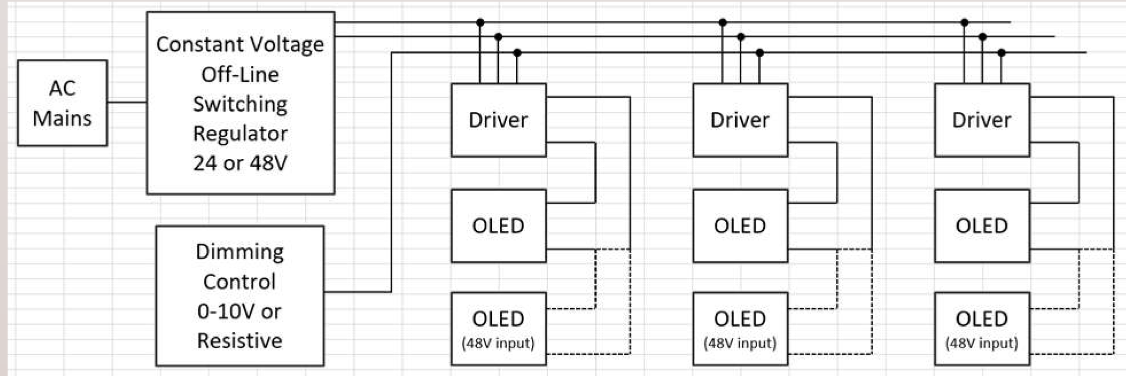
1. A hybrid polymer/Aluminum sub-assembly has been developed.

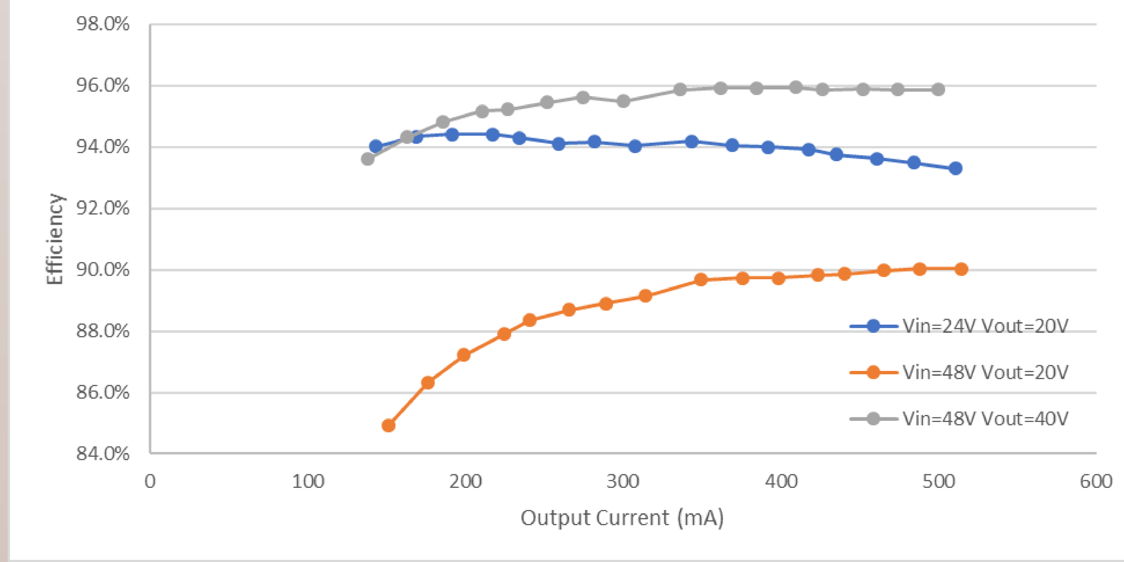
Lower Cost Driver Development

Re-evaluated driver concept. Returned to traditional architecture.

Features Include:

1. Small size - 67 x 7.7mm. Long / thin shape allows the driver to be covered in shrink tubing and incorporated into the wiring harness.
2. Selectable outputs - End user can set output current from 140 to 520mA.
3. Insulation displacement input connector makes wiring multiple drivers together quick and easy.
4. 24 or 48 volt input. 48 volt input allows two OLEDs to be driven from a single driver, reducing system cost.
5. Flexibility - OLEDs of various sizes and types can be used in a single fixture.
6. High Efficiency - DC to DC efficiency of >95%.
7. Low cost - Expectations of < $6 per driver (<$3 per OLED when driven from 48V)





SUMMARY

1. Development of high brightness panel is focused on hybrid white OLED formulation and bendable internal light extraction.
2. Close to target efficacy (90 lm/W) with good CCT and Duv.
3. Further OLED formulation optimization and lifetime improvement is needed.
4. Bendable IEL has been demonstrated including baking conditions to remove water before OLED coating.
5. Hot spot reduction process demonstrated to increase yield of large panels (376mm x 80mm).
6. A hybrid polymer/Aluminum sub-assembly has been developed. Electrical contacting method still in development.
7. Lower cost, small form factor driver has been developed and prototyped.
8. Combining all sub-tasks into ultra-thin, bendable, high-efficacy OLED light engine is primary remaining task.