Organic Vapor Phase Deposition Technology for OLED Research and Fabrication

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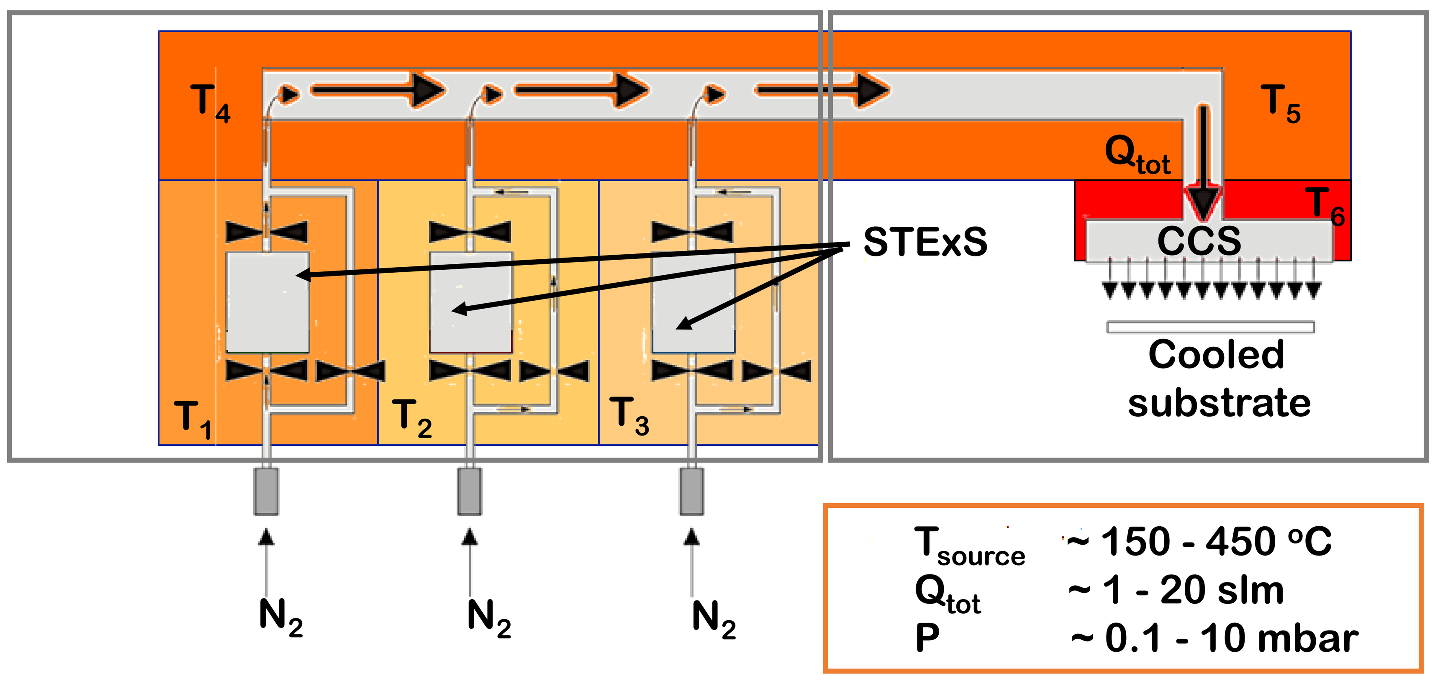
Introduction

The performance and cost of large-area OLED are critical issues currently since conventional vacuum thermal evaporation (VTE) tools possess limited control over film thickness, uniformity, and dopant concentration over large-area substrates. Moreover, VTE suffers from inefficient material utilization (below 20 %). The initial setup costs for equipment are also high due to need of very low pressure (ca. 10^{-6} mbar) in the evaporation chamber. In order to overcome these drawbacks, AIXTRON has developed innovative OLED deposition equipment based on organic vapor phase deposition technology, which is suitable for fast and uniform deposition on large-area substrates up to Gen8 size (2.5 x 2.2 m^2) and beyond.

OVPD® Schematic & Thermal Management

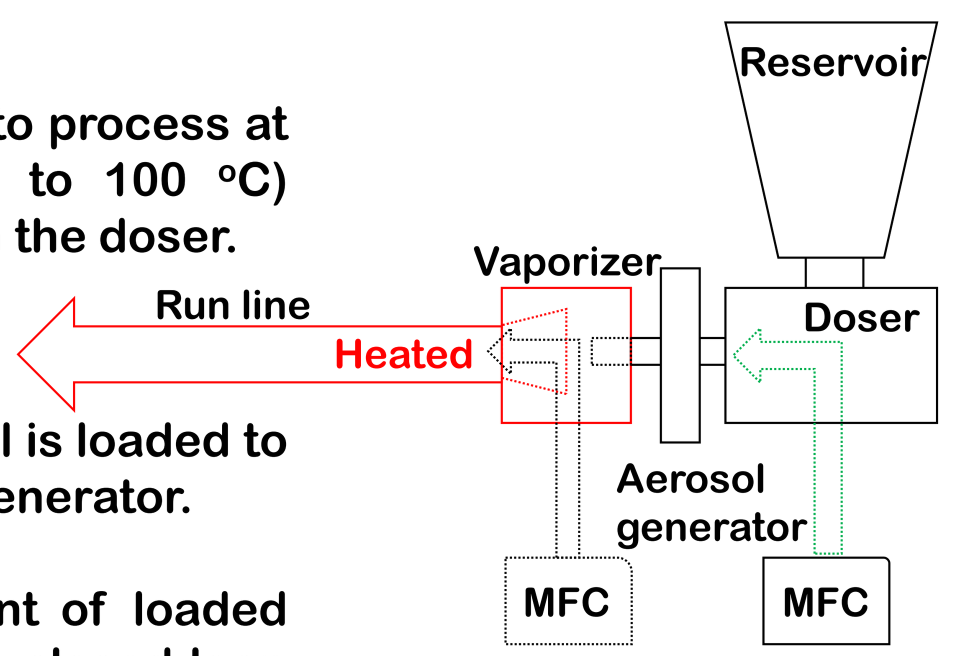


Temperature distribution: $T_1, T_2, T_3 < T_4 < T_5 < T_6$

Combination of OVPD and Close Coupled Showerhead (CCS)

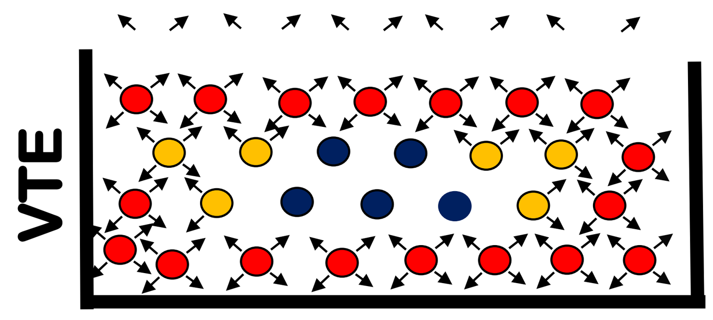
STExS™ – Short Thermal Exposure Source

1. Material is charged to reservoir and stored under vacuum.
2. Material can be dried prior to process at elevated temperatures (up to 100 °C) with assistance of N_2 flow in the doser.
3. Required amount of material is loaded to vaporizer through aerosol generator.
4. The doser metering (amount of loaded material) is adjusted by closed-loop control to achieve the desired evaporation rate.



Material evaporation in STExS™

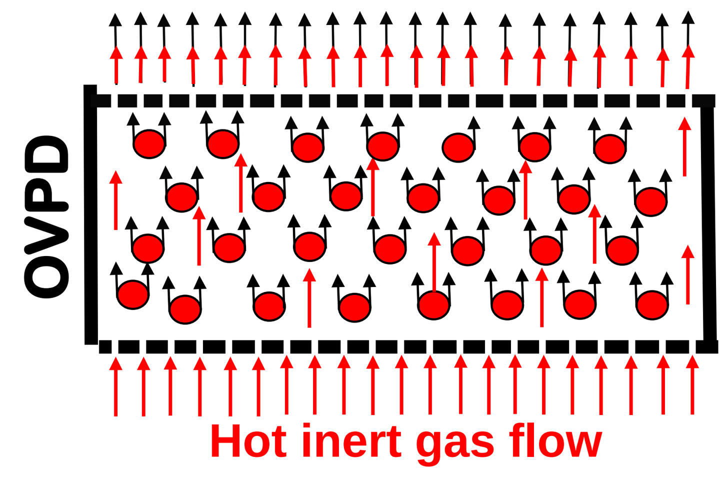
Efficient Evaporator Design: STExS™ Principle



Hot-crucible evaporator in VTE technology

Majority of particles do not participate in evaporation or inhibit evaporation of neighboring particles.

Absorbed energy due to the latent heat of vaporization is slowly compensated from the crucible walls.



Hot carrier gas vaporizer in OVPD technology

Majority of particles can evaporate at their theoretical limit, uninhibited by vapor from adjacent particles.

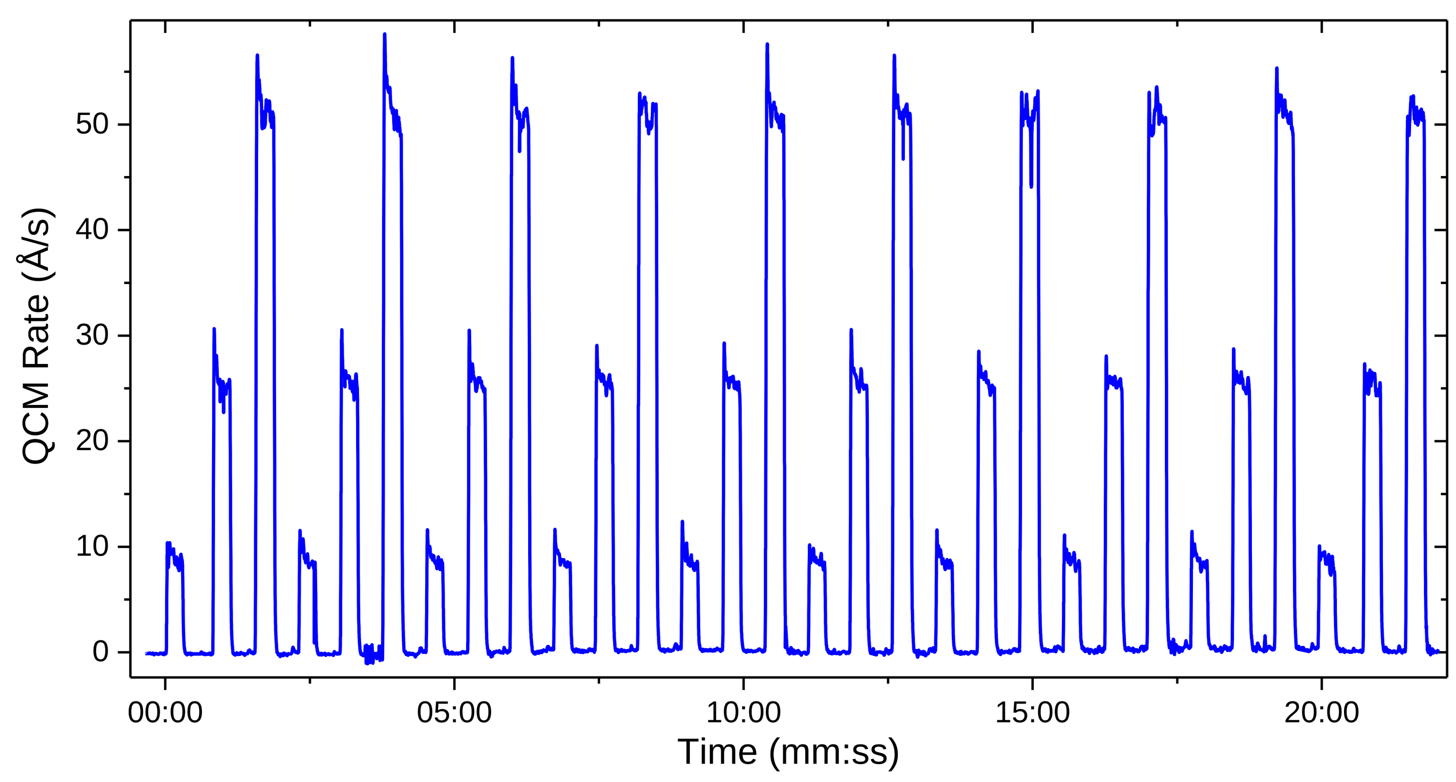
Absorbed energy due to the latent heat of vaporization is replenished by hot nitrogen.

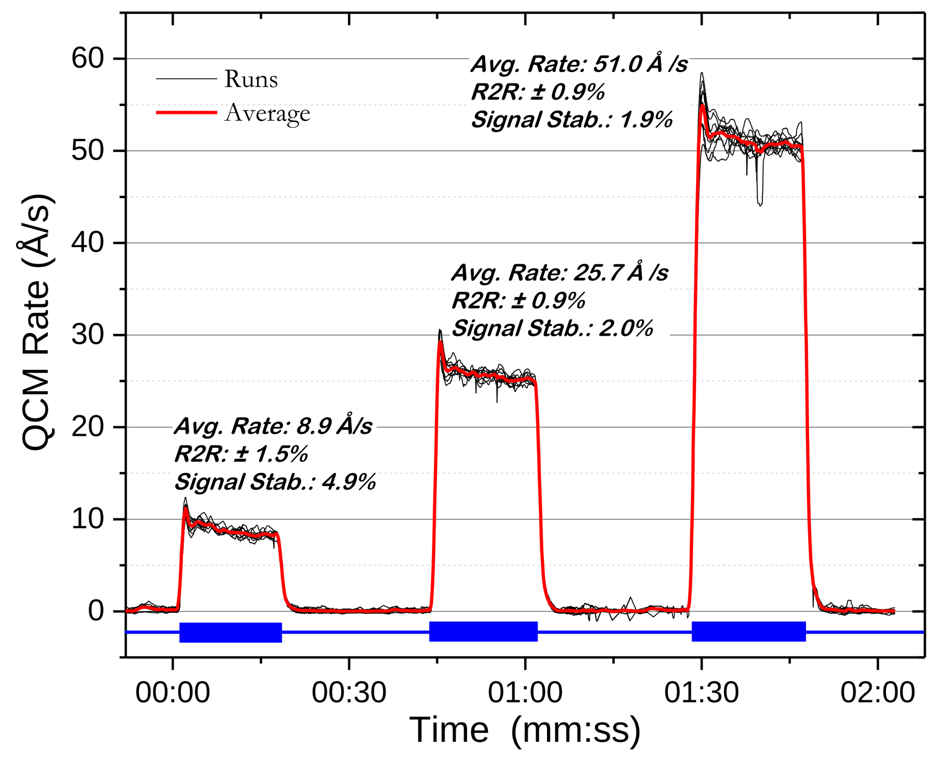
$$J_i = \frac{\alpha \cdot M \cdot A_{Surface} \cdot \left(p^0_{i(T)} - p_{i(T)}\right)}{\sqrt{2\pi \cdot M \cdot RT}}$$

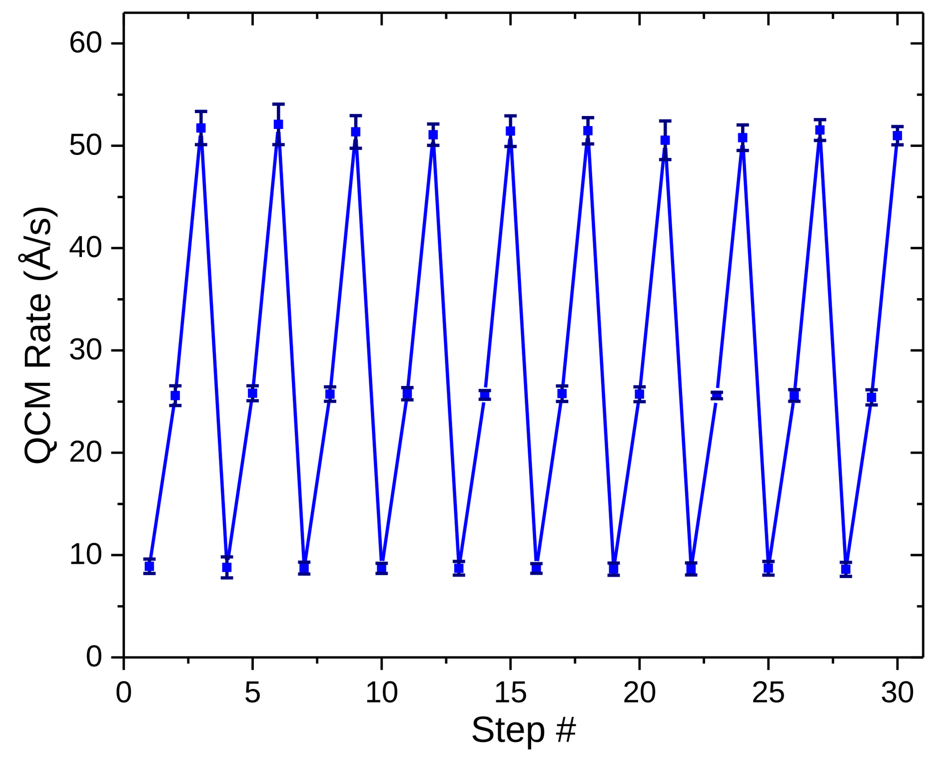
J_i = evaporation rate (kg/s)
α = evaporation coefficient
$P^0_{i(T)}$ = vapor pressure of species i
$p_{i(T)}$ = partial pressure in gas mixture
T = temperature (K)
R = 8.3143 (J/mol-K)
M = molecular weight (g/mol)

1. Increased evaporation coefficient α: powder particles are heated individually by hot gas flow → uniform temperature distribution.
2. Increased effective surface area $A_{Surface}$ of the powder: separated powder particles.
3. Reduced partial pressure $p_{i(T)}$ around all powder particles: vapor cloud surrounding each particle continuously removed and surface crust formation inhibited.

STExS™ Performance in OVPD Processes







Subsequent deposition steps of Alq_3. Process conditions: source temperature 350 °C, pressure 0.9 mbar, N_2 flow through the source 5 slm, total flow through the showerhead 20 slm, and average doser metering parameters of 0.7, 2.4 and 4.9 to achieve the desired rates of 10, 25 and 50 Å/s for Gen8 size substrate.

High material flux in on-state & fast ramp-down in off-state
- → Fast layer switching, vaporization inhibited and stopped within few seconds
- → Feature for precise control of layers interface

Process reliability & reproducibility
- → Controllable deposition rates up to 50 Å/s
- → Stable process with run-to-run variations below 1.5 % for average deposition rates of 8.9, 25.7 and 51.0 Å/s over 30 runs

Conclusions

1. Proprietary STExS™ evaporation source technology ensures: the lowest achievable thermal stress for organic materials and high deposition rates (up to 50 Å/s) for Gen8 size substrate.
2. High material throughput and reproducibility of deposition process on large-area substrates make this technology the ideal candidate for low-cost production of OLED displays, OLED lighting and organic photovoltaics.