Challenges for OLED Deposition by Vacuum Thermal Evaporation

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Veeco

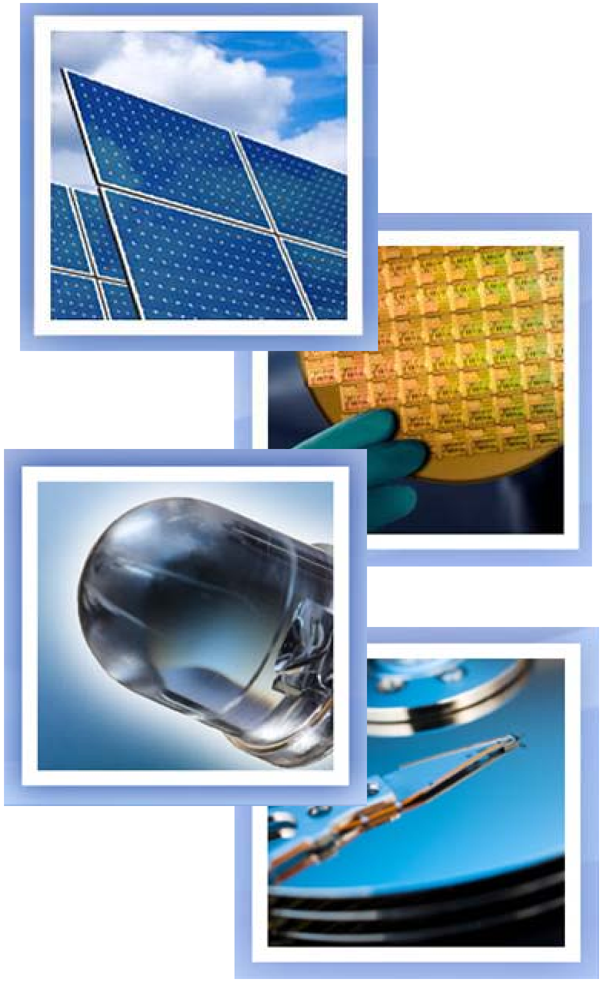
Innovation. Performance. Brilliant.

Outline

- Introduction to Veeco
- Methods of OLED Deposition
- Cost Challenges to OLED Technology
- Veeco's Source Technology
- Summary & Discussion

Veeco Overview

- Products and markets
  - LED & Solar BU
    - MOCVD, MBE, CIGS systems
    - OLED, CIGS sources
  - Data Storage BU
    - IBE, IBD, DLC, PVD
- Key facts:
  - Founded in 1990
  - Over 300 patents
  - Over 1000 employees worldwide
  - Over 25 global locations
  - 2010 Revenue >$900M



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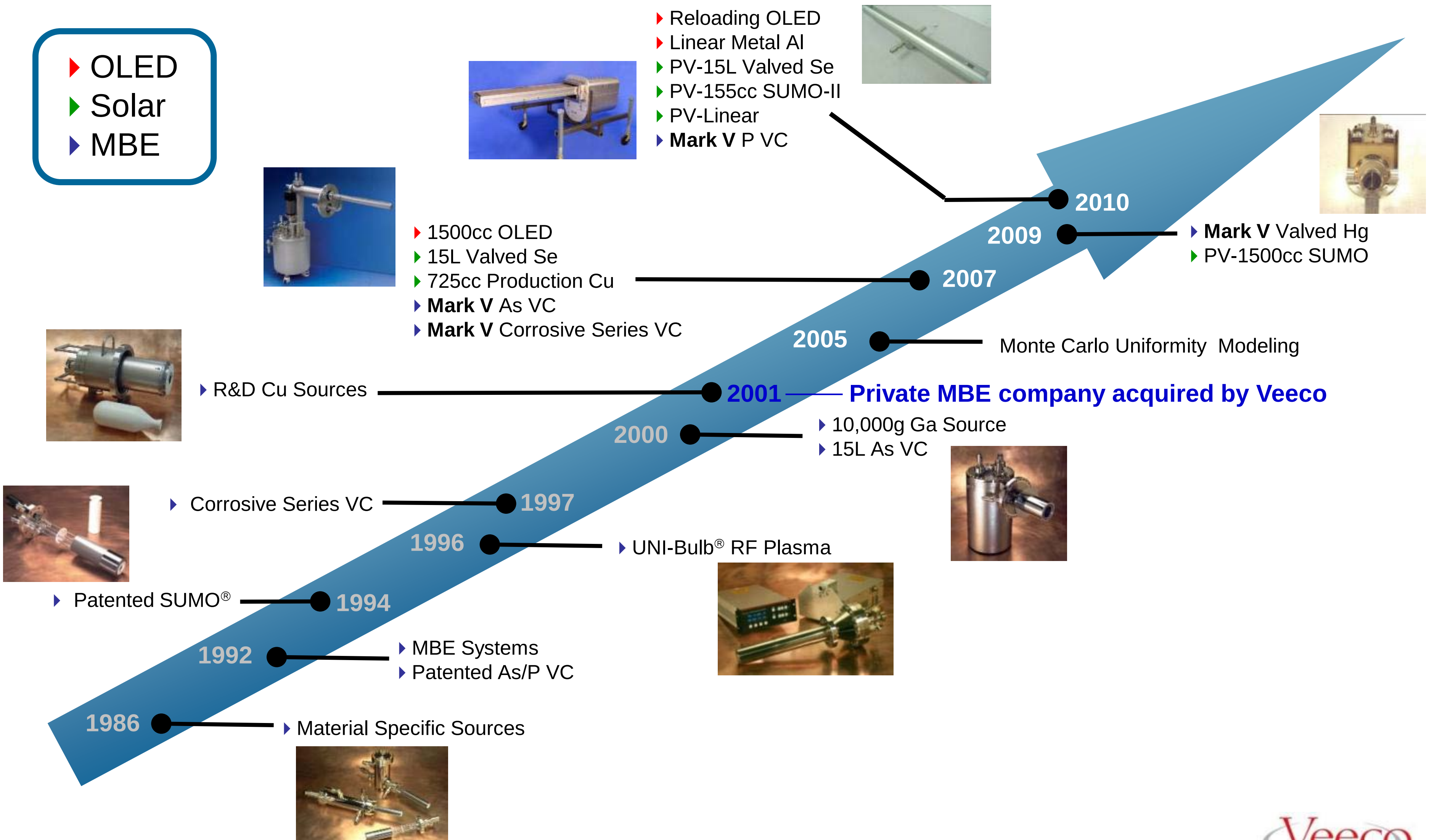
Veeco St Paul: >20 Years of Thermal Deposition Source Innovation



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OLED Deposition Technologies

Method	Advantages	Disadvantages
Thermal Evaporation	Device Performance & Lifetime Complex layer stacks	Materials Utilization Material Degradation Substrate Heating
Solution Processing	Processing Cost Materials Utilization	Device Performance Solvent Management Orthogonal Solvent Compatibility
Vapor Phase Deposition	Morphology Control Large Area Potential	Device Performance and Lifetime Material Degradation

There are a variety of variations and hybrids of these basic technologies

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Why VTE

Advantages

- Best demonstrated efficiencies
- Best demonstrated lifetimes
- Compatible with almost all materials
  - Not necessarily scalable
- Accurate film control for co-depositions and multilayered structure

Challenges

- Materials Utilization
  - Tradeoff with uniformity
- Material Degradation
  - Thermal budget
- Substrate Heating
- Rate control
  - Especially for long term operation

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OLED Markets and Process Requirements

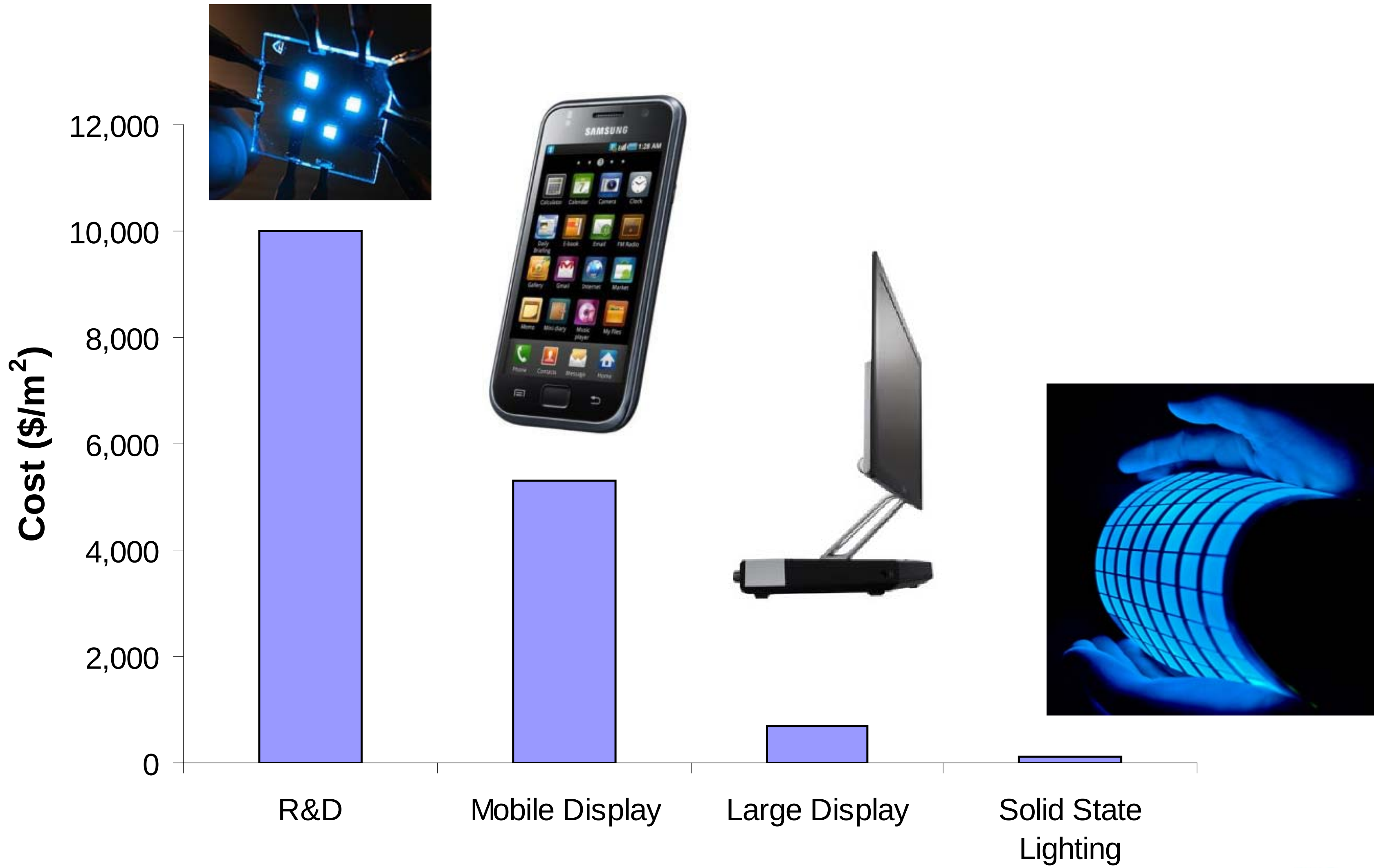
Market Requirements

Scale	Market Size ($)	Area (m^2)	Cost ($/$m^2$)
R&D	Millions	0.04	10k
Mobile Display	100s Millions	0.7	5.3k
Large Display	Billions	2.0	700
SSL	Billions	0.7+	<100

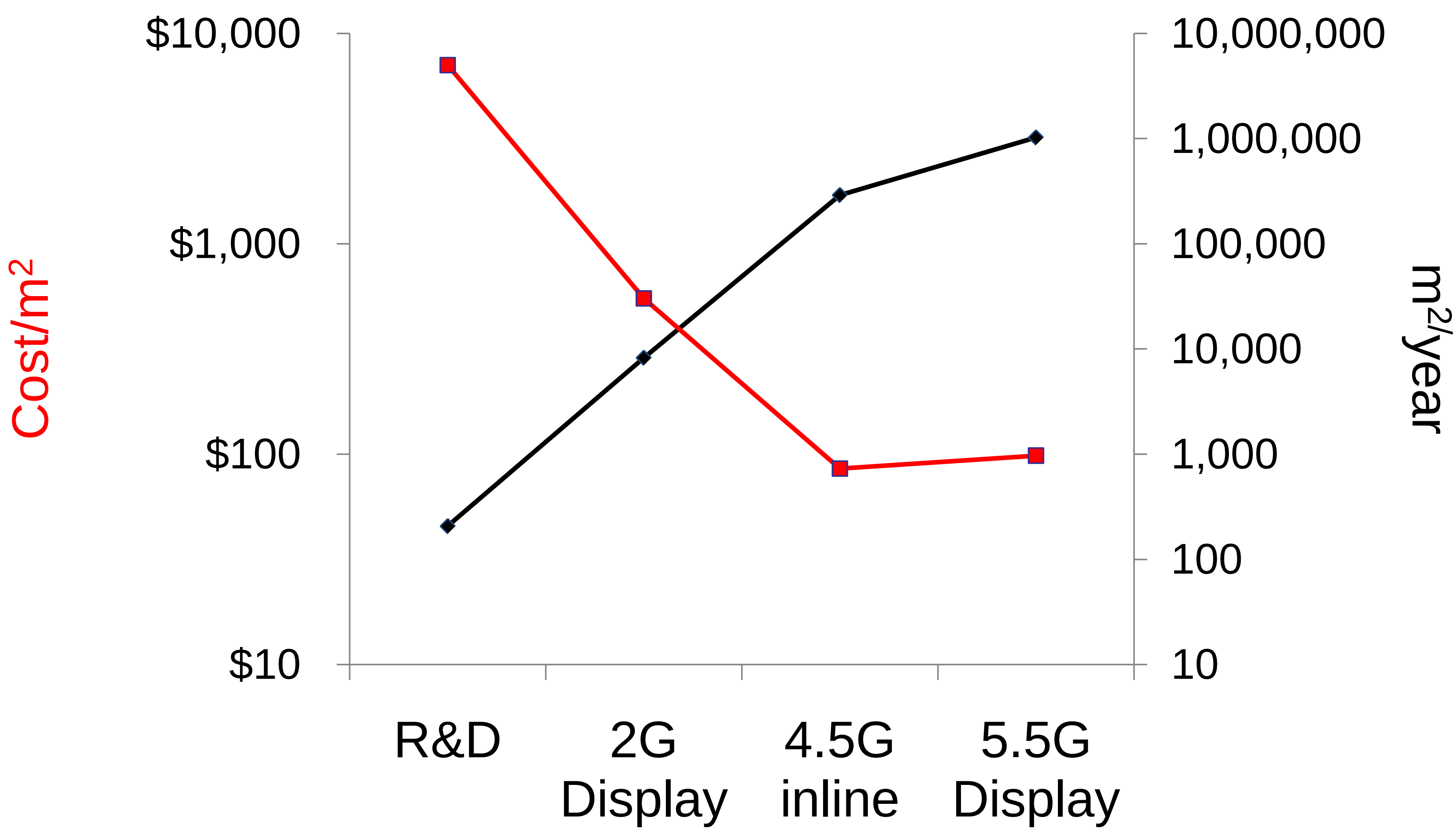
Implication for OLED Process

TACT (min)	Dynamic Rate (Åm/s)	Utilization (%)	Uptime
10	0.33	<5	1 day
3	5.2	20	3-5 days
2	12.5	50	5-7 days
0.5	40	>70	>2 weeks

Technology Cost Requirements



Relative Cost and Area of Systems



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Bigger Not Necessarily Better

OLED	G5.5	2'x4'
TACT Time	1 min	1 min
Uptime	85%	80%
Yield	95%	90%
Yielded Panel Area Per Year	925,000 m^2	250,000 m^2
System ASP	**$150M**	**$20M**
5 Yr Depreciation Cost ($/$m^2$)	30	16
OLED Chemical Cost ($/$m^2$)	10	20
Glass, ITO, Cathode, Encap	41	30
Operating Cost + Labor ($/$m^2$)	9	10
Total Cost ($/$m^2$)	**90**	**76**

Can achieve <$10/6" panel but each tool will produce 8M panels/year

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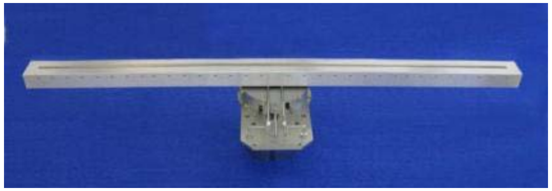
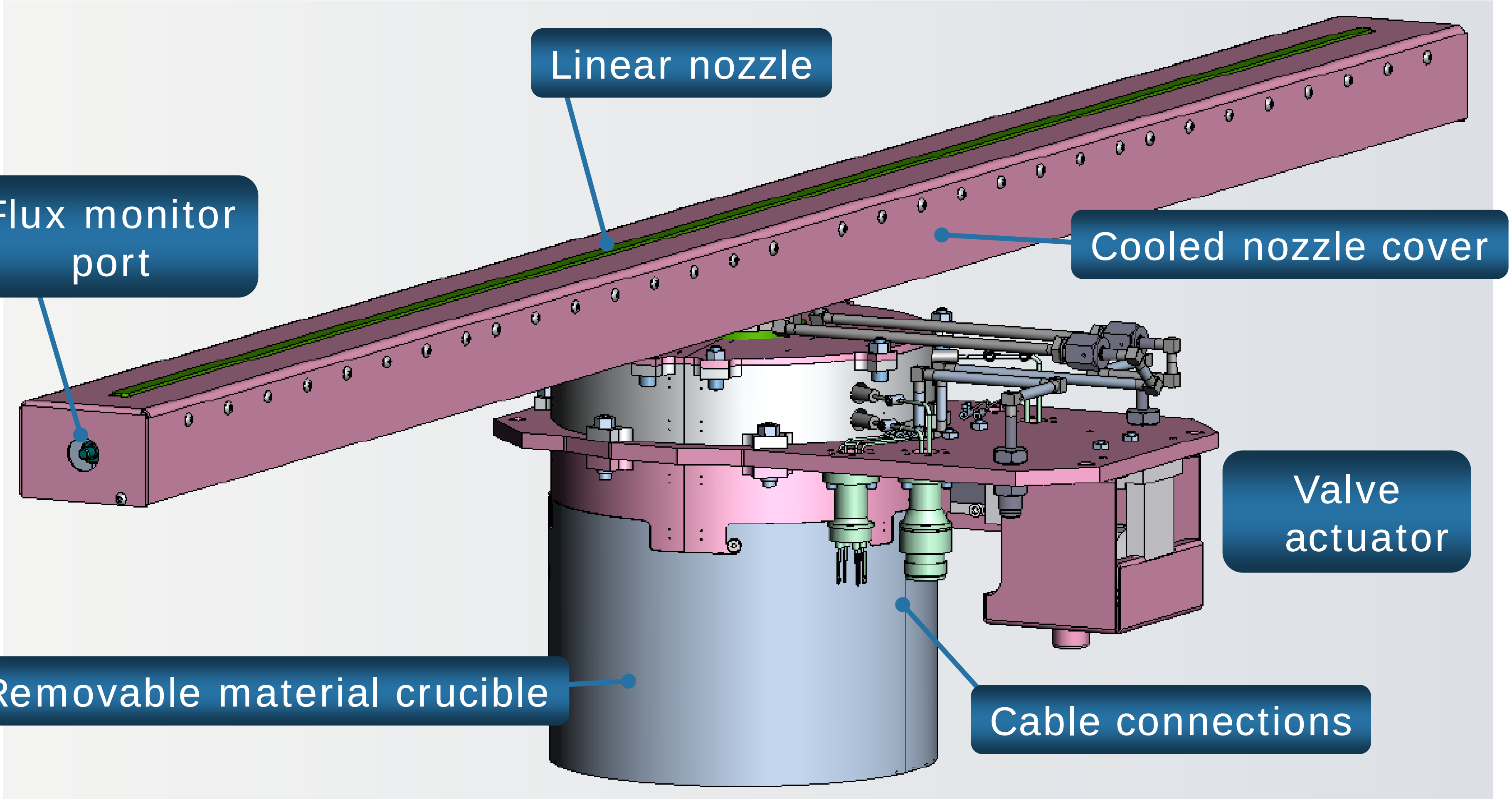
Veeco Organic Source Product Line

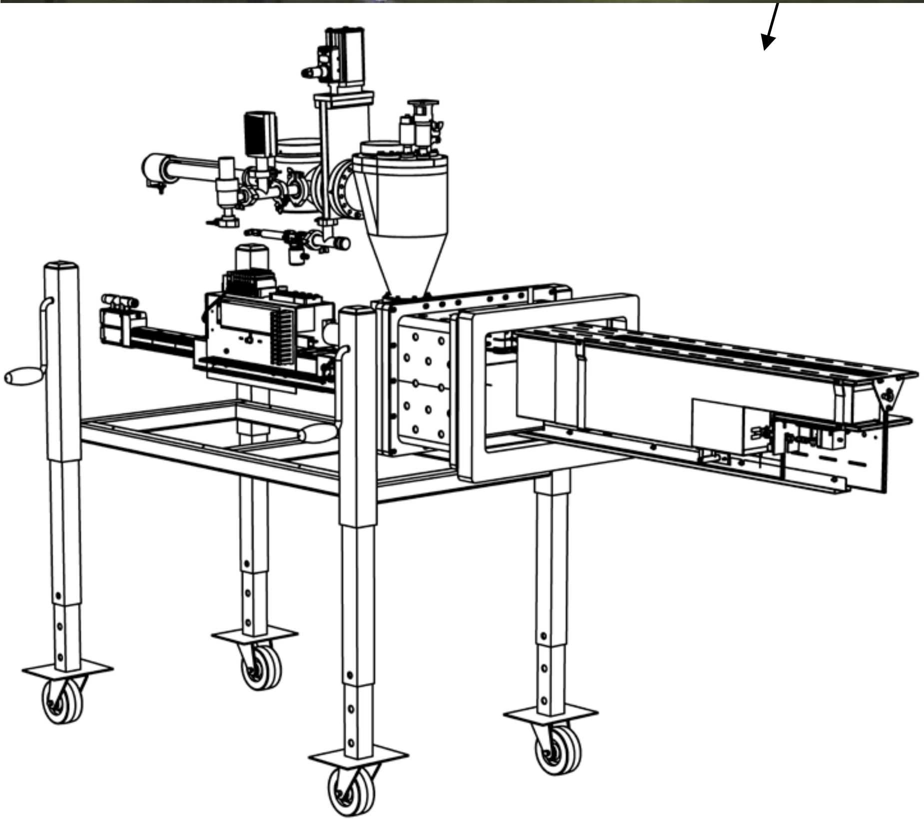
Source	Market	Features
Point Source 	R&D	▪ Low Cost ▪ Simple maintenance and material replacement
Bulk Valved Source 	▪ R&D ▪ Medium volume production (Mobile Display)	▪ Valve ▪ Nozzle Distribution ▪ Scanning & Fixed ▪ Flexible Geometry
Re-loading Source 	▪ Medium volume production (Mobile Display, TV) ▪ High volume production (TV, Lighting)	▪ Valve ▪ Nozzle Distribution ▪ Re-loading for high uptime and minimized degradation

OLED Bulk Valved Source

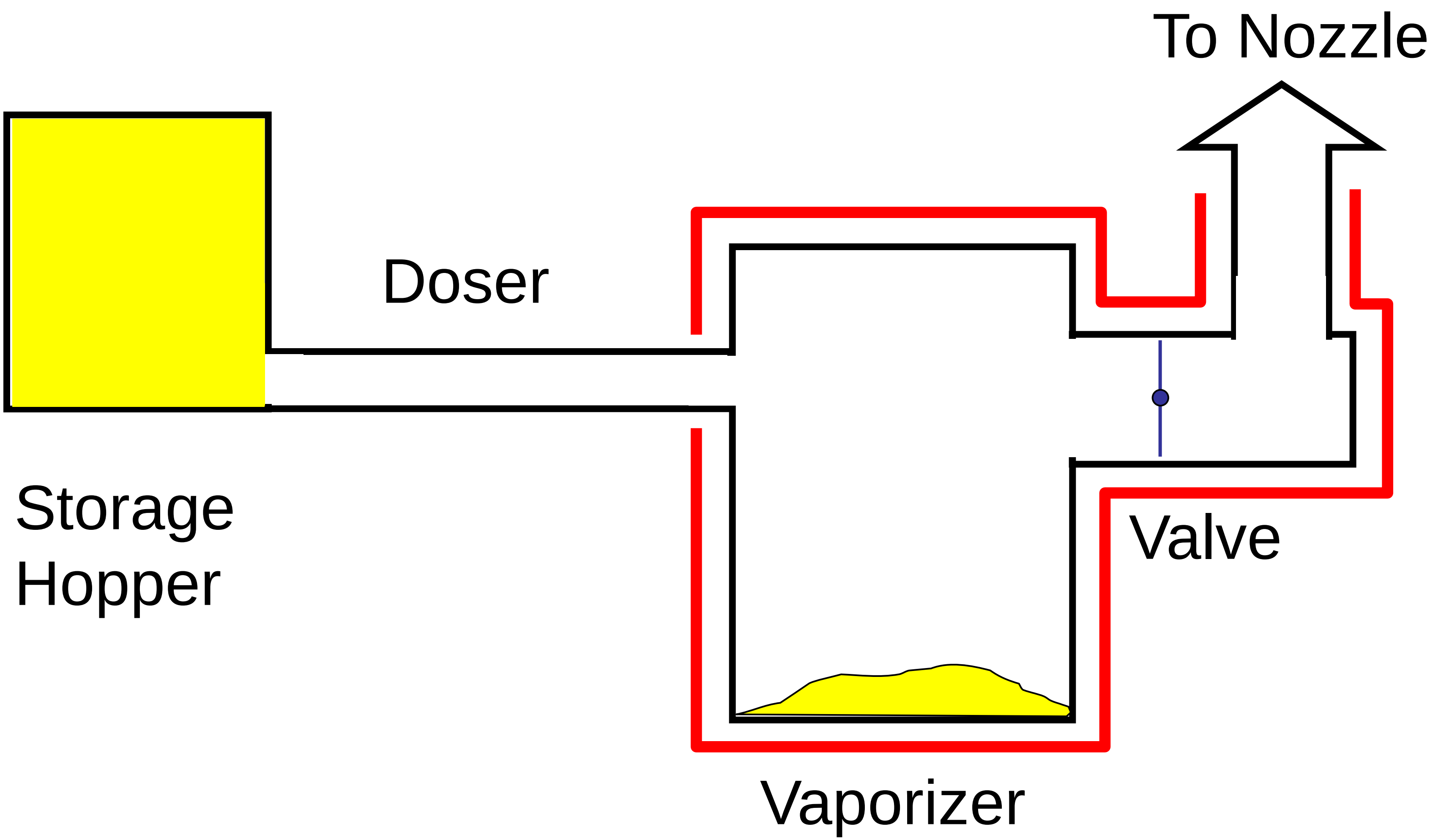


Organic Reloading Source

- Separate vaporization and distribution zones for easy scaling
  - Enables operation over a wide flux range (dopant to host)
- Bulkhead mounted for high speed in-line systems
- Closed loop valved flux control for rapid rate changes and precision control
- Low residence time of material in vaporizer to minimize degradation
- Source can be reloaded during normal operation
  - Enables extended operating times between system maintenance



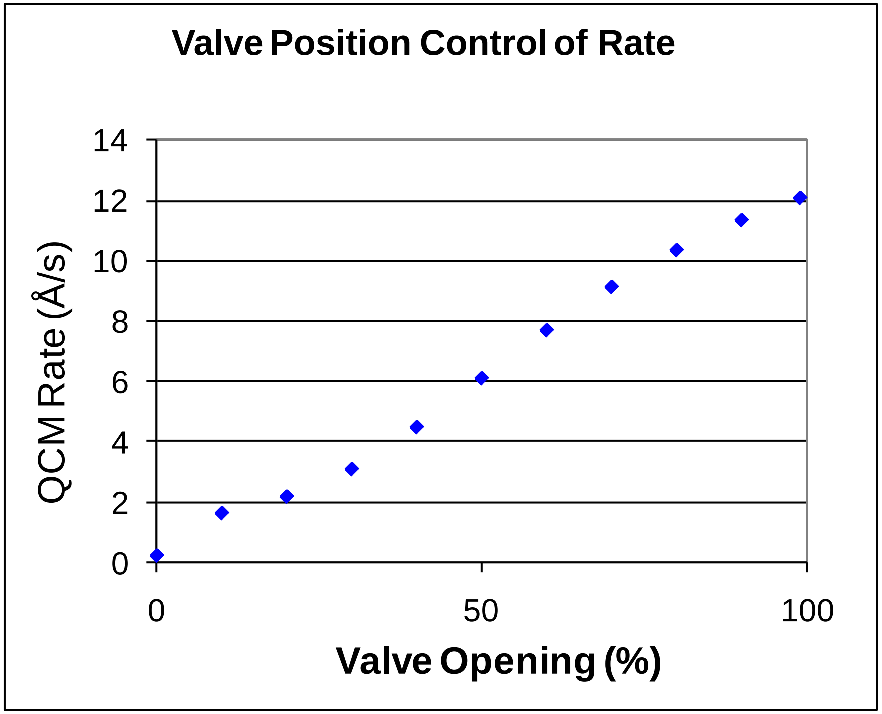
Dosing Sequence

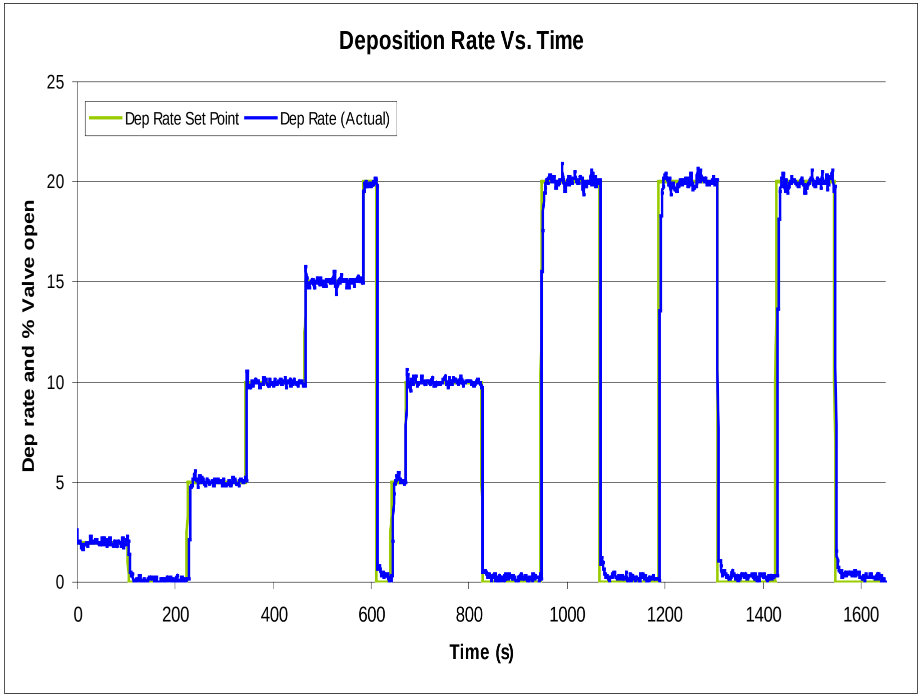


Key Technologies for OLED Source

- Valve – enables rapid flux control
  - Compensate for evaporation rate variation
  - Idle source between substrates
- Flux gauge – provides feedback for valve
  - Necessary for rapid flux control
  - Requires much longer lifetime than conventional gauge technology
- Control algorithms - integrated control of flux
  - Control software that can keep source in optimum operating range
  - Enables reloading process, which causes large changes in rate
- Nozzle – large area distribution
  - Achieve high utilization and uniformity on large substrates

Key Technologies: Valve





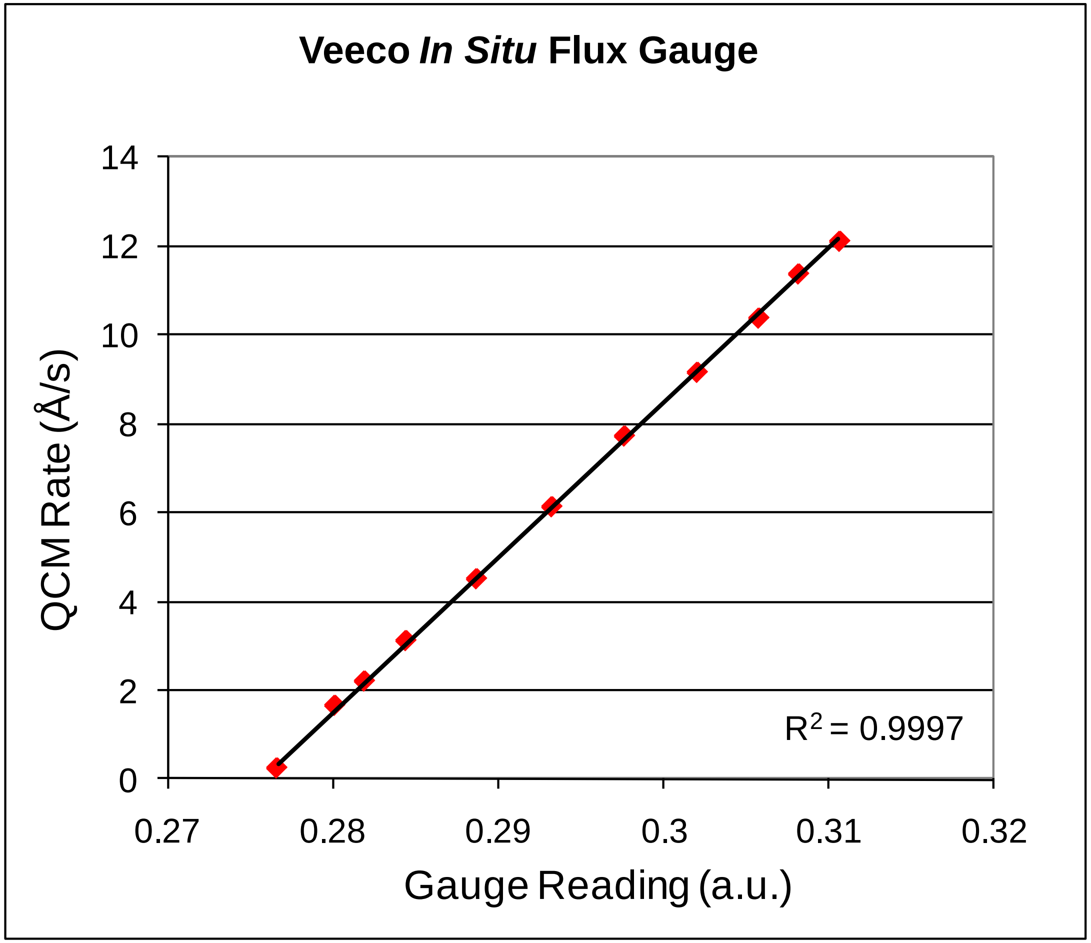
- Large Dynamic Range
- Highly Reproducible

- 100x rate control
- < 2s response rate

•Valve reduces wasted source material.

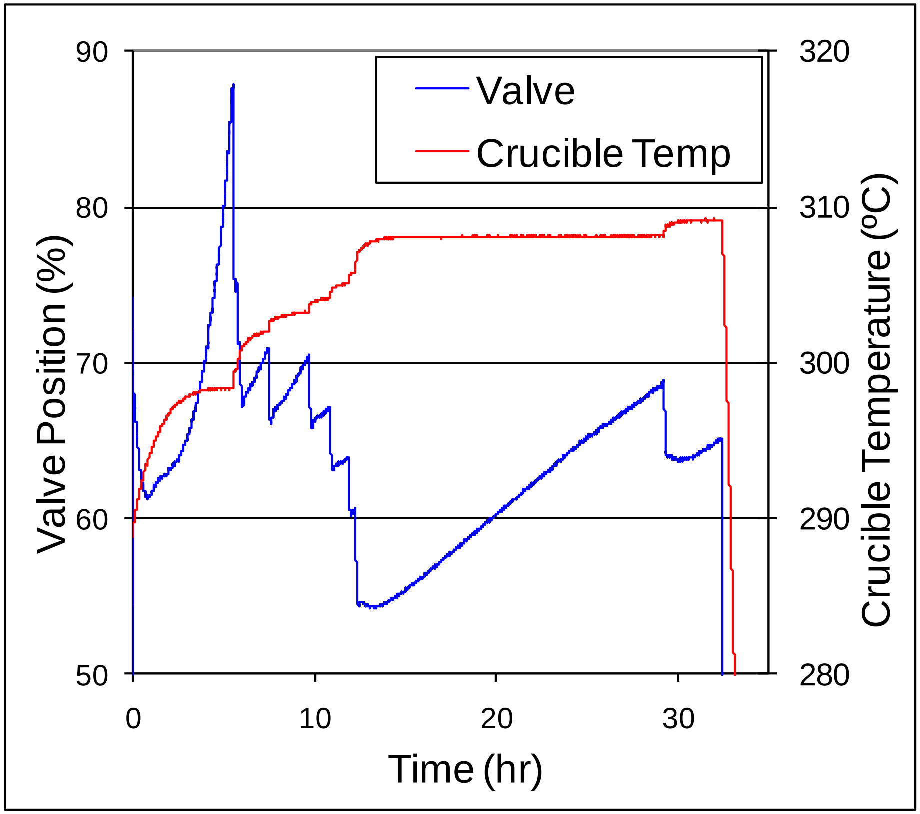
•Allows rapid flux control to improve yield and CoO

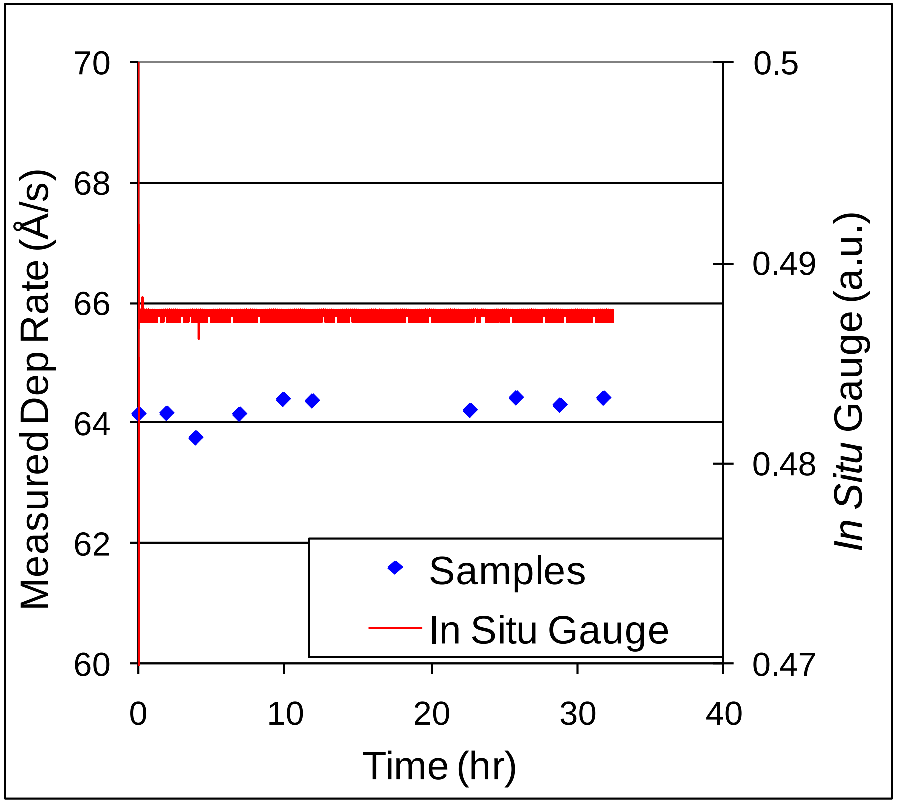
Key Technologies: Flux Gauge



- Internally-developed *in situ* flux gauge integrates directly to sources
- Large linear range allows precise flux measurements
- Allows closed loop control of valve
- No lifetime error/drift issues as seen in QCMs
- Greatly improves flux stability
- Improves panel yield and CoO

Key Technologies: Flux Regulation

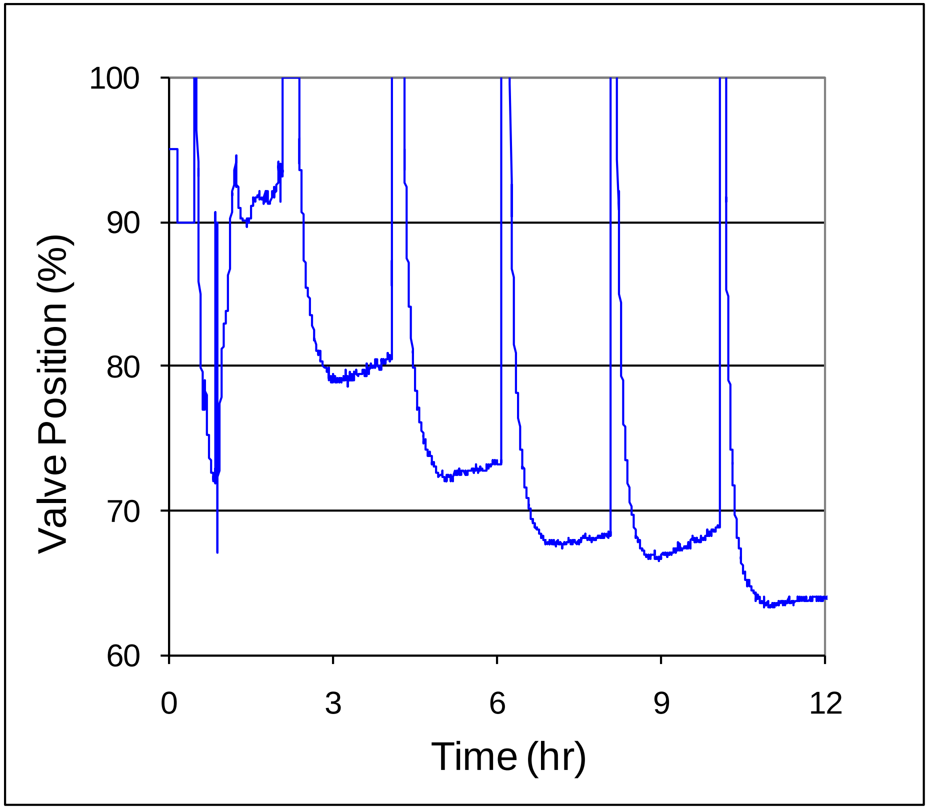


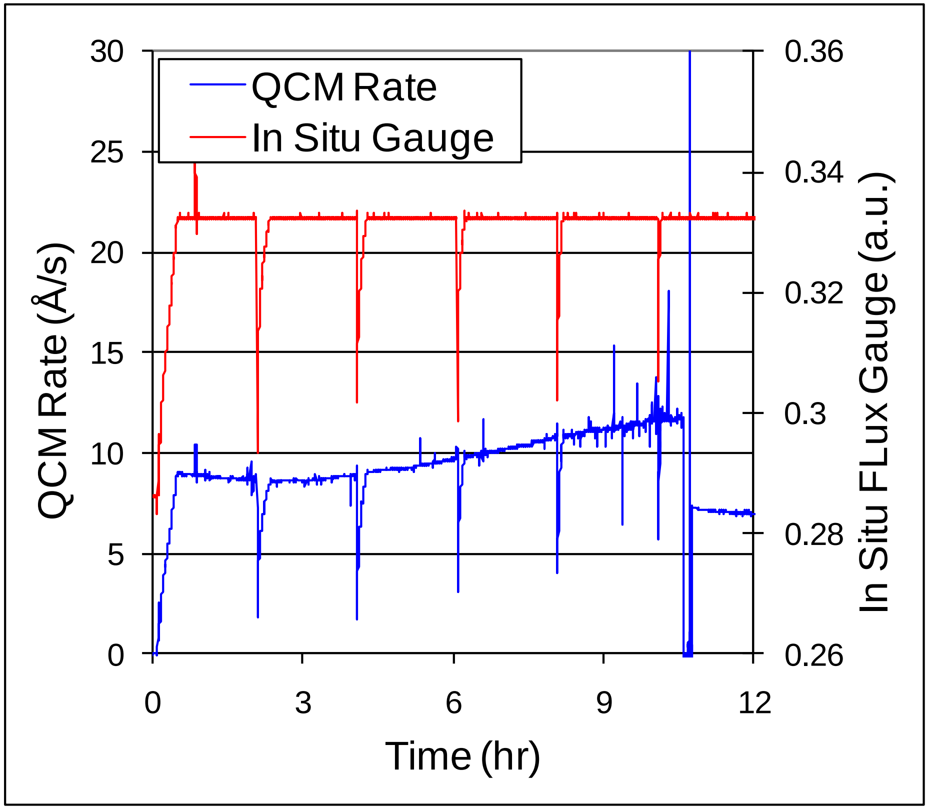


- Deposition Rate regulated to <±1% for >30 hours
- Crucible temperature deliberately changed by 18ºC during test.

Key Technologies: Flux Regulation

12 hrs flux control with material reloading in 3 hr intervals.





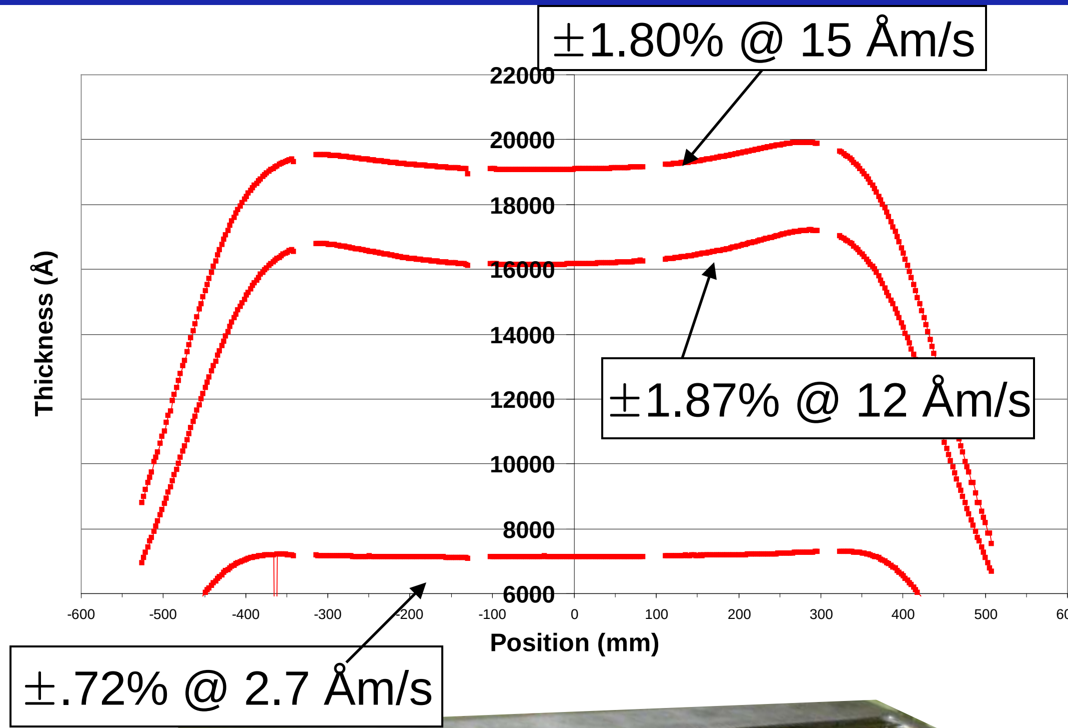
- In Situ Gauge accurately controls over entire test.
- QCM readings develop errors and issues as material accumulates.

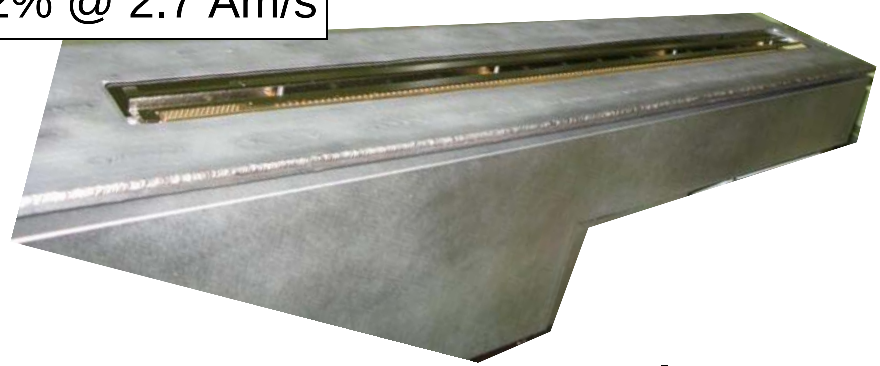
Key Technologies: Nozzle (Uniformity)

4G (0.73m) System

- Uniformity*=±0.72 to ±1.87% depending on rate
- 1 Valved Source with linear nozzle
- 37% material utilization
- Source-to-substrate distance = 300mm
- Material; multiple

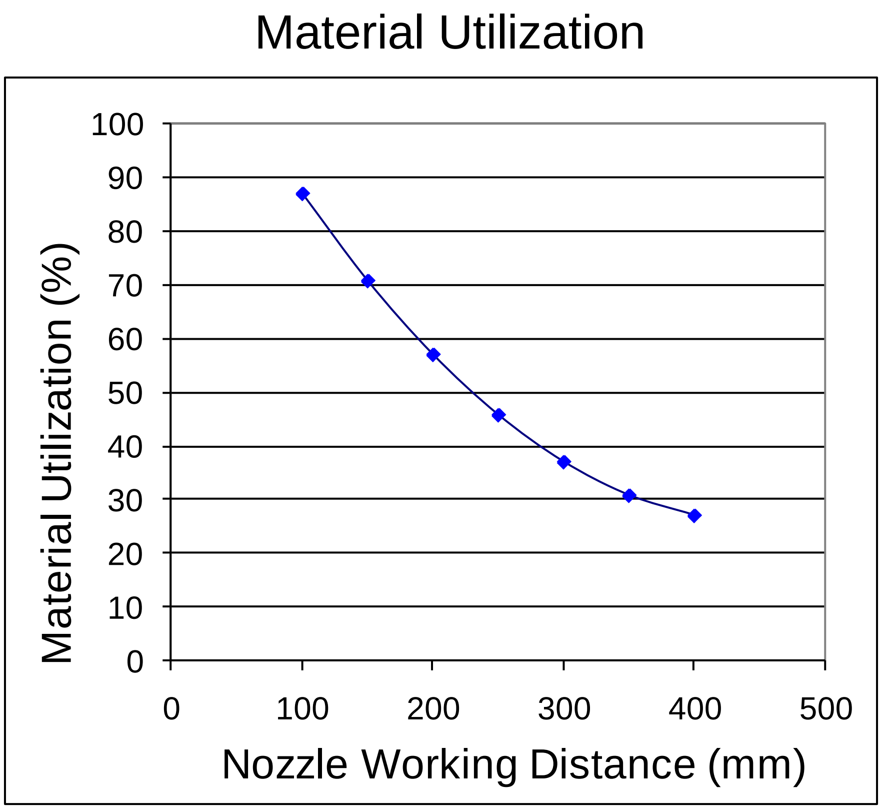
* Measured by ellipsometry

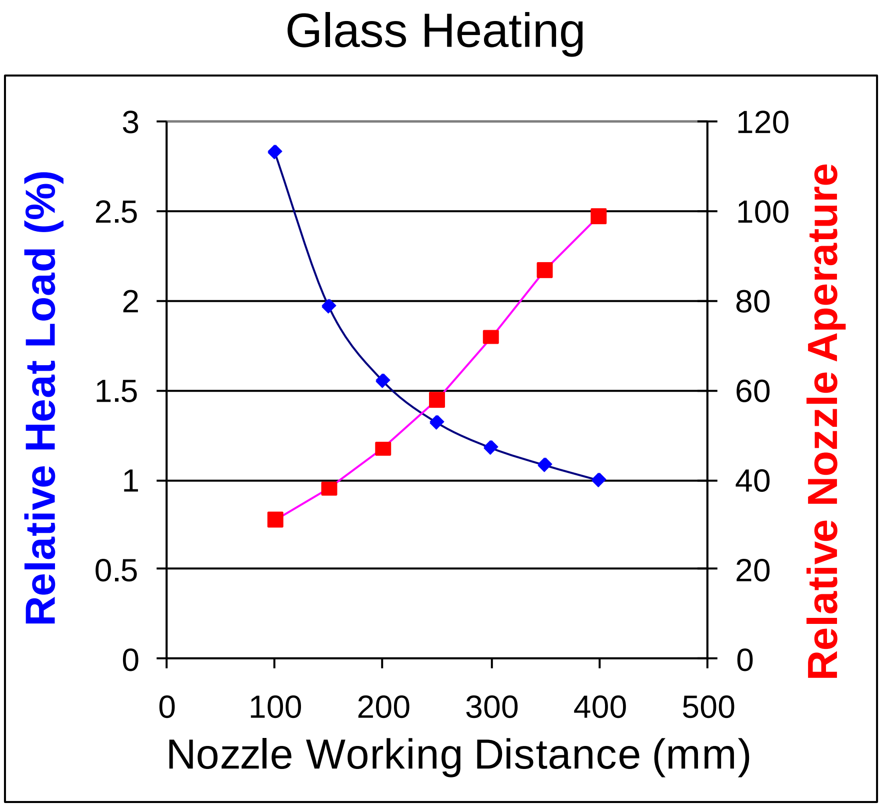




Gen III, 730 mm nozzle

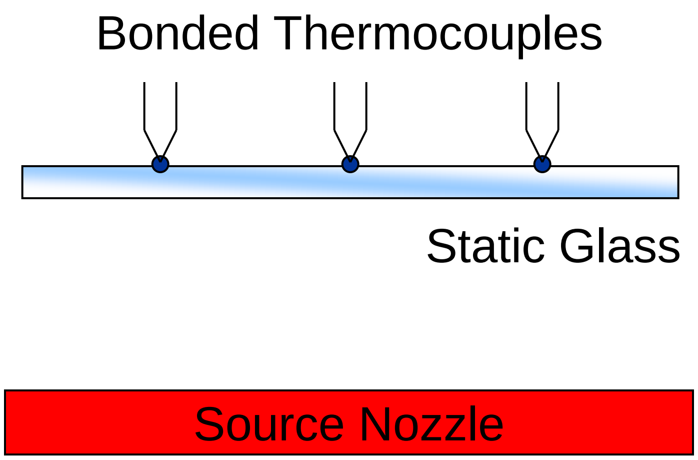
Key Technologies: Nozzle (Design)



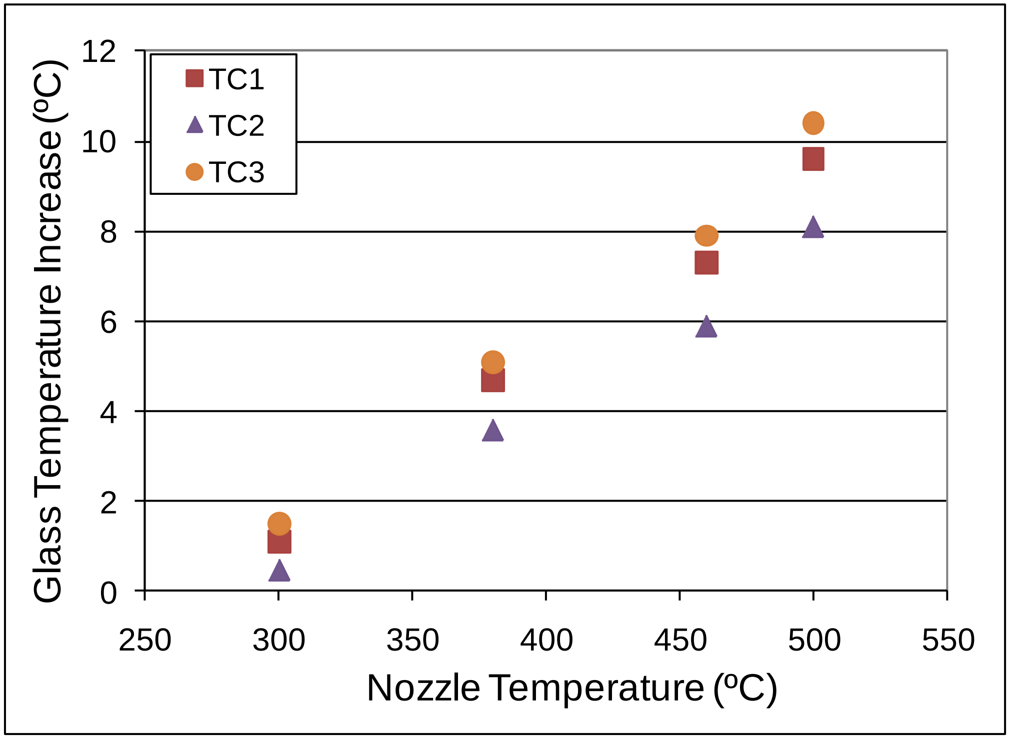


- Strong tradeoff between material utilization and OLED/Glass heating
- Careful consideration must be given to impacts on nozzle conductance and uniformity.

Key Technologies: Nozzle (Heating)

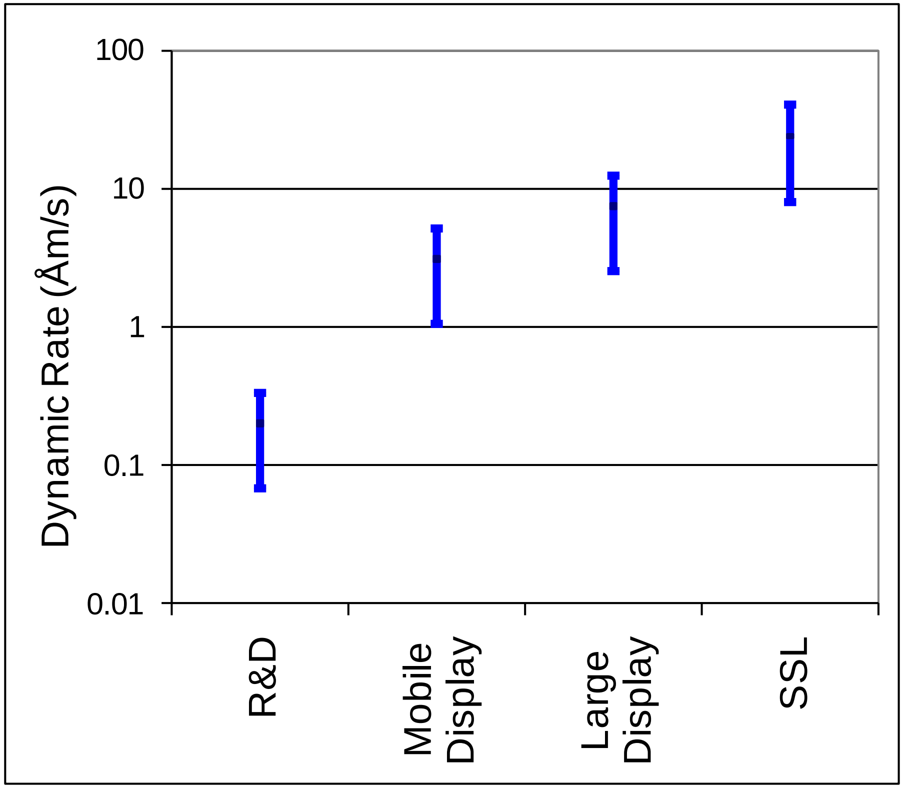


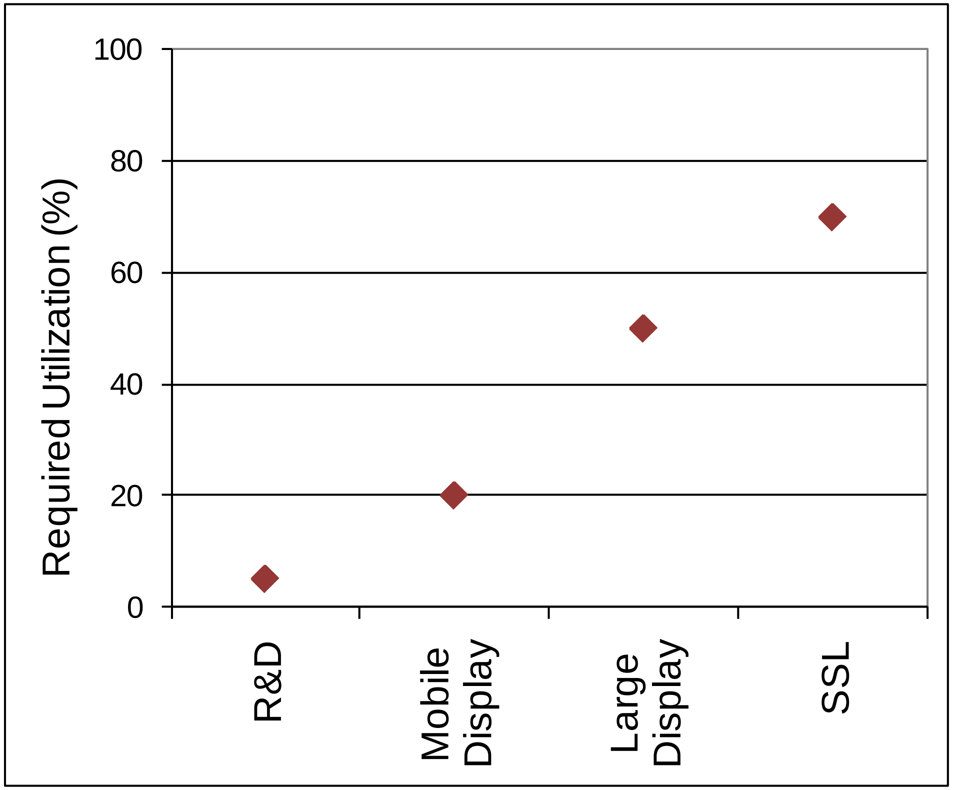
Heating of Static Glass by Nozzle



Average temperature increase is less than 10ºC even for static glass.

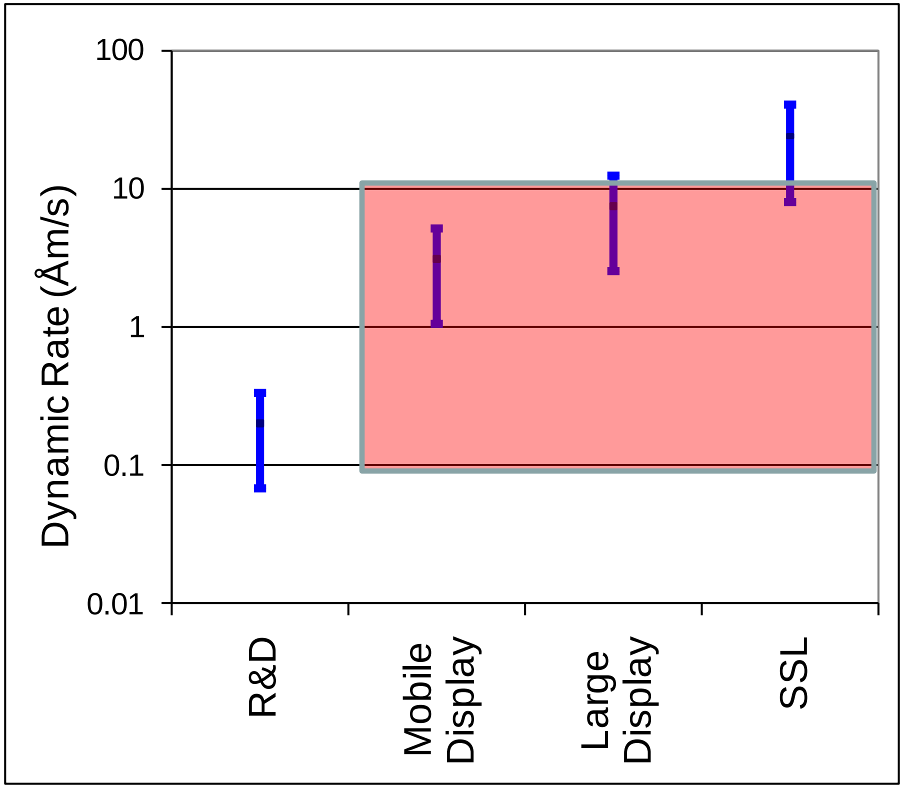
Requirements for Roadmap

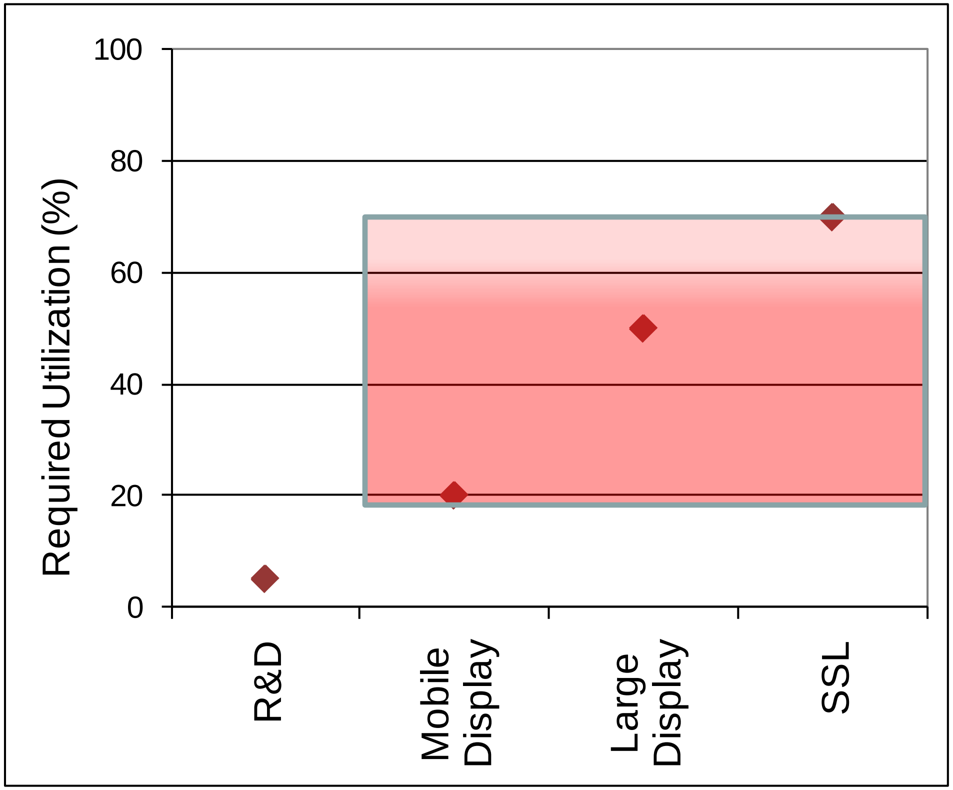




- Reloading source has adequate dynamic rates for the MD and LD markets. Improvements are needed for SSL.
- Reloading source needs utilization improvements for LD and SSL markets.

Requirements for Roadmap – Current Results





- Reloading source has adequate dynamic rates for display markets. Improvements are needed for SSL.
- Utilization can be achieved, but requires system design optimization

Conclusions

- Manufacturing process for current OLED technologies is feasible, however targeted equipment required
  - Need a target device structure
  - Market entry size challenging

- Need R&D that is factoring in manufacturing needs
  - Many aspects of device design still based on hero results
  - Materials only have to last hours for R&D testing
  - Lots of “if we simply add _____, this will be manufacturable”

- Veeco has developed thermal evaporation source technologies capable of large area displays and SSL

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