

C | D | T

**Fundamental Issues with IJP P-OLED  
Devices: Identification and Corrective  
Actions**

*SID Los Angeles May 20<sup>th</sup> 2011*

*Mark Crankshaw, Daniel Forsythe, Ilaria Grizzi, Gary Williams*

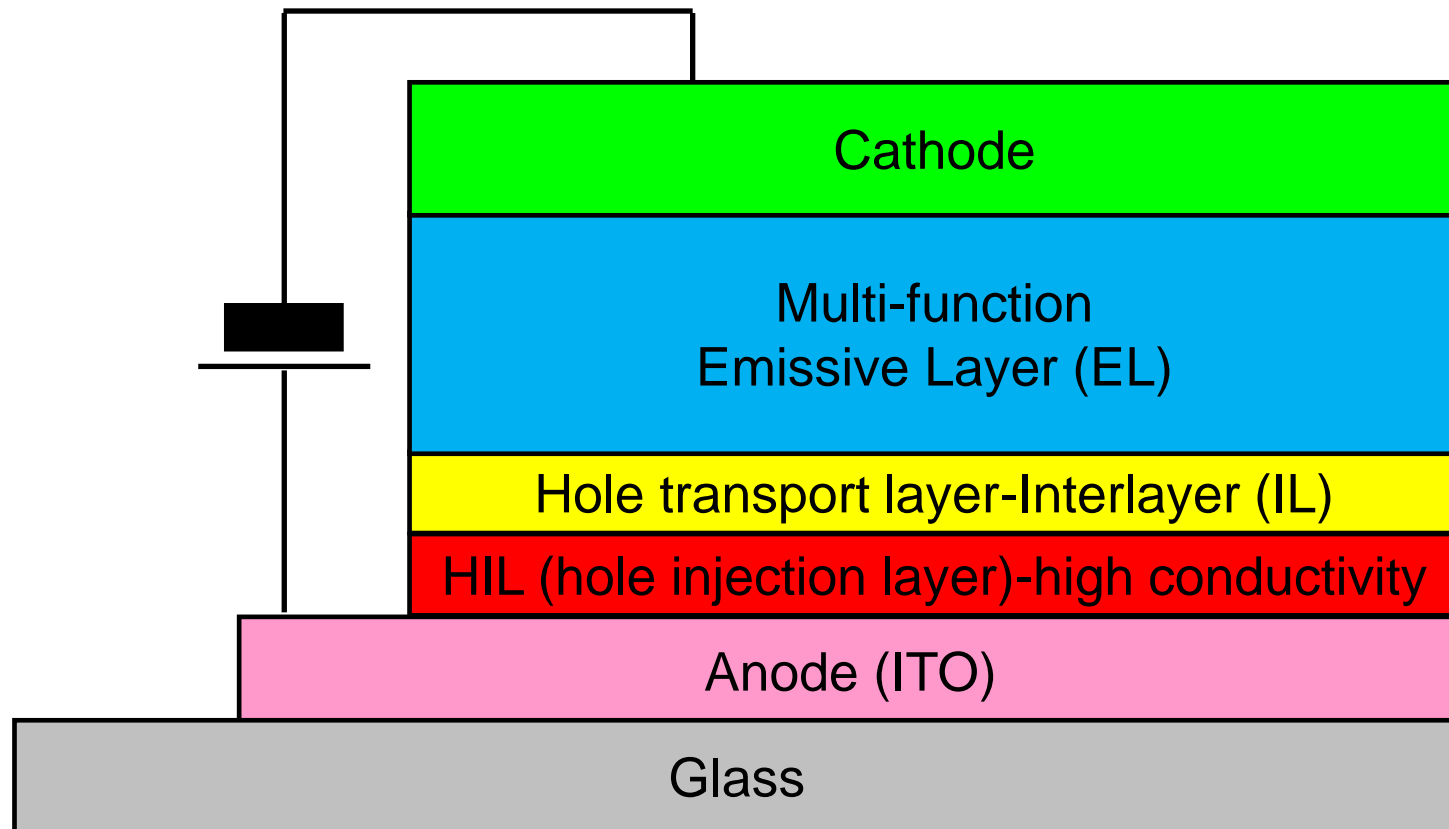
How to achieve Ink Jet Printed (IJP) devices with comparable performance to Spin Coated (SC) ones?

1. Ensure current paths are all contributing to emission
  2. Ensure no detrimental contamination
- We will show that by changing the bank design and fabrication process parity between ink jet printing and spin coating can be achieved

# P-OLED Device Structure

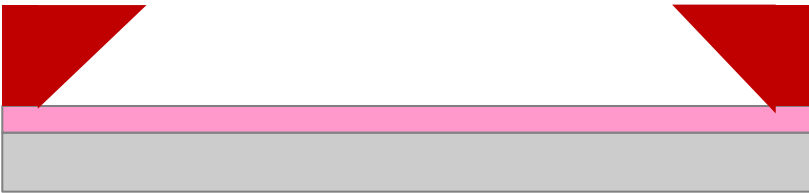
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Spin Coated and Ink Jet Printed (IJP)



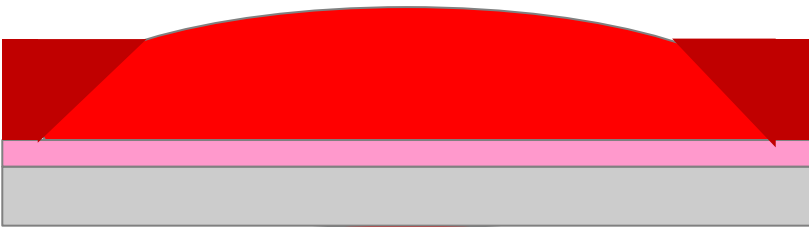
# Alternative Leakage Pathways

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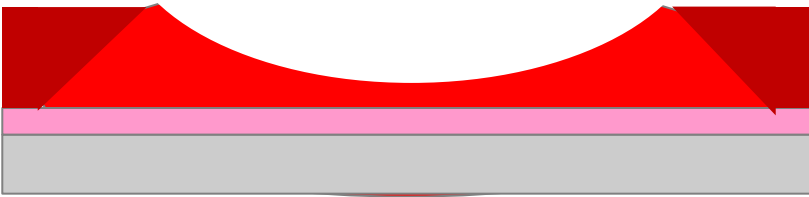
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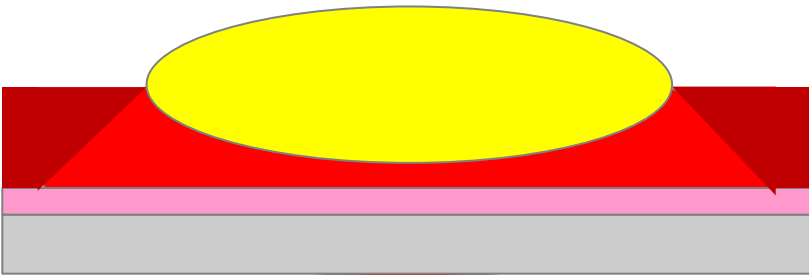
# Alternative Leakage Pathways

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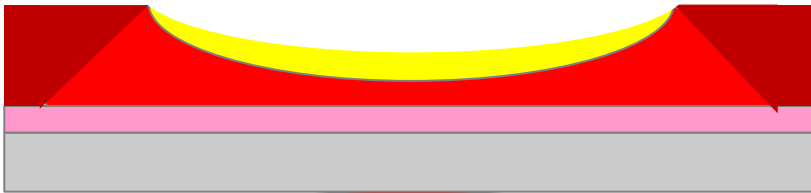
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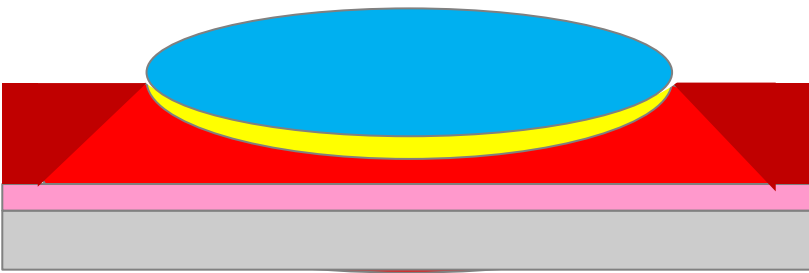
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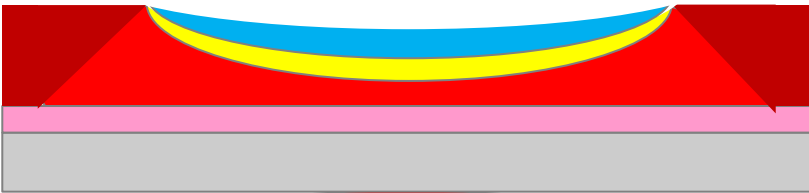
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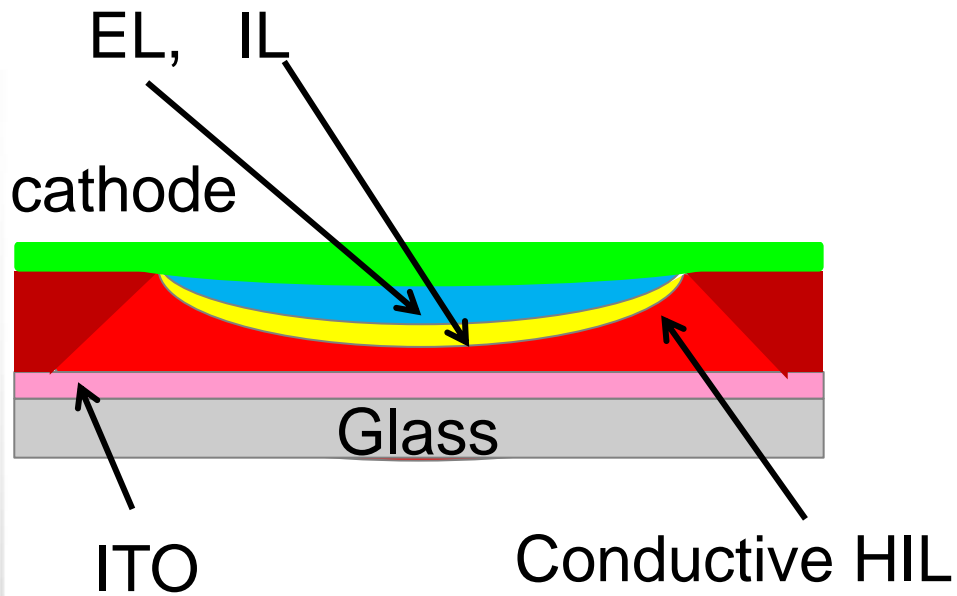
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# Alternative Leakage Pathways

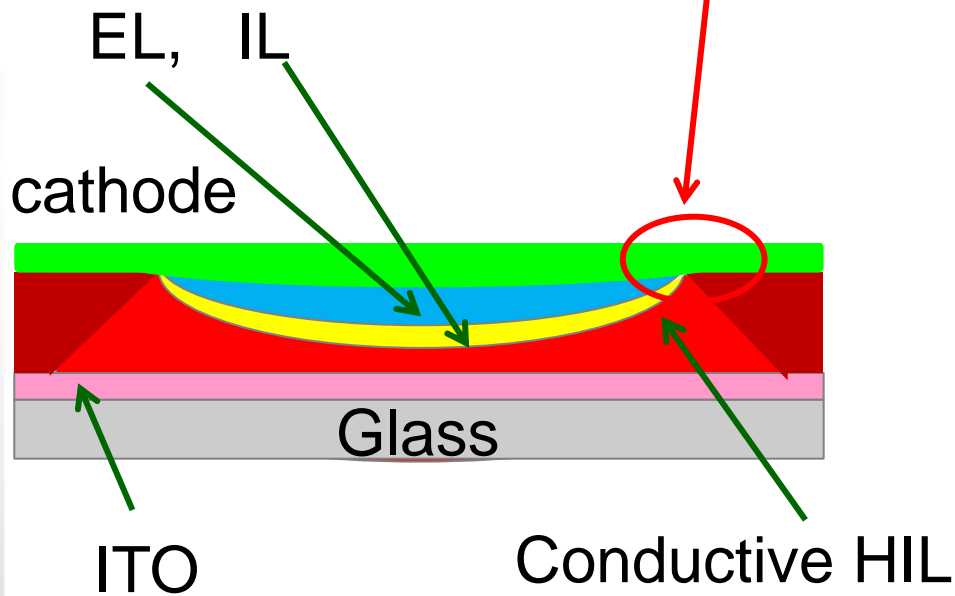
C|D|T



# Alternative Leakage Pathways

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Opportunity for alternative current paths with thin IL/LEP separating HIL and cathode



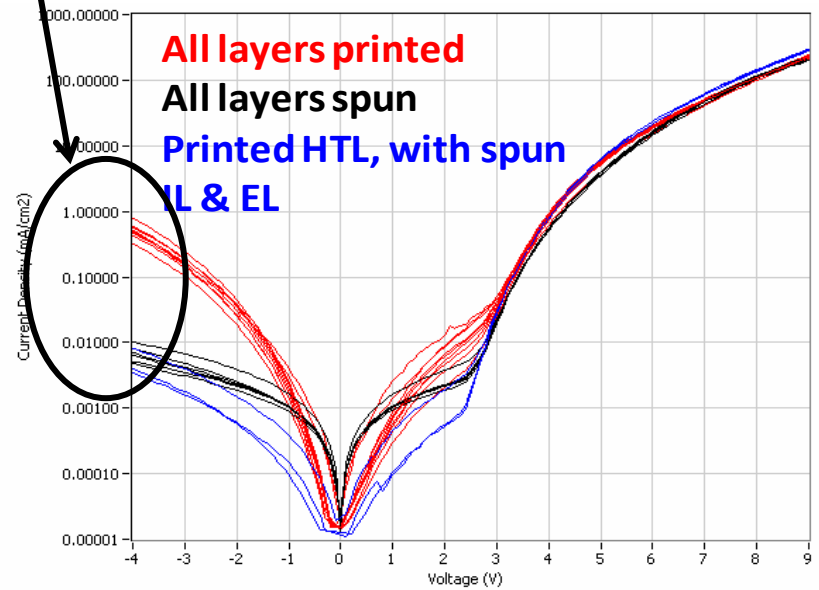
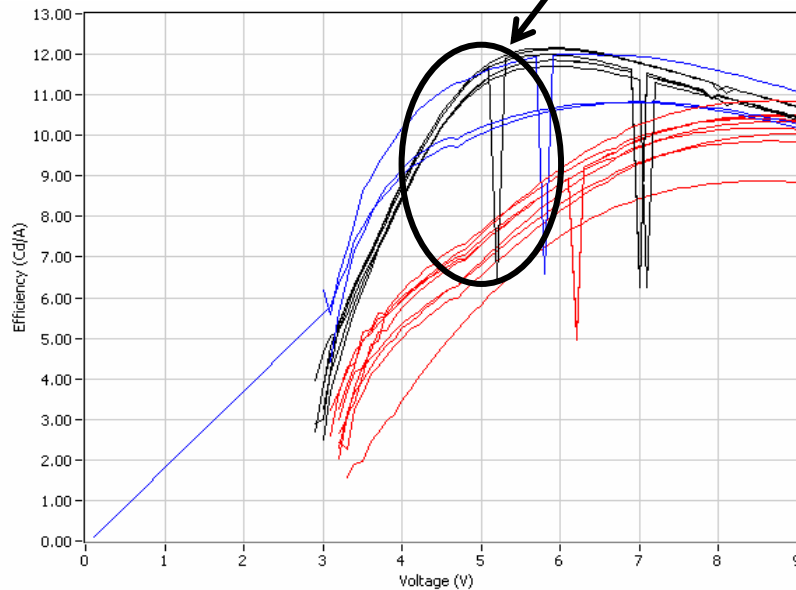
# Alternative Leakage Pathways

C|D|T

Opportunity for alternative current paths with thin IL/LEP separating HIL and cathode

Impact on device characteristics:

Significant leakage current and poor efficiency at low luminance when a thin layer on IL/LEP covers HIL on pixel edges (red curve)



# New Bank Architecture

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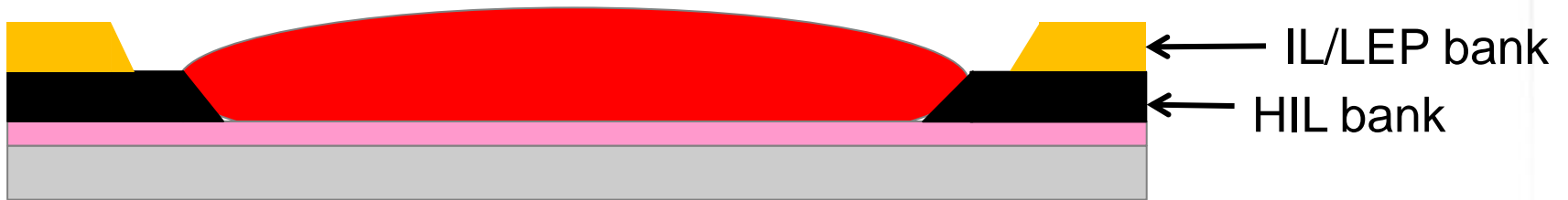
Eliminate Alternative current paths



# New Bank Architecture

C | D | T

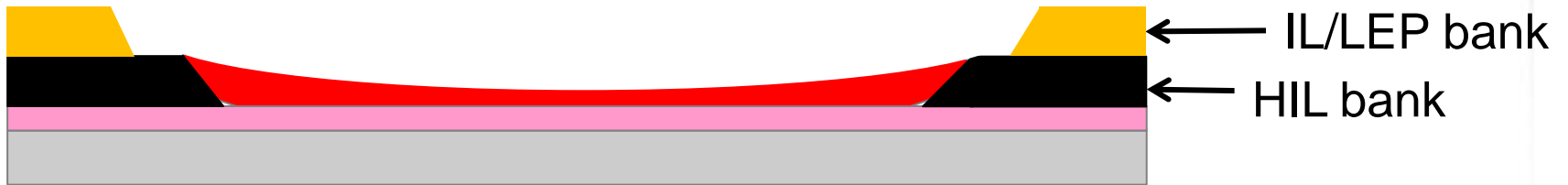
Eliminate Alternative current paths



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C | D | T

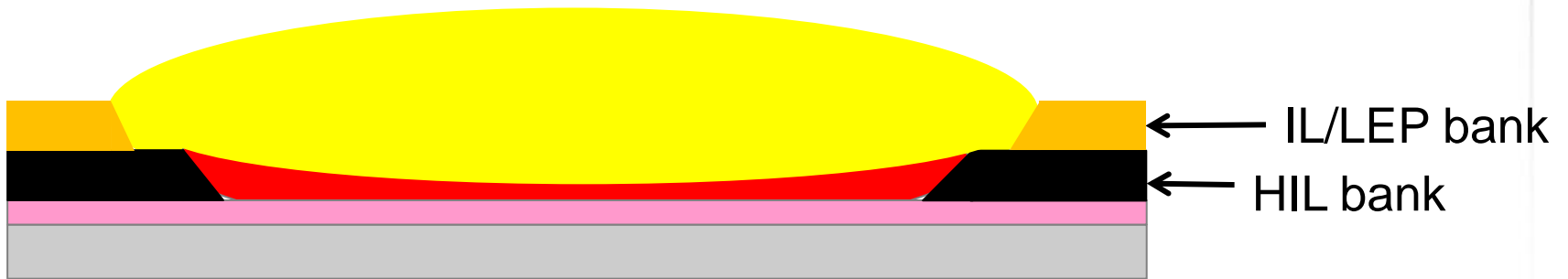
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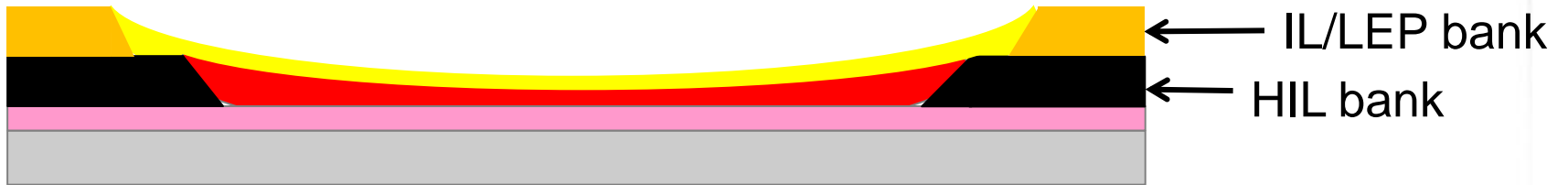
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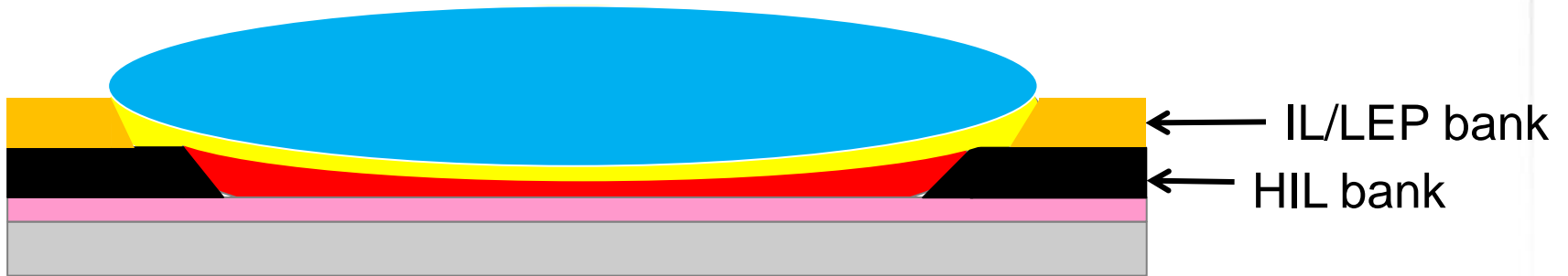
Eliminate Alternative current paths



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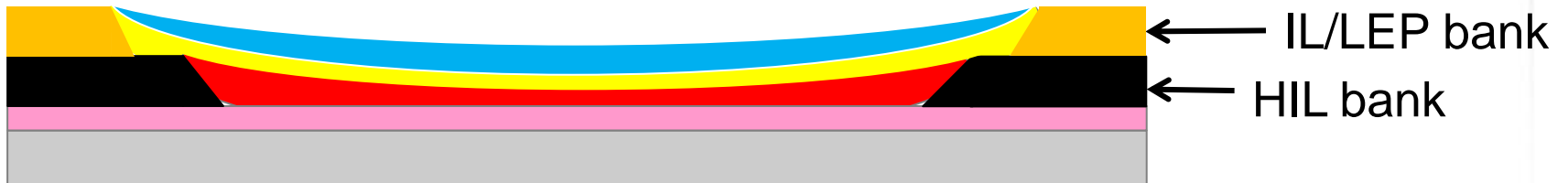
Eliminate Alternative current paths



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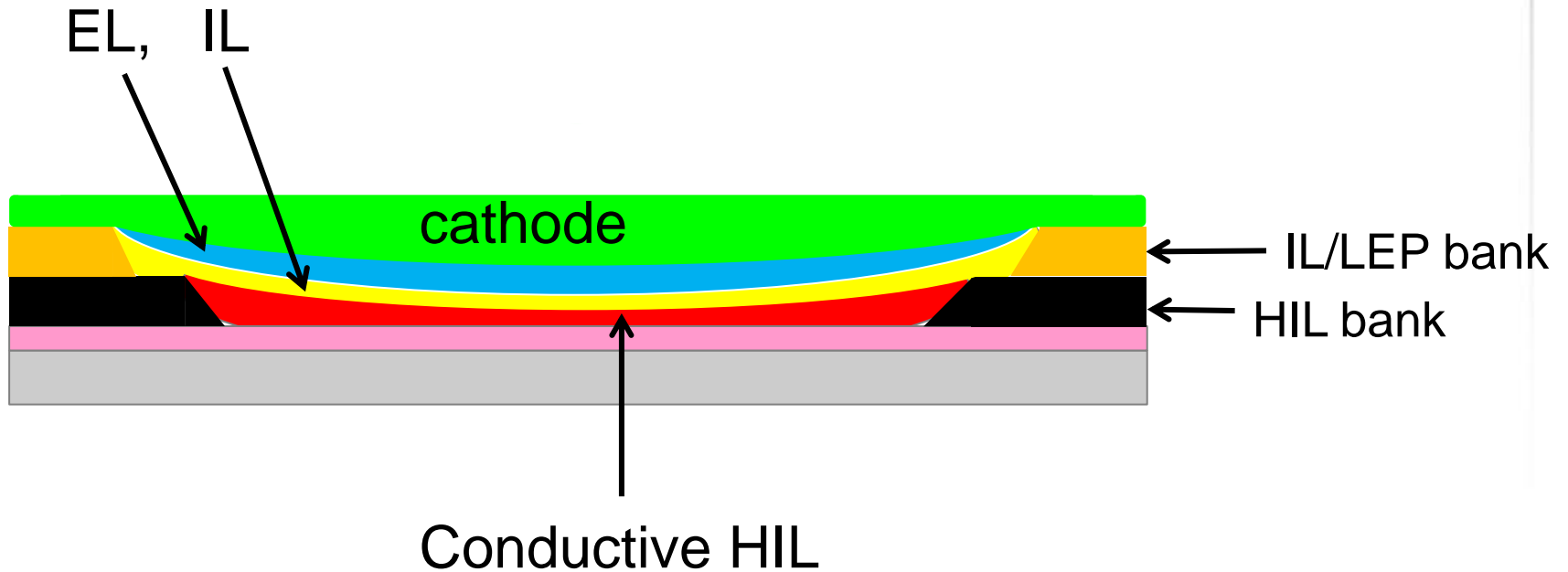
Eliminate Alternative current paths



# New Bank Architecture

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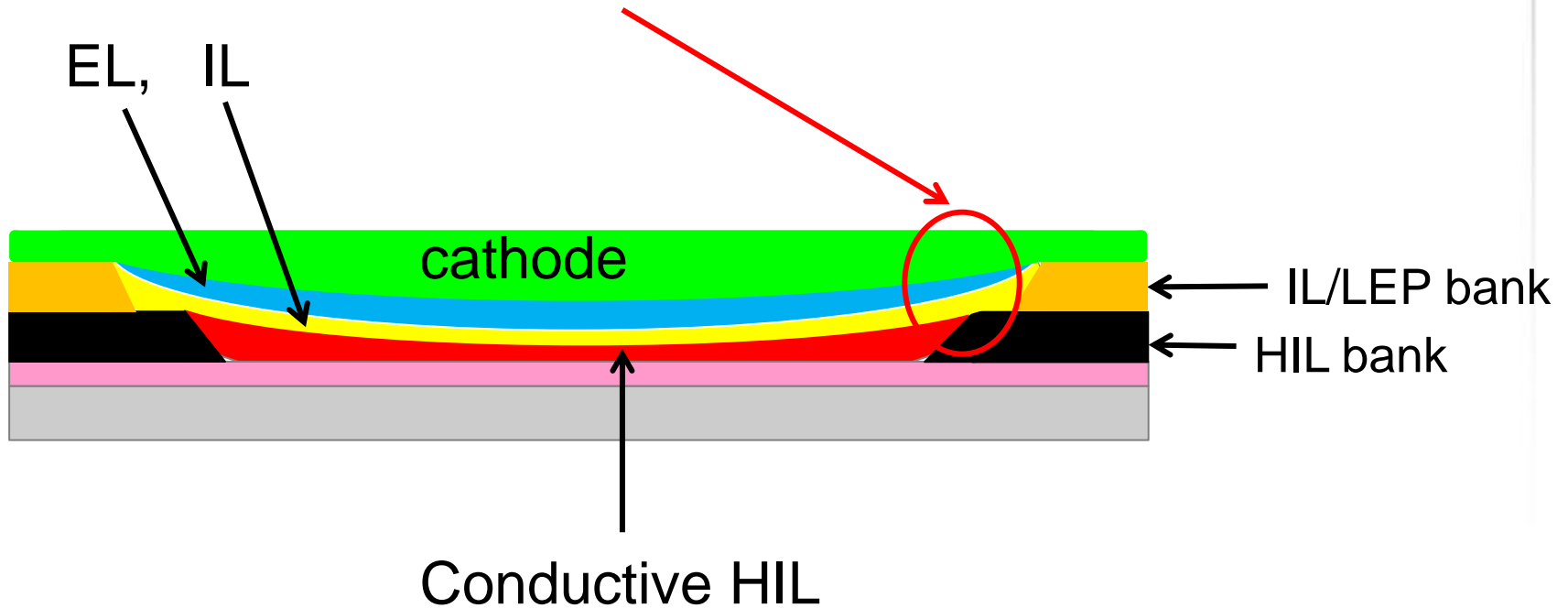
Eliminate Alternative current paths



# New Bank Architecture

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Eliminate Alternative current paths: Achieved by ensuring thick iL and LEP over the HIL

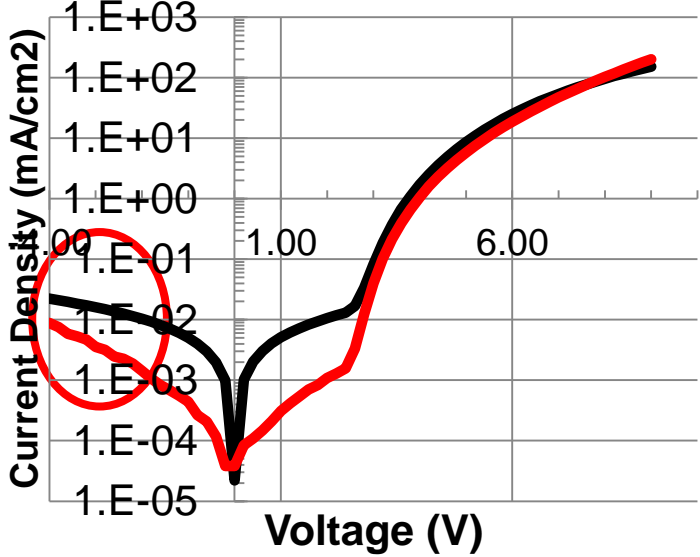
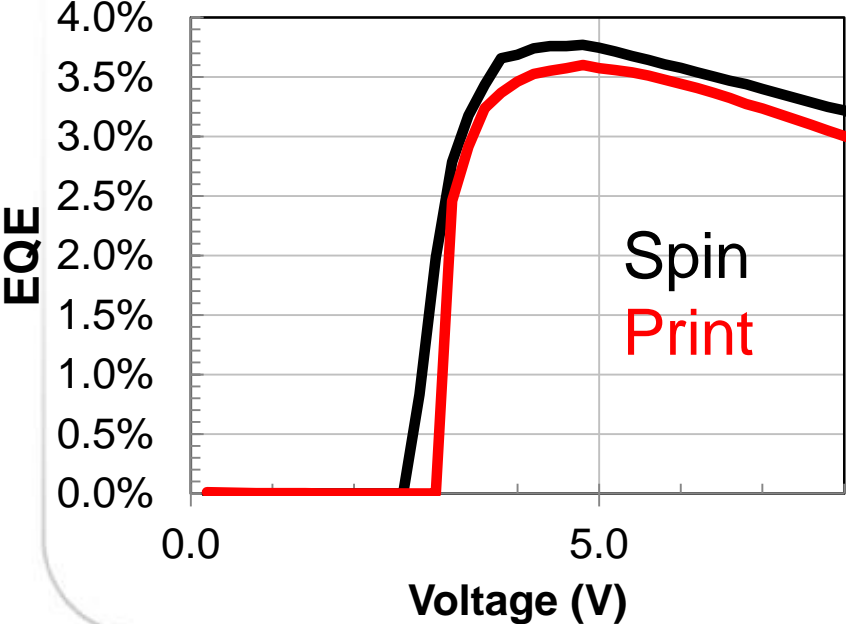


# New Bank Architecture

Eliminate Alternative current paths: long leakage path between cathode and HIL

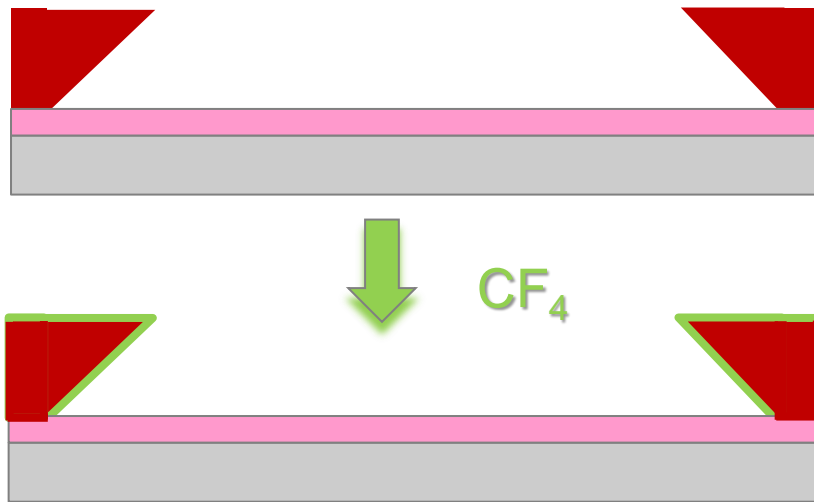
Impact on device characteristics:

Very low leakage current in printed devices and parity in efficiency between spin coated and IJP devices



# Contamination:

Identify sources of detrimental contamination



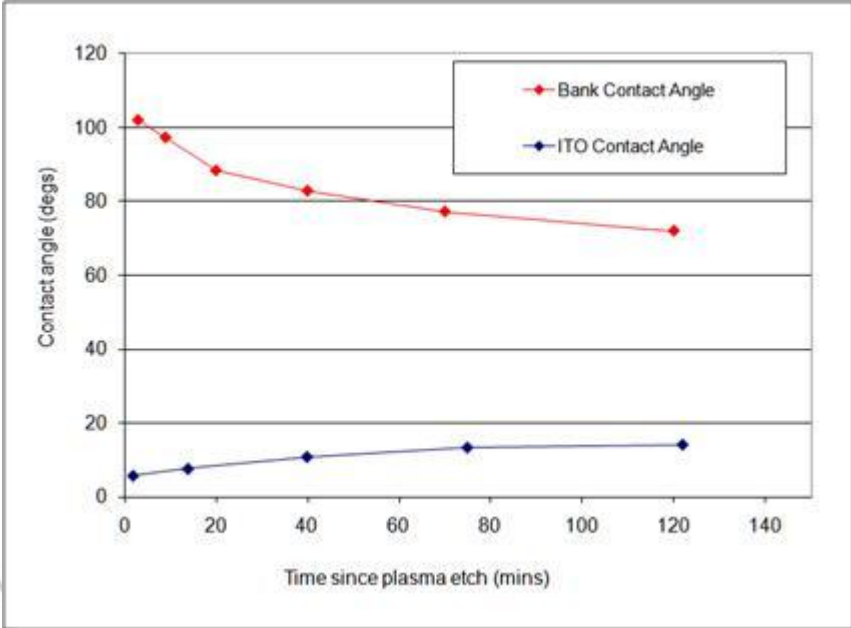
Bank is not “intrinsically” hydrophobic  
A surface treatment (typically CF<sub>4</sub> plasma) is required to increase surface tension between HIL and bank so that the fluid is contained

**BUT**  
CF<sub>4</sub> Impacts Lifetime

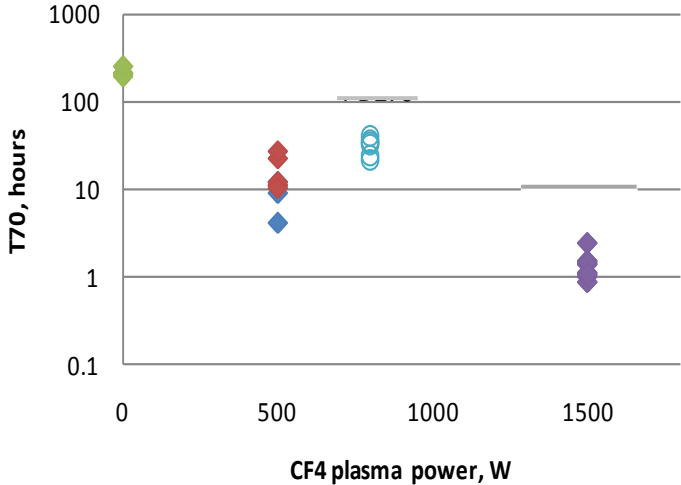
# Contamination:

Key Learning:  $CF_4$  Surface Treatment Negatively Impacts Lifetime

Contact Angle Post Plasma



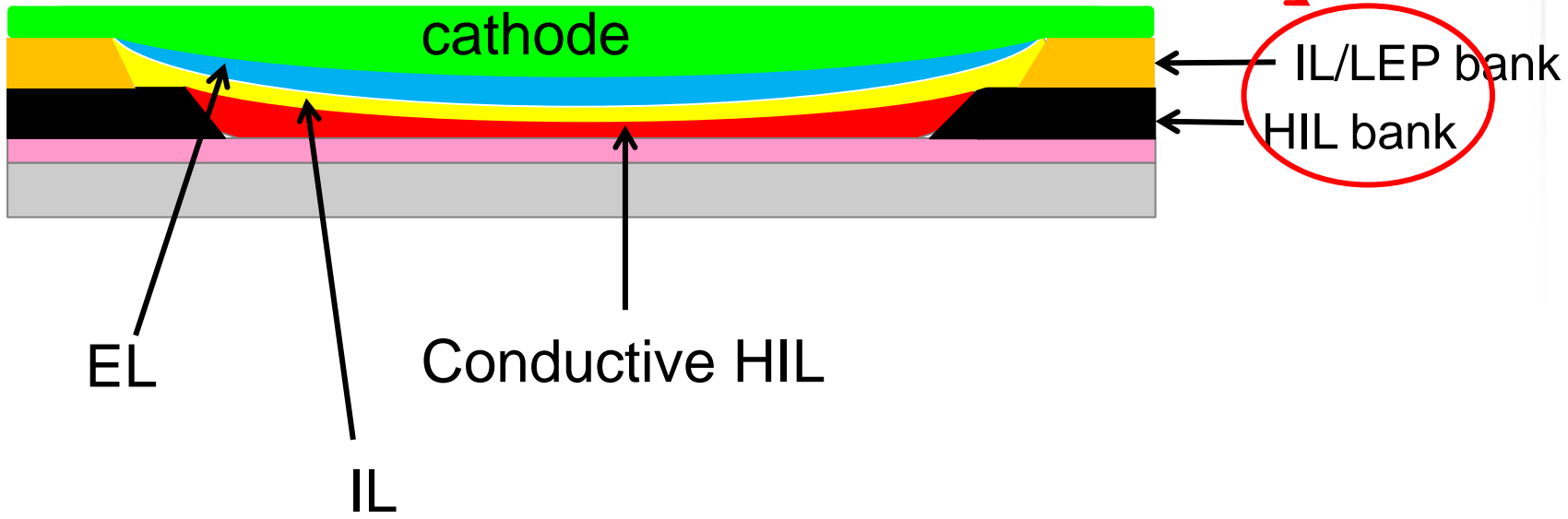
Lifetime versus  $CF_4$  Plasma Power



$CF_4$  is also a process issue as contact angle changes with time post plasma exposure

# Contamination-free bank

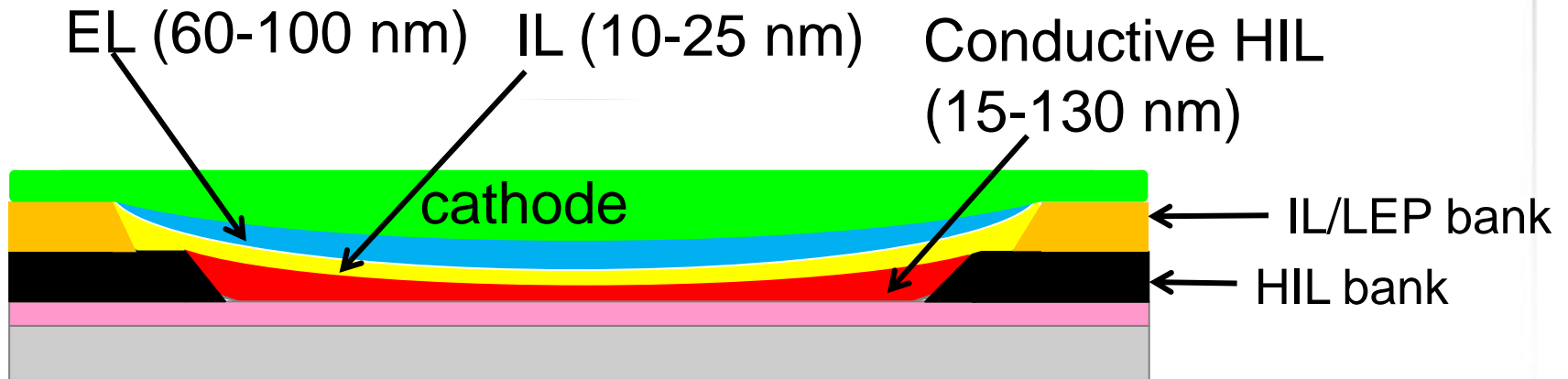
Eliminate HIL, iL and LEP contamination  
IL/LEP bank is intrinsically hydrophobic and lipophobic  
HIL Bank is Hydrophobic and Lipophylic



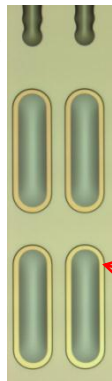
# Contamination-free structure

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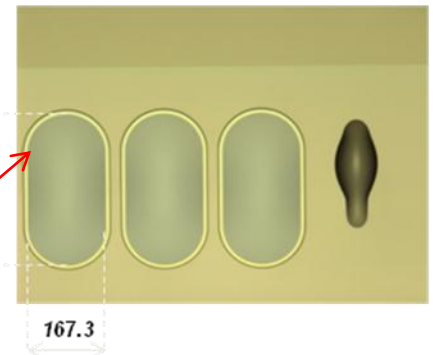
New Bank structure eliminate HIL, IL and LEP contamination, is compatible with a range of layer thicknesses and pixel sizes



CDT Standard pixels  
198 $\mu$ m x 50 $\mu$ m



Larger pixels  
335 $\mu$ m x 167 $\mu$ m



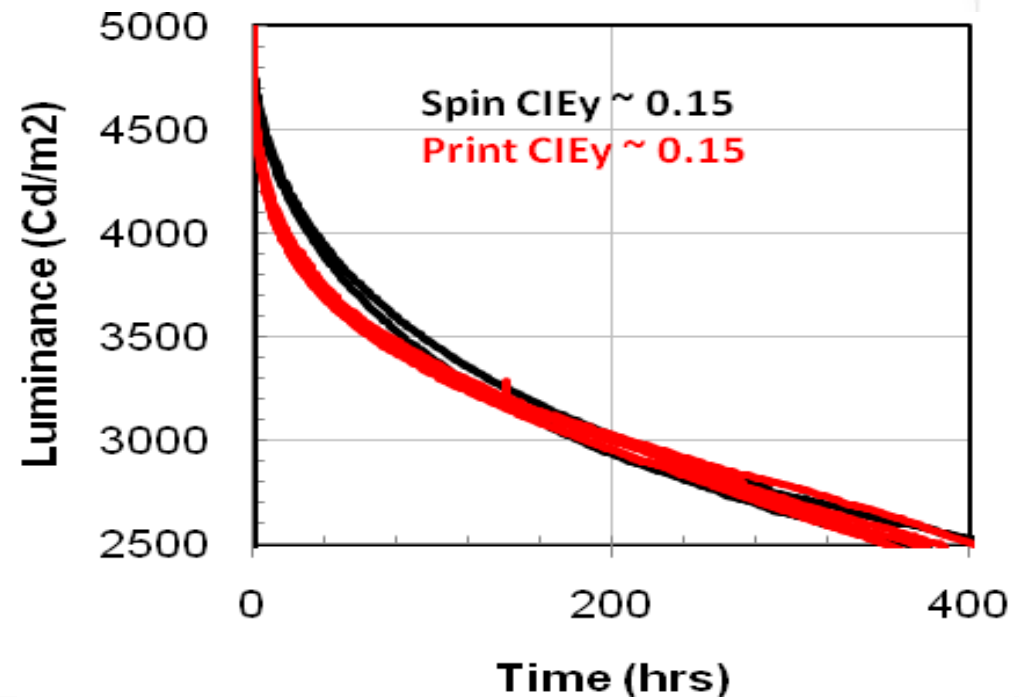
**Good HIL wetting and containment on inner bank independent of geometry**

# Parity between IJP and SC lifetime

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Eliminated 1) leakage paths 2)  $CF_4$  contamination from bank.  
**Degradation of IJP devices equivalent to Spin Coated devices (no significant additional mechanism introduced by process- Air exposure, solvent- or film morphology).**

**10,000 blue material.  
Statistically equivalent  
lifetime in IJP and Spin  
coated devices**



# IJP Efficiencies and Lifetime vs SC:

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	CIEx,y	V@1000 cd/m2	Efficiency cd/A @1000 cd/m2	LT50@1000 cd/m2
Red	0.65-0.35	~6.4 V	16	~150,000
Red	0.65-0.35	~7 V	16	>100,000* hrs
Blue	0.14-0.15	~5.3V	4.3	~10,000 hrs
Blue	0.14-0.15	~5.5V	4	~10,000 hrs

\*Life test not completed

\*\* Green under development

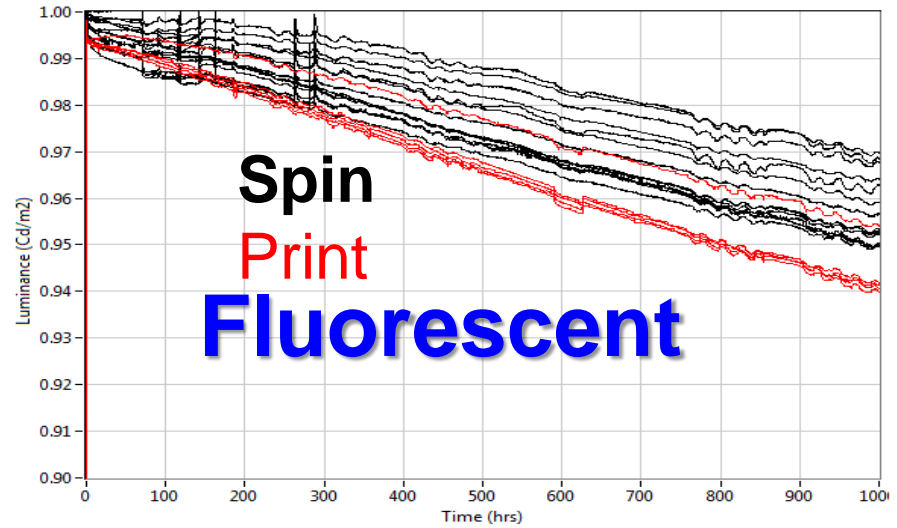
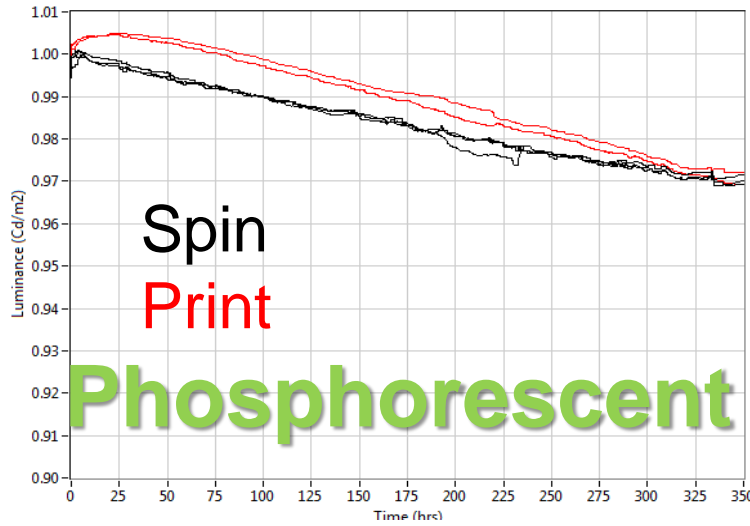
Note: Older generation scaled-up materials used for this investigation and not optimised device structures

# Image sticking in IJP devices

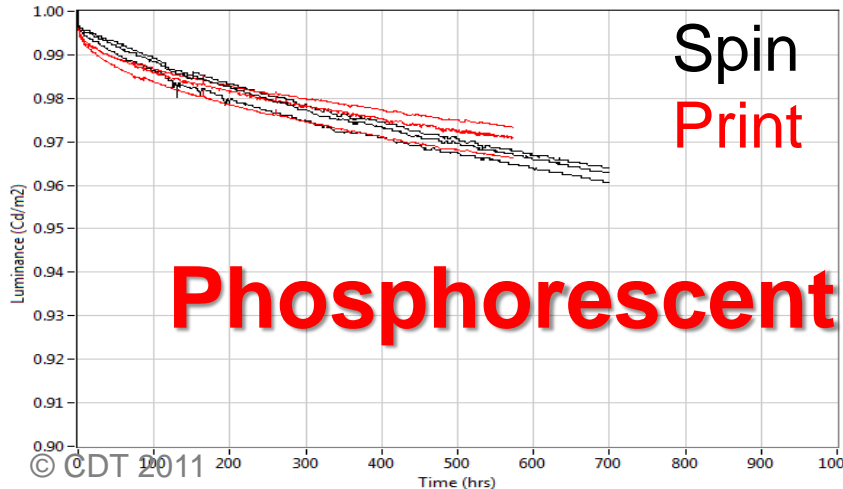
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Image sticking is another important metric for display applications

Luminance vs Time Plot (RT9678-IJT885, Print, 18591-10-18-3 Pix 2)



Luminance vs Time Plot (RT8526-COMET239, Spin, 15915-06-21-1 Pix 4)



Initial degradation in printed devices equivalent with spin coated devices for both Phosphorescent and Fluorescent materials

# Conclusion

To achieve good performance from IJP devices:

- Avoid current leakage pathways that reduce power efficiency
- Avoid contamination from processes and surface treatments

**When this is done: Parity is Achieved**

Below is latest public domain research material performances

Spin/BE data @1000cd/m2	Red			Green		Blue			
Efficiency [cd/A]	11	16	31	28	54	9.0	5.2	6.3	9.2
Colour (C.I.E.)	x=0.67 y=0.32	x=0.65 y=0.35	x=0.63 y=0.37	x=0.35 y=0.60	x=0.31 y=0.63	x=0.14 y=0.22	x=0.15 y=0.13	x=0.15 y=0.12	x=0.14 y=0.14
Lifetime [hrs]	200k	170k	350k	200k	190k	34k	21k	14k	15k
Vd [V]	6.0	5.2	5.7	4.4	5.6	5.0	4.8	4.8	4.5

- CDT technical Team
- SCC TRL technical team
- Extra special thanks to Plextronics for HIL ink
- You all