FUNDAMENTAL PROCESSES GOVERNING OPERATION AND AGEING IN STATE OF THE ART P-OLEDS

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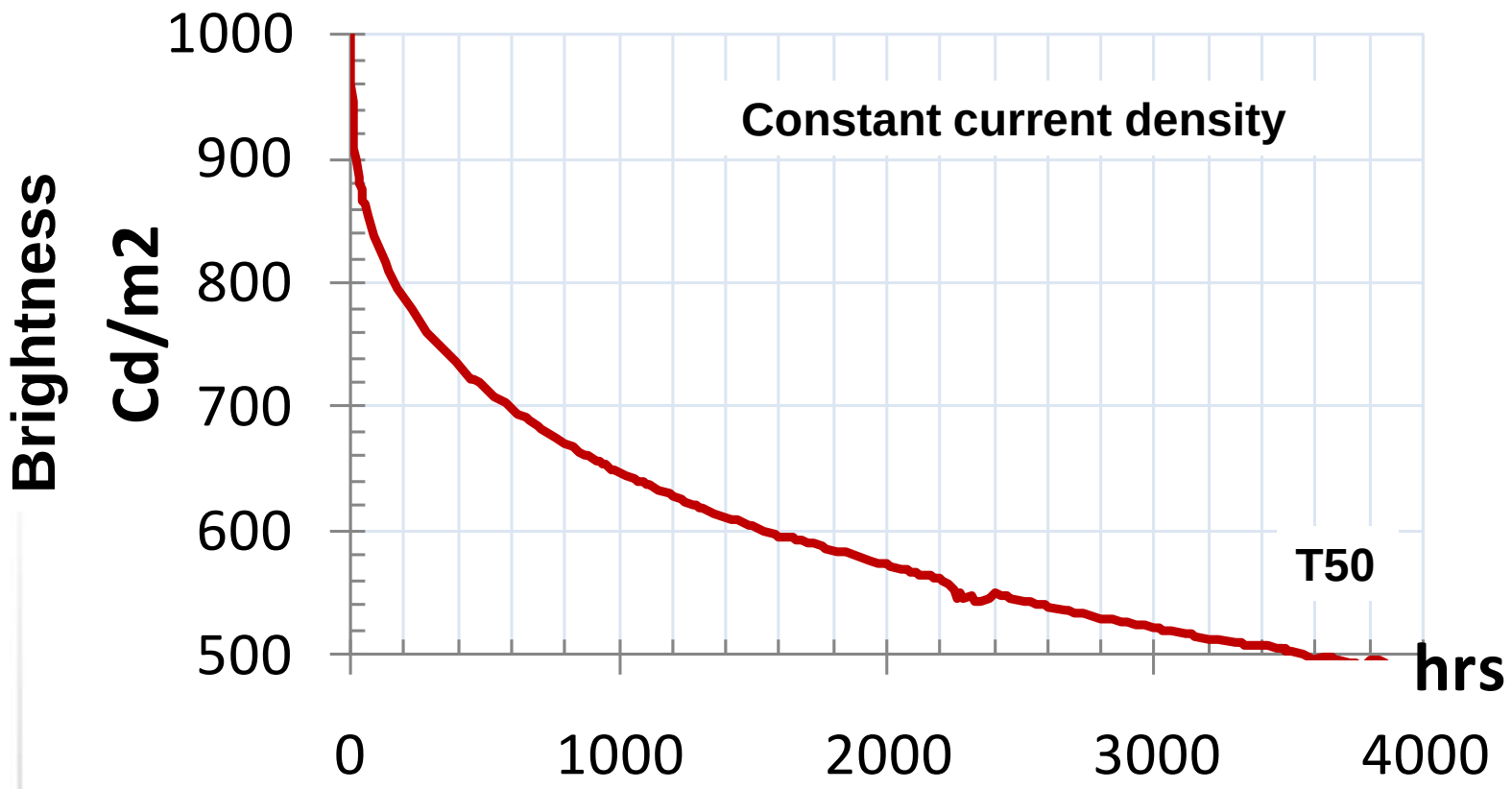
Lifetime testing of P-OLED devices



Key challenge for P-OLED – extending T50

Talk overview

Device fundamentals	• Basic device structure • Model materials
Degradation analysis	• Loss of carrier injection • PL decay
PL decay analysis	• What generates quench sites • Properties of degraded material

Talk overview

CDT

Device fundamentals	• Basic device structure • Model materials
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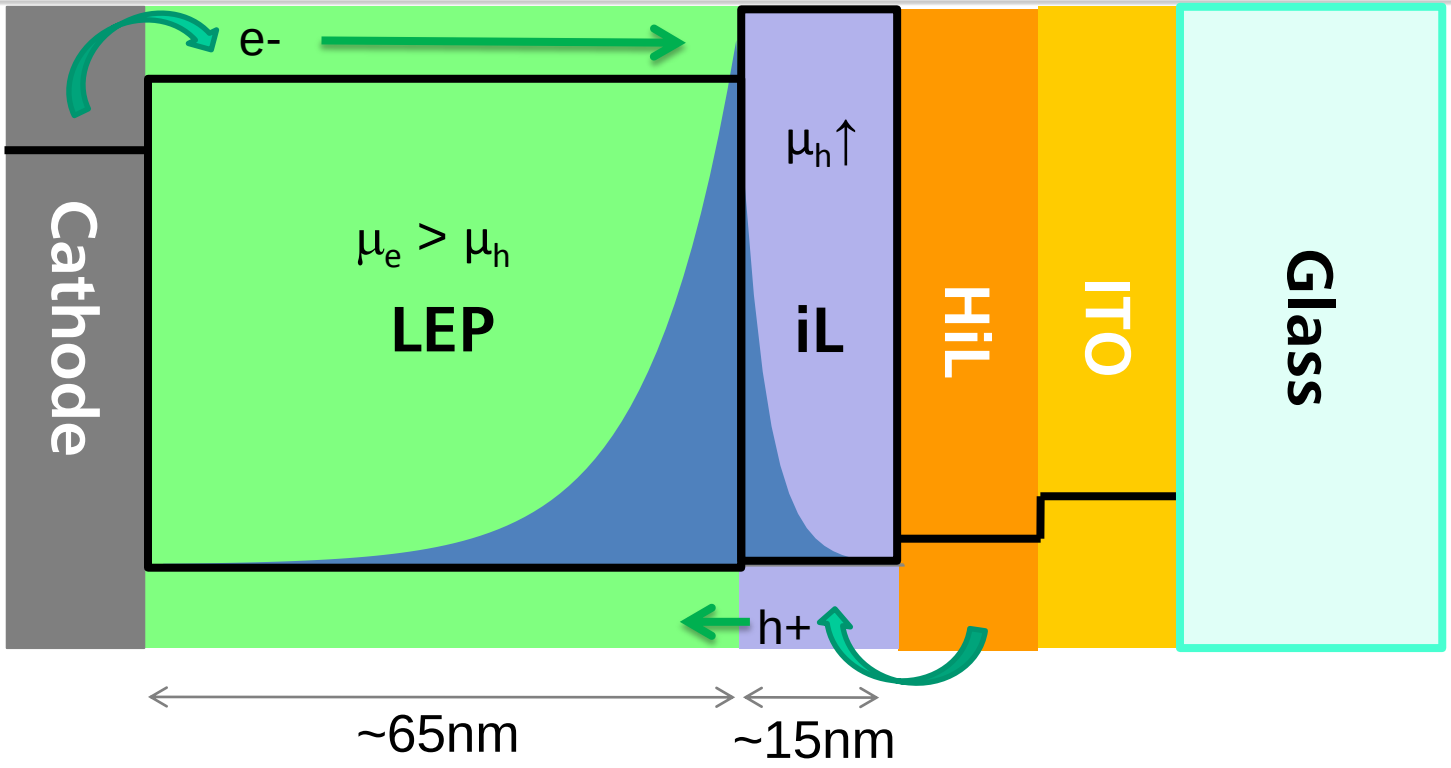
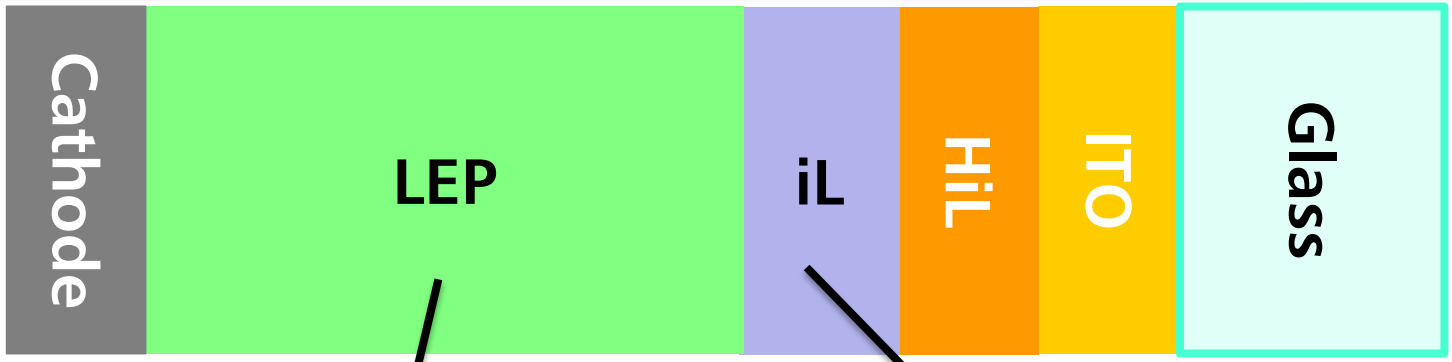
SUMITOMO CHEMICAL

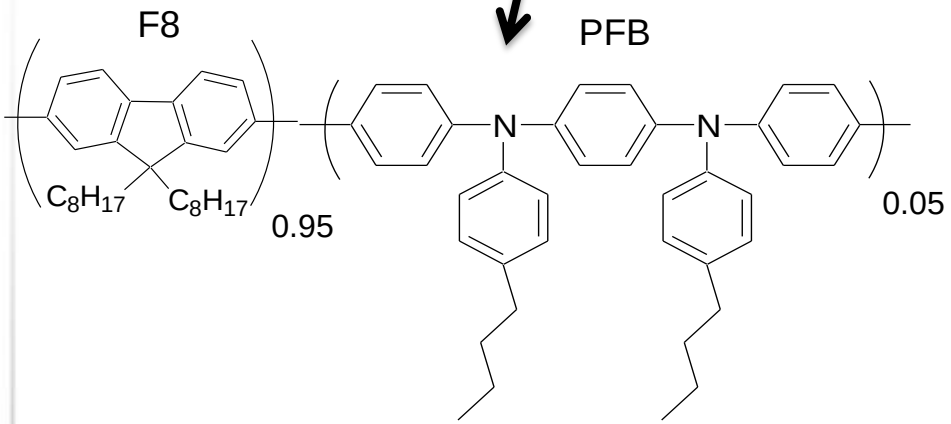
Device structure



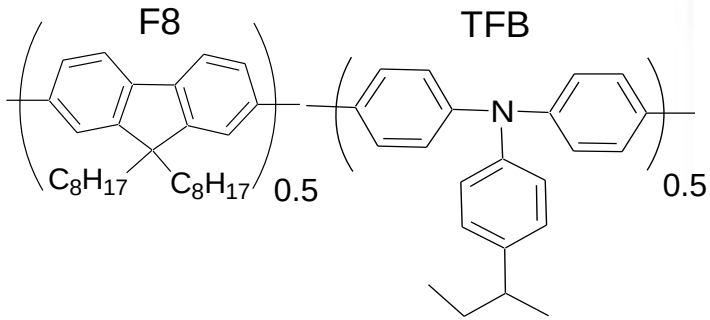
→ LEP thickness and mobilities - Optimum RZ for outcoupling
→ iL - hole injection, efficiency and lifetime
→ HIL and ITO thicknesses – tuned for colour and outcoupling
→ Electrodes / charge injection layers - thermally stable

Model materials





Random copolymer
F8:PFB 95:5



A-B copolymer
F8:TFB 50:50

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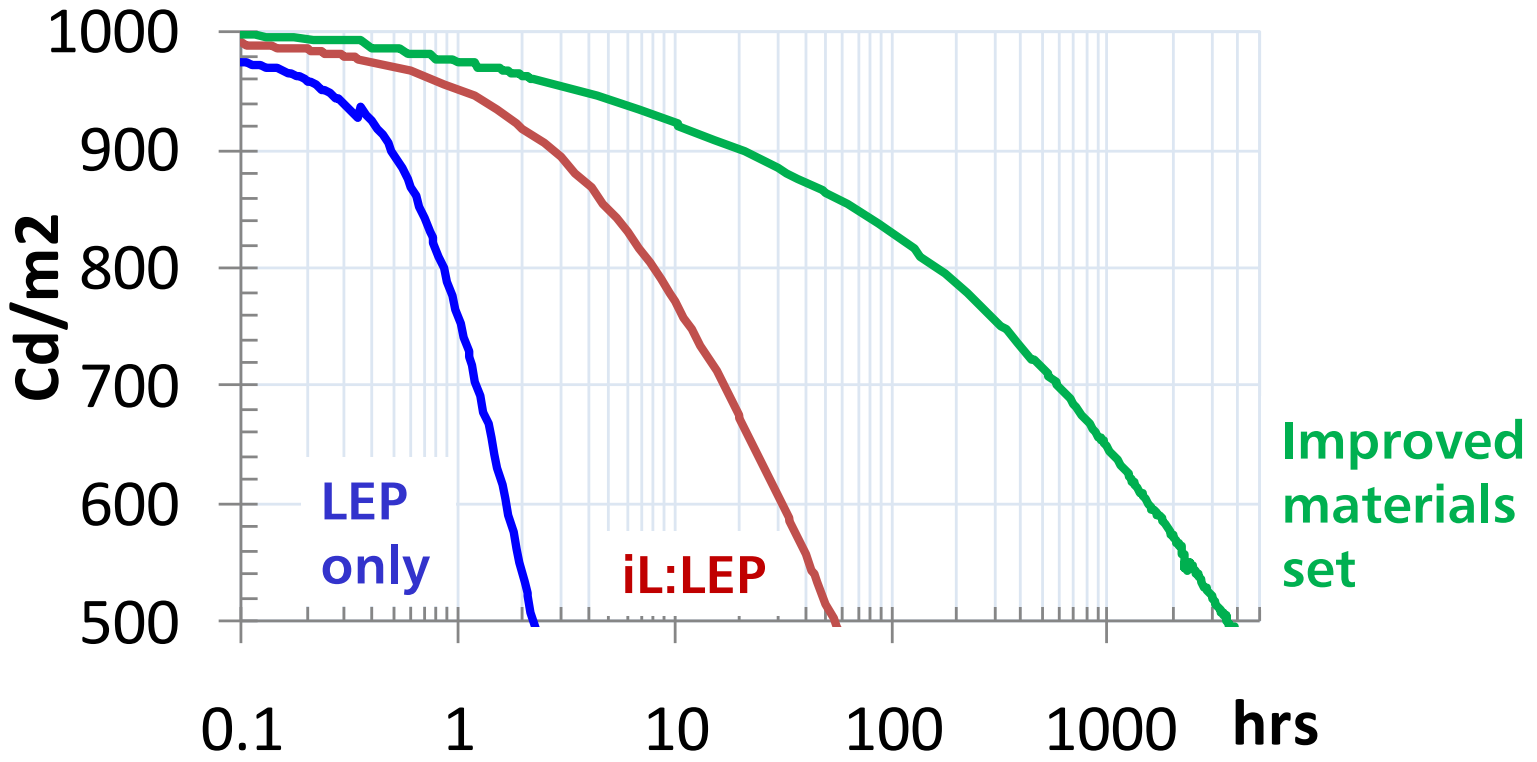
Degradation analysis

iL:LEP = Model materials



Degradation analysis of 3 systems spanning over 1000x in lifetime

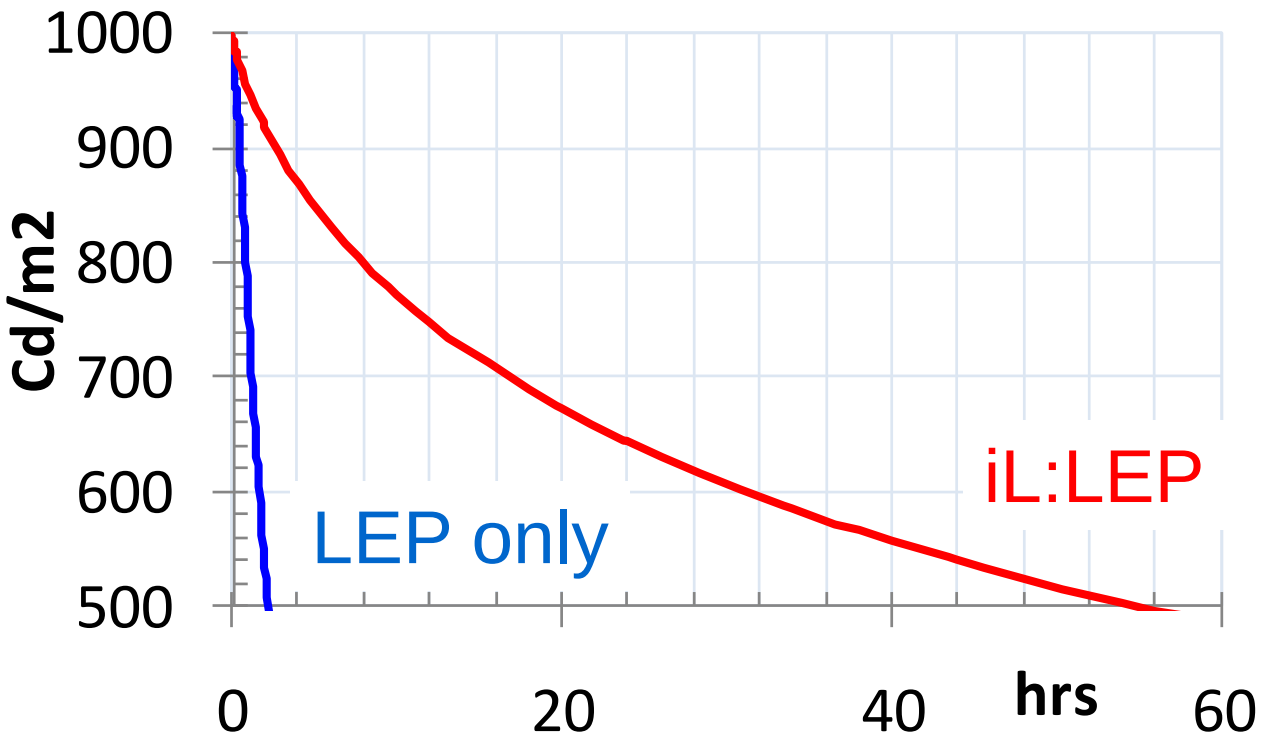
Case study 1

LEP only vs iL:LEP

Model materials

Impact of iL

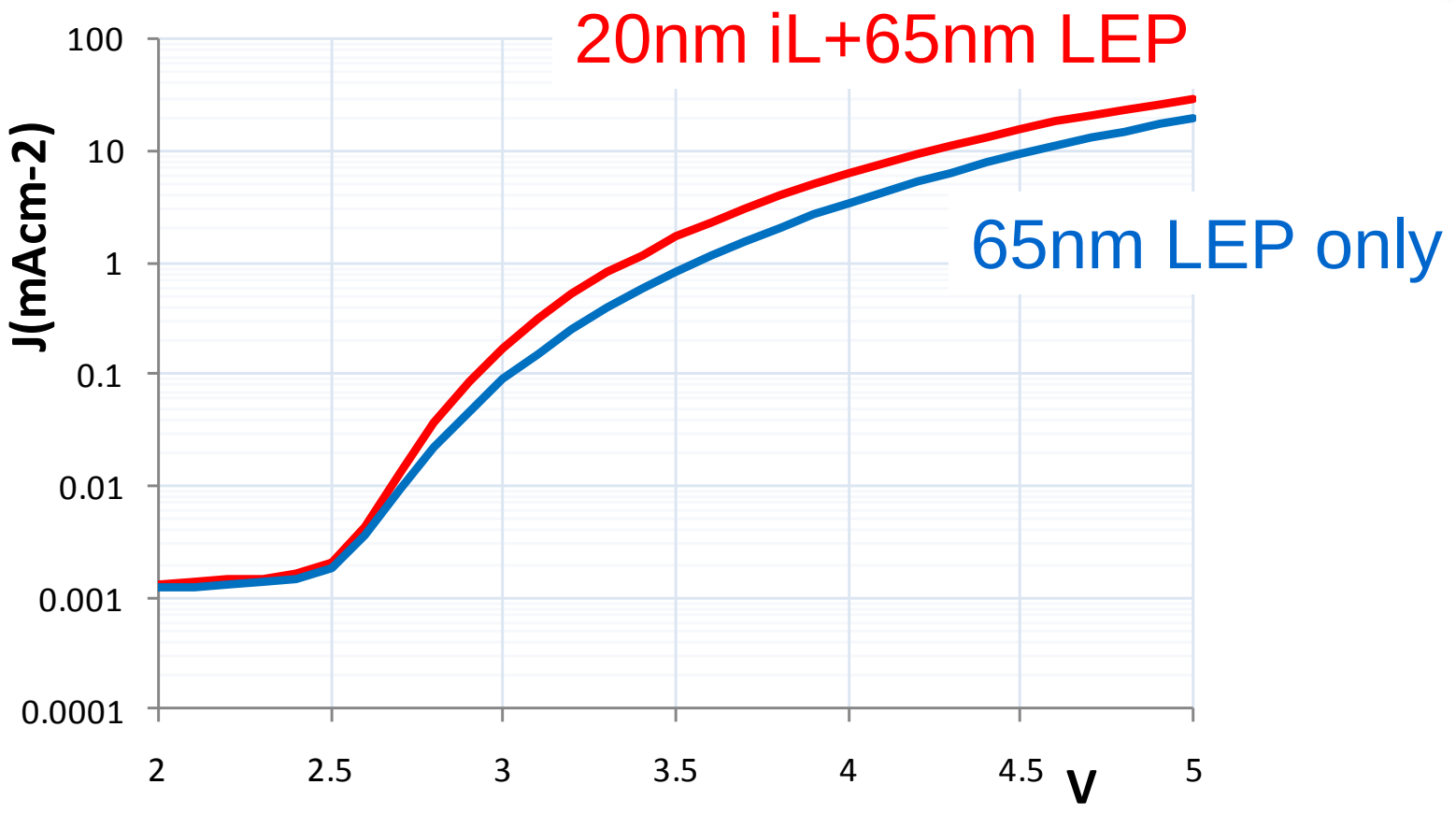
iL:LEP = Model materials



iL improves lifetime ×25

Impact of iL

iL:LEP = Model materials

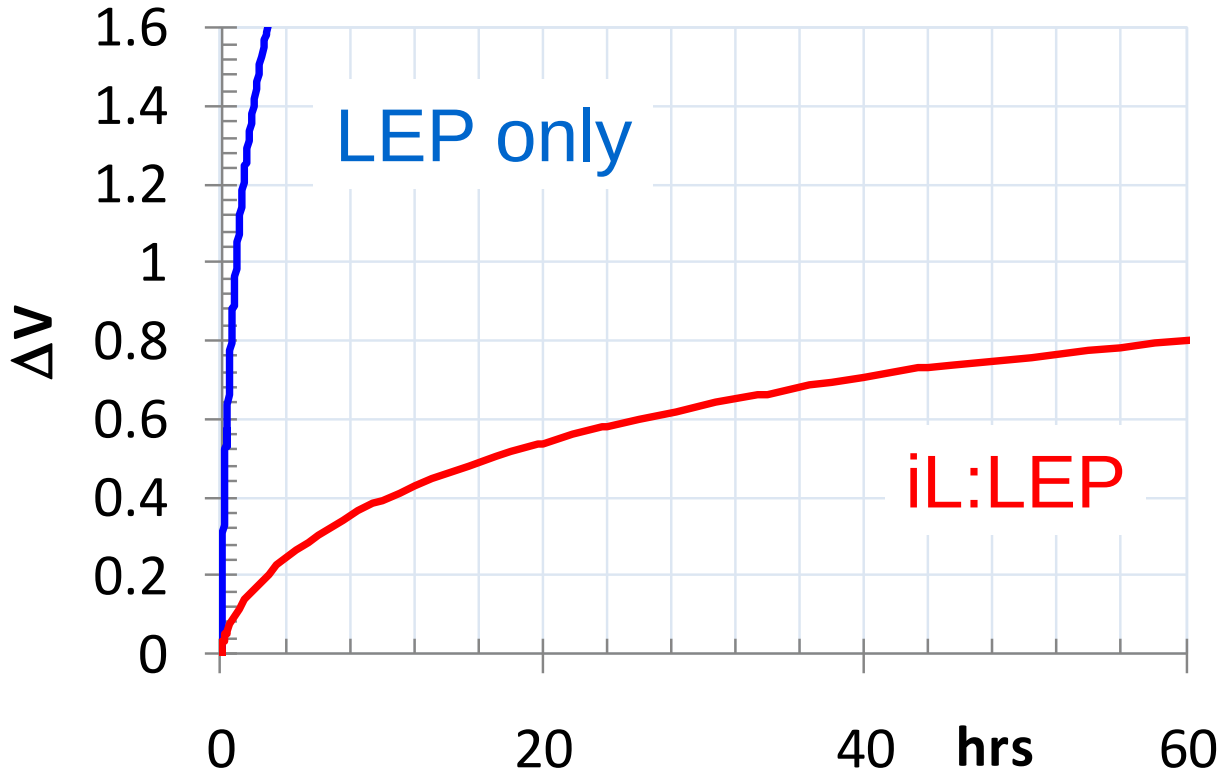


iL improves hole injection

Impact of iL

C|D|T

iL:LEP = Model materials



iL significantly reduces ΔV/Δt and ΔV at T50

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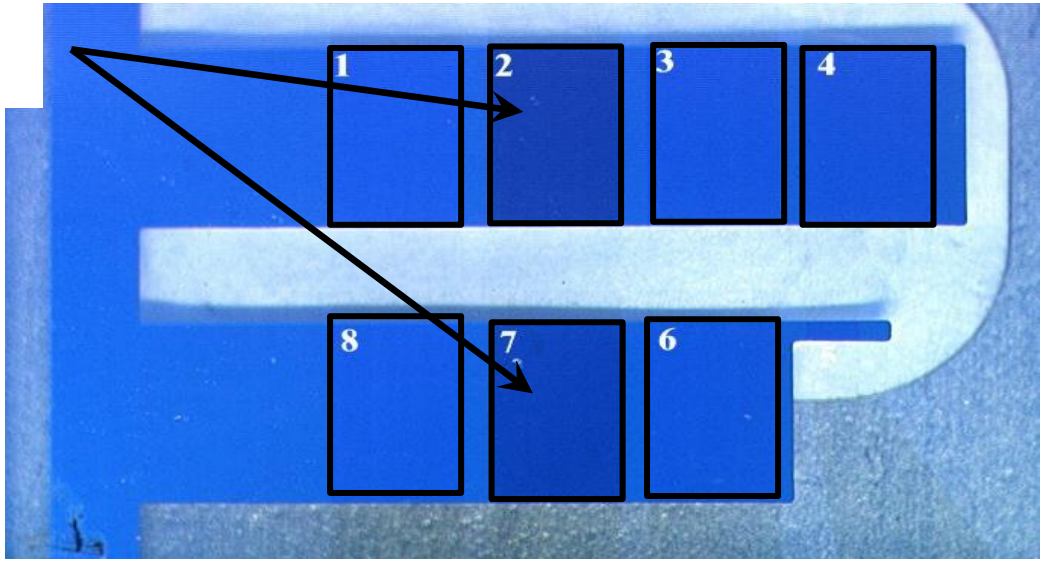
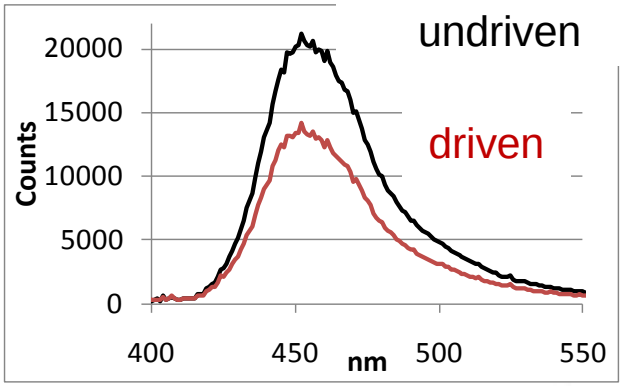
PL degradation

iL:LEP = Model materials

Driven pixels

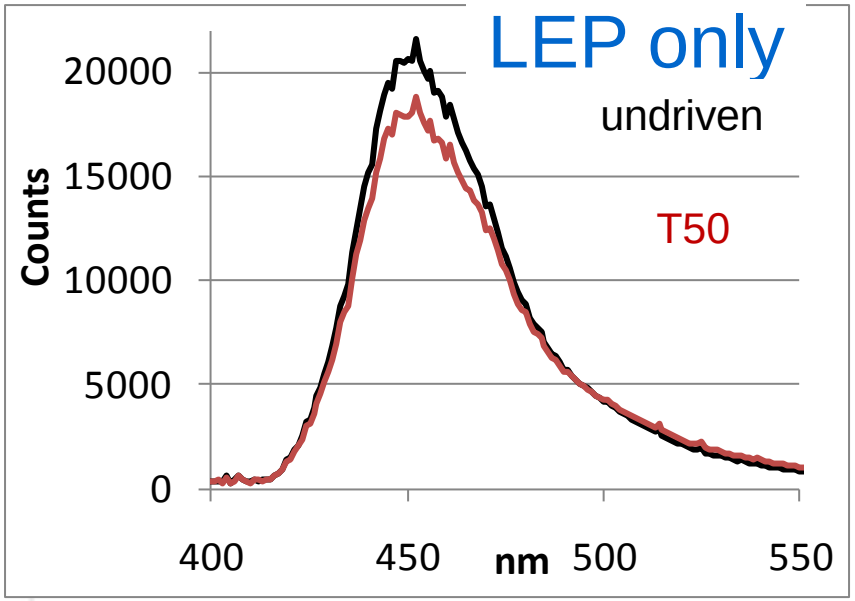


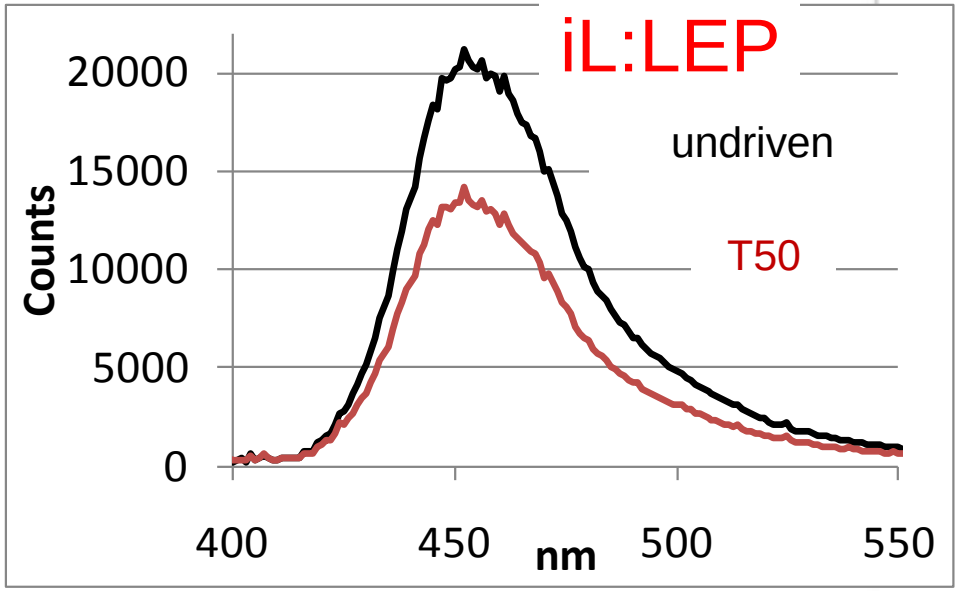


→ UV fluorescence can show clear evidence PLQE drop
→ Note no greenshift in degraded spectrum

Impact of iL

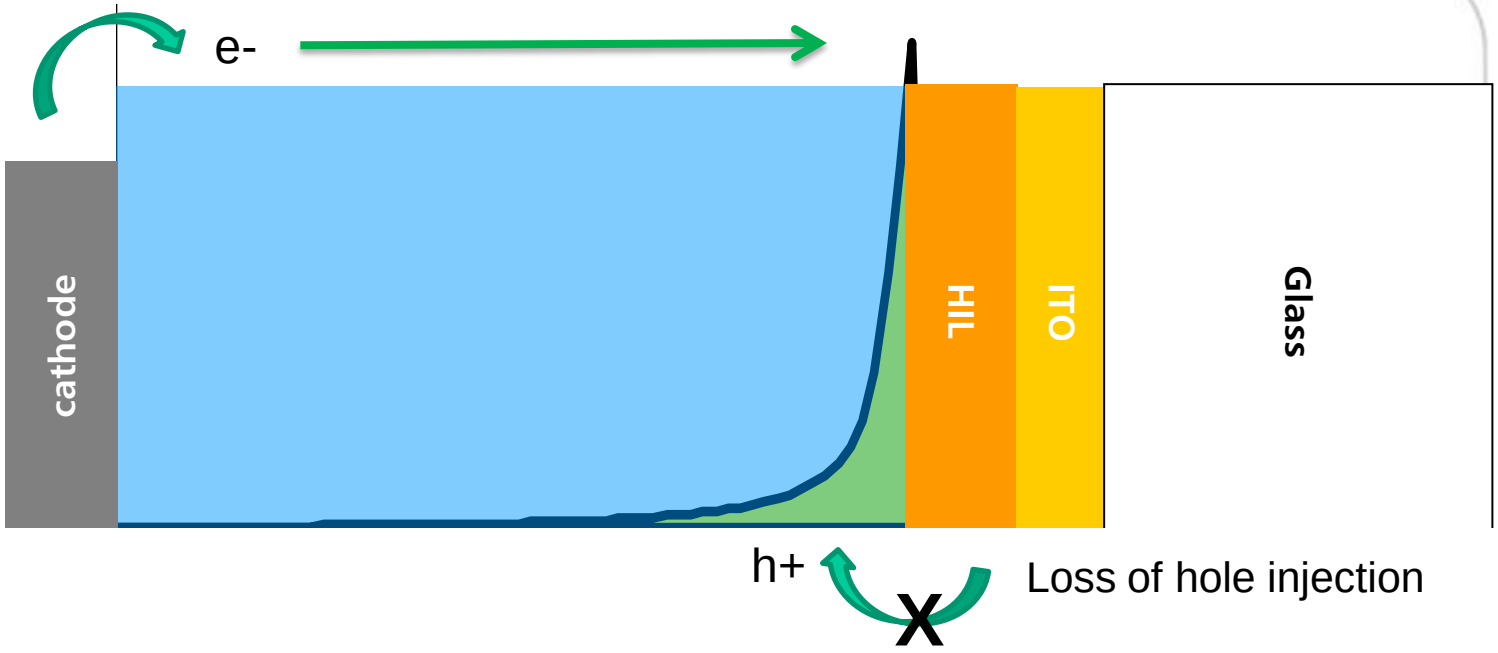
iL:LEP = Model materials





→ Relative importance of PL degradation increased with iL

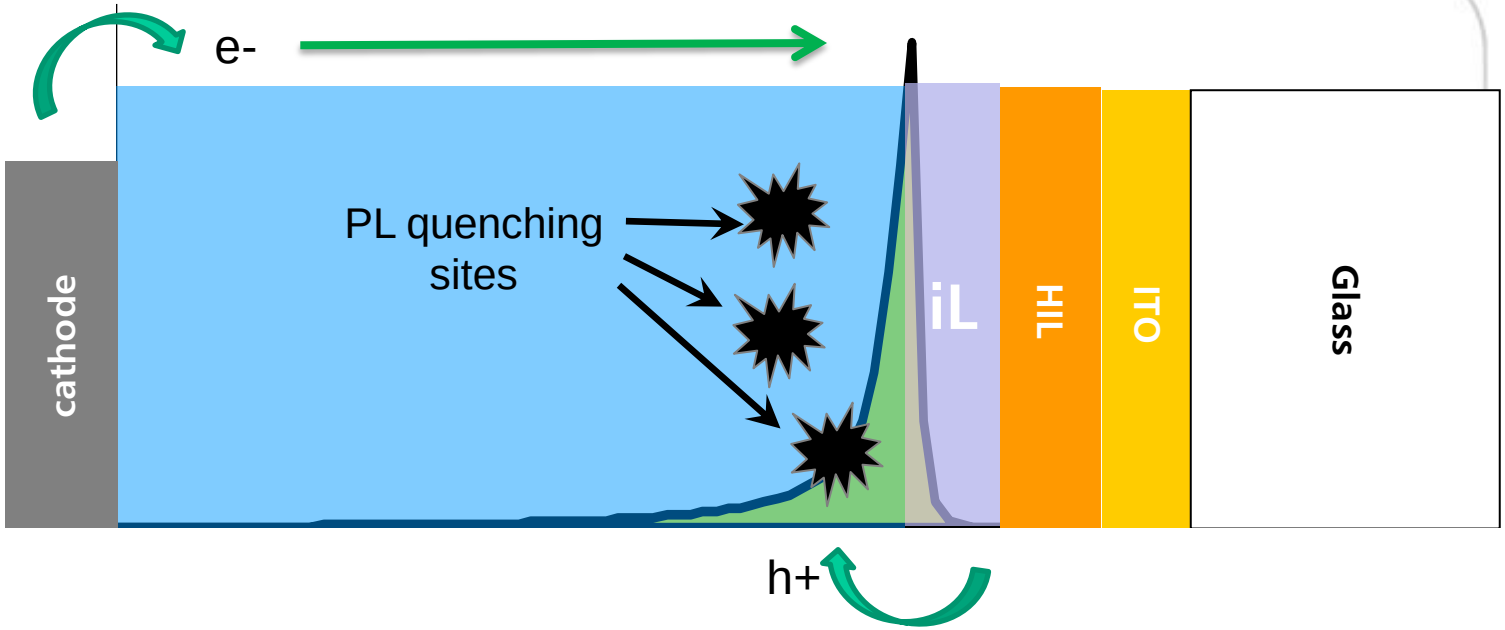
iL vs iL free device degradation



→ Understand in terms of 2 degradation mechanisms

→ iL free device degradation dominated by hole injection fa*ilu*re

iL vs iL free device degradation

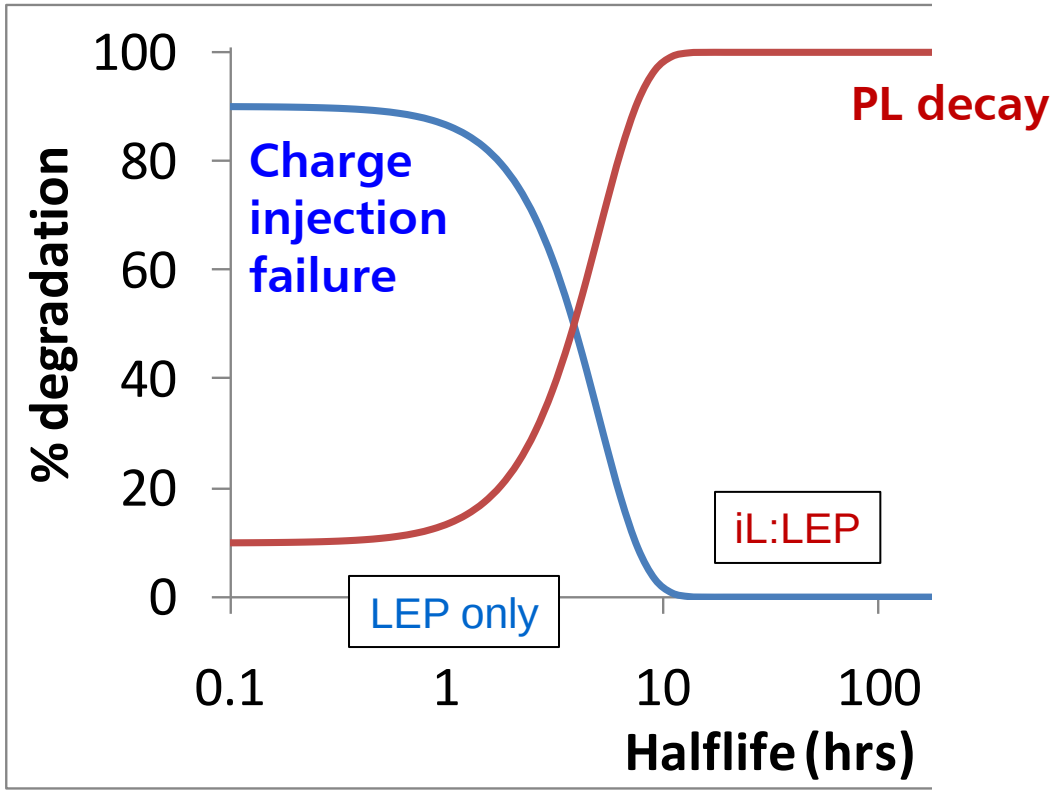


→ Understand in terms of 2 degradation mechanisms

→ iL free device degradation dominated by hole injection failure

→ Stabilising charge injection failure allows us to look at intrinsic material stability, dominated by PL decay

Summary : Degradation mechanisms

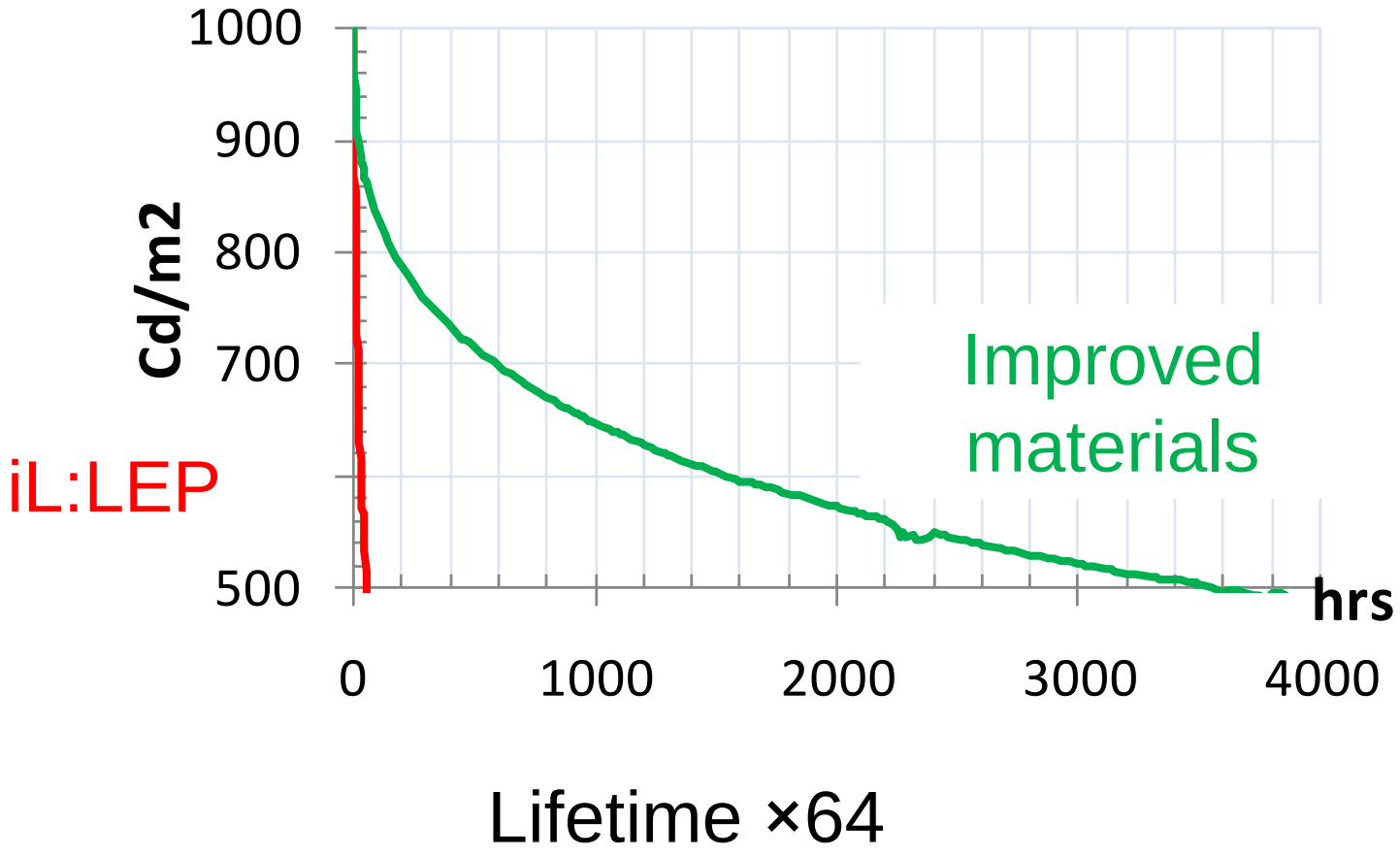


Case study 2

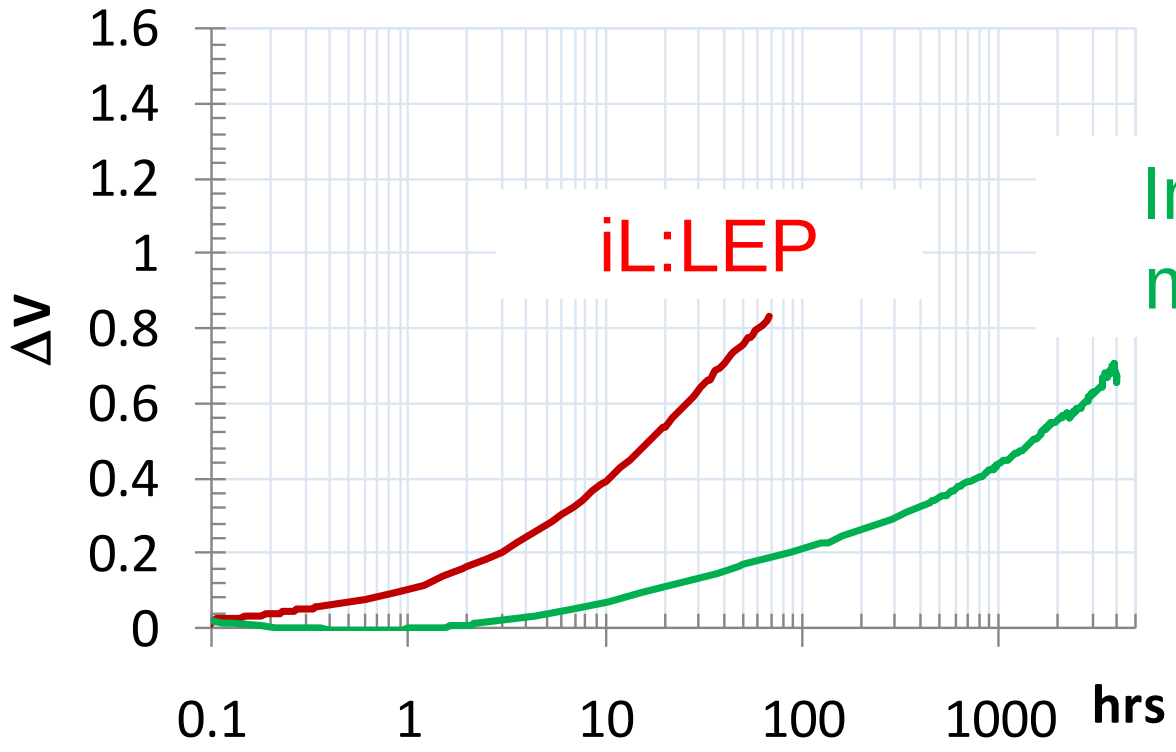
Model materials vs improved materials

iL:LEP device structure

Impact of improved materials



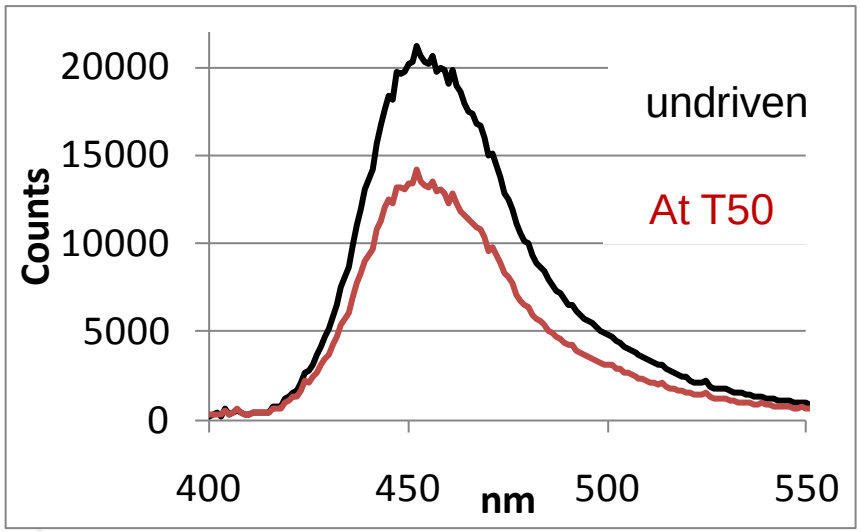
Impact of improved materials



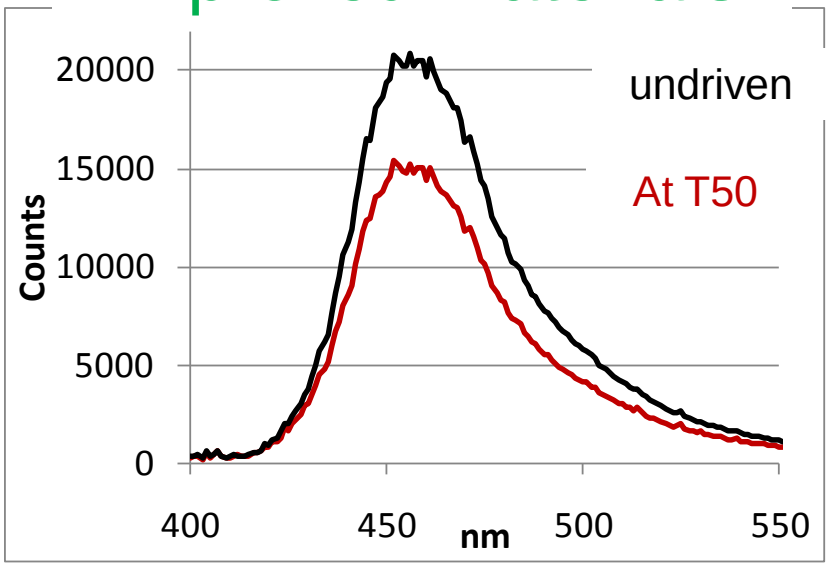
ΔV/Δt improved, but ΔV at halflife similar.

Impact of improved materials

iL:LEP

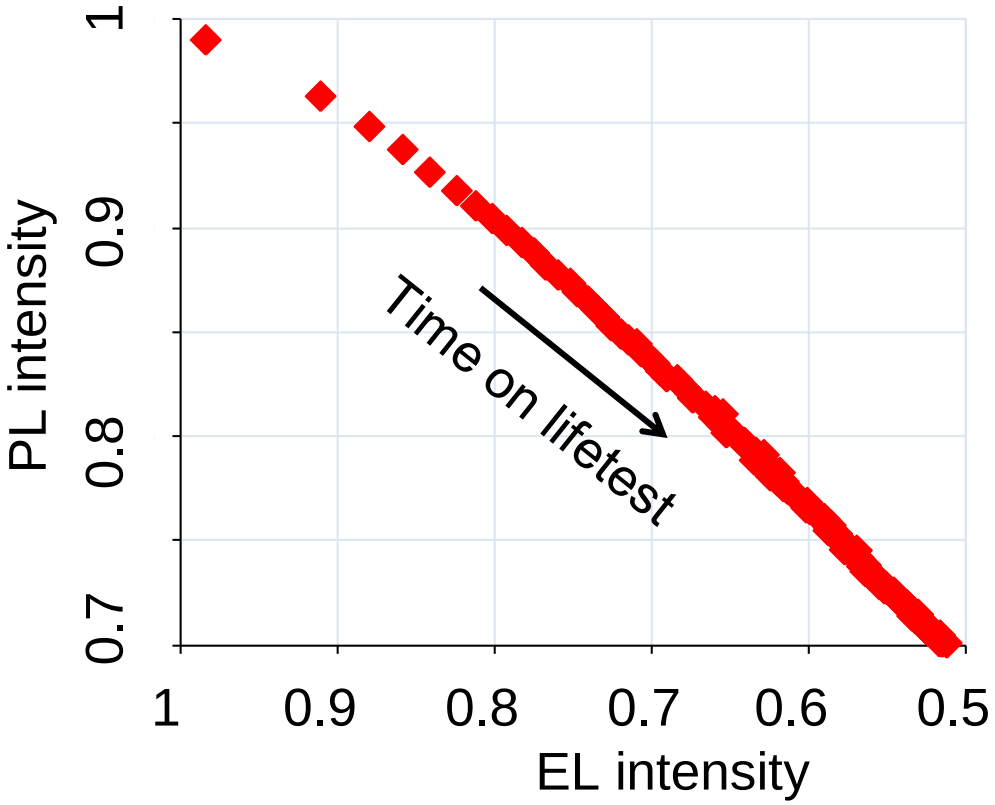


Improved materials



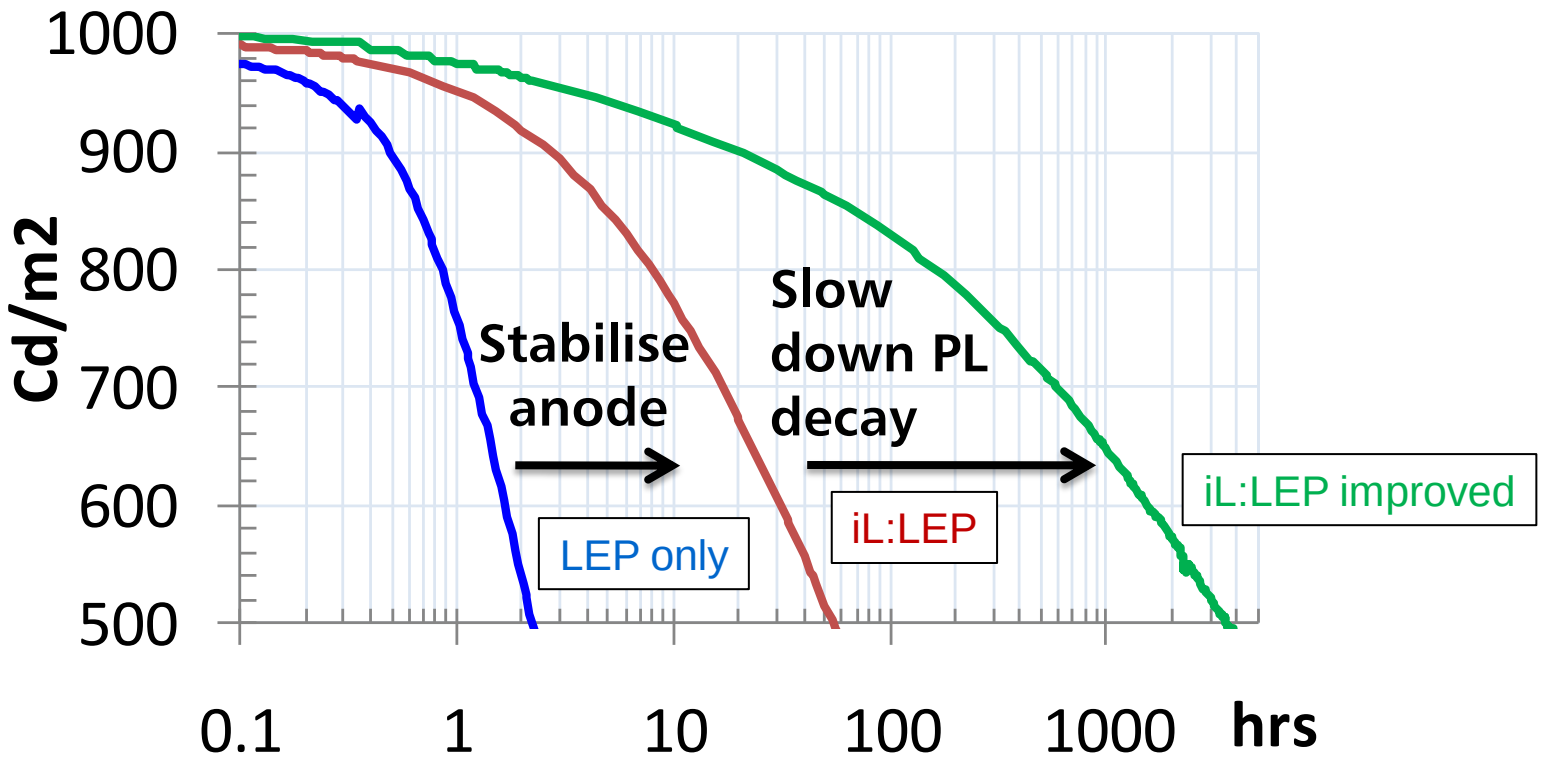
PL drop similar (~30%) over lifetime

EL vs PL decay



- 30% drop in PL for 50% drop in EL
- Narrow RZ suggests that PL drop might explain all of EL drop
- PL decay dominates degradation in model and improved materials

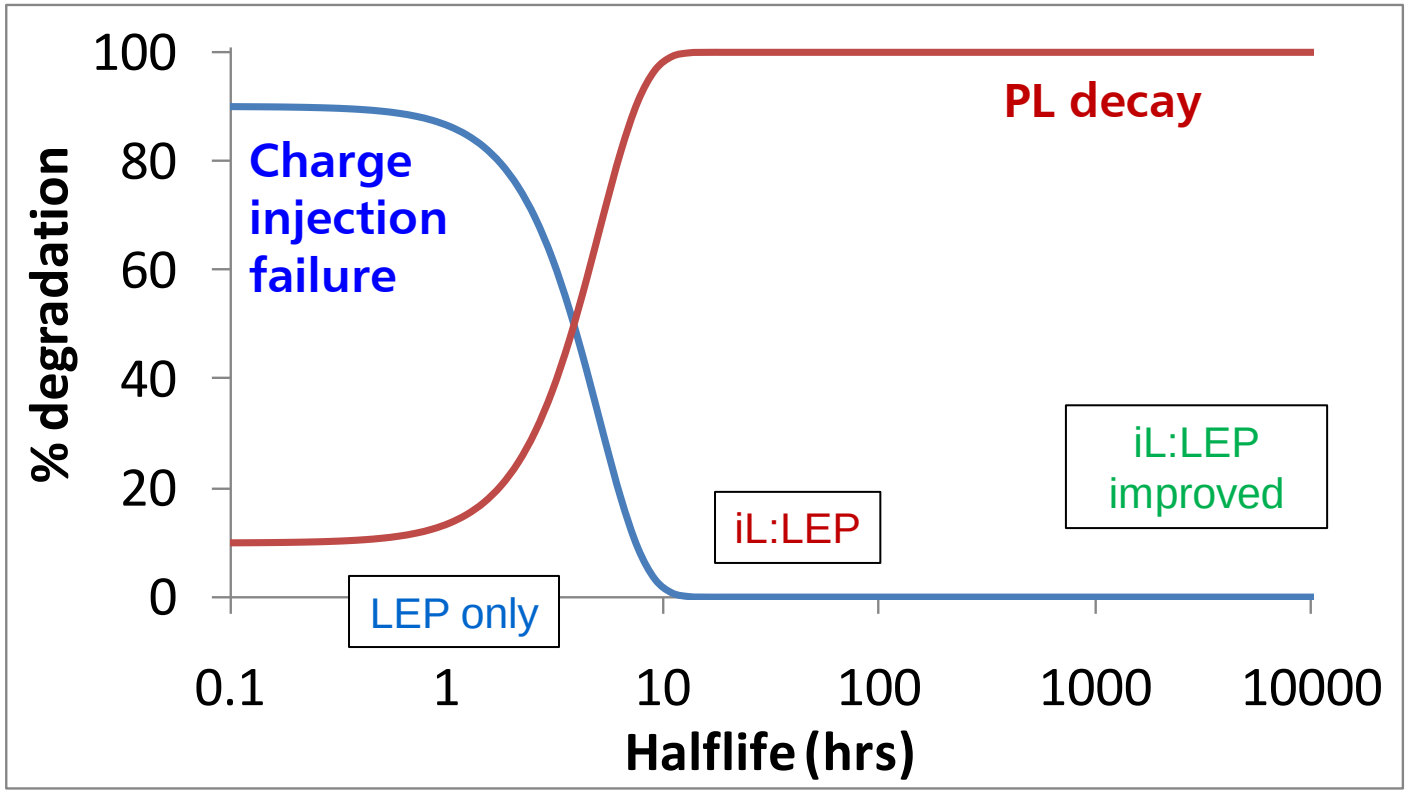
Summary : Degradation mechanisms



→ Stabilising injection allows us to probe intrinsic material stability
→Slowing down PL decay rate can give dramatic improvements in T50

SUMITOMO CHEMICAL

Summary : Degradation mechanisms



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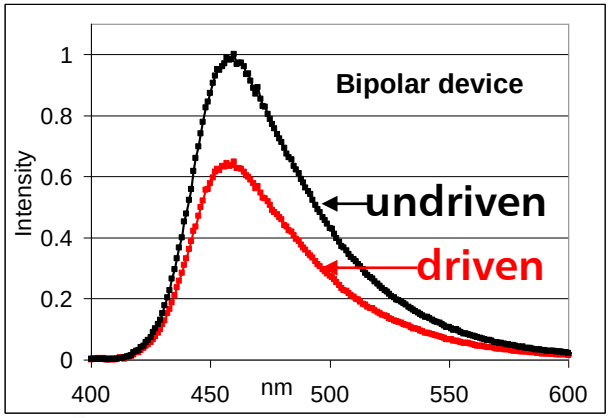
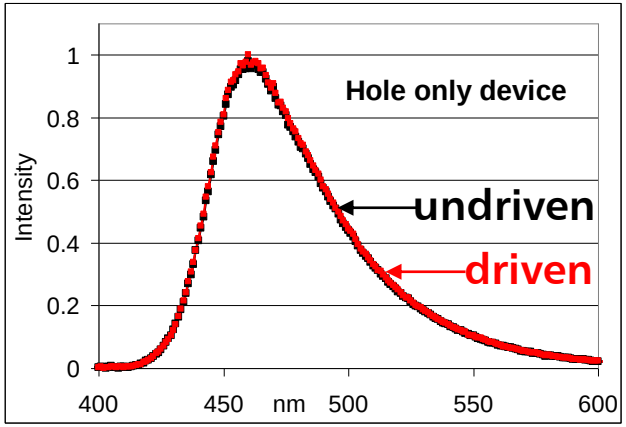
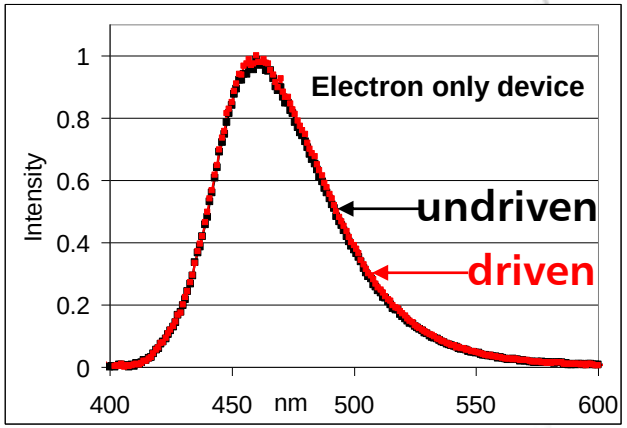
Cause of PL decay

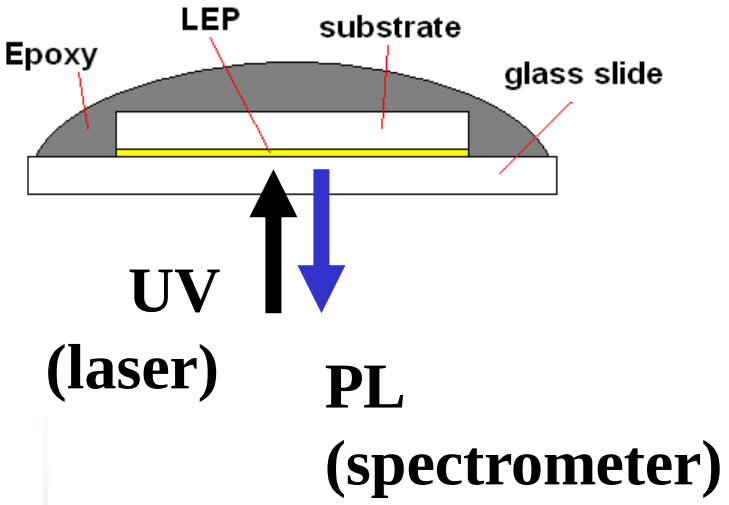


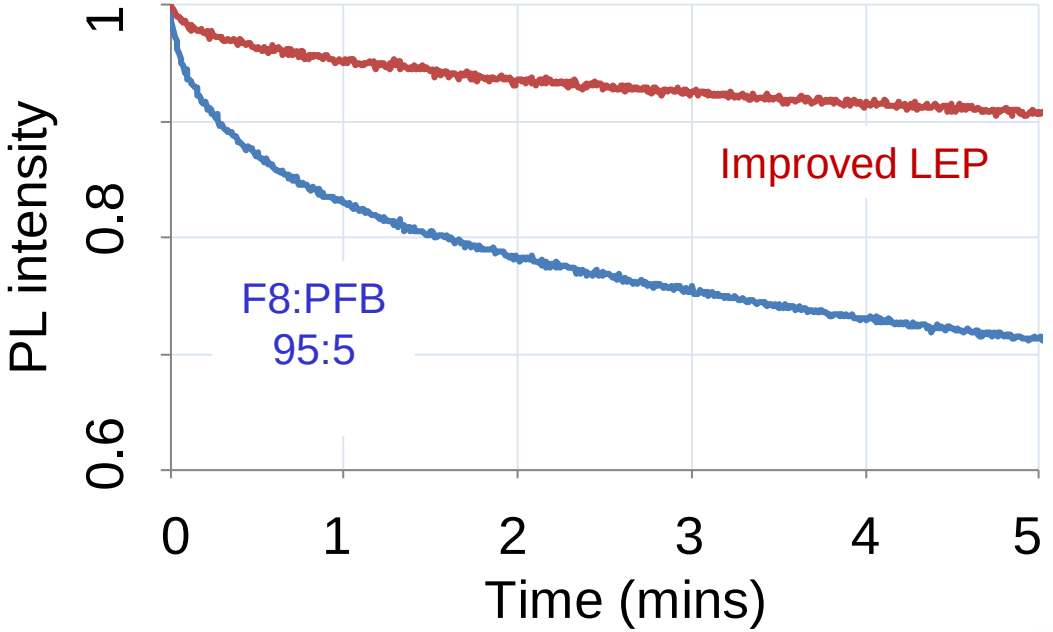




→Charge fluence alone does not generate PL quenching sites

Cause of PL decay



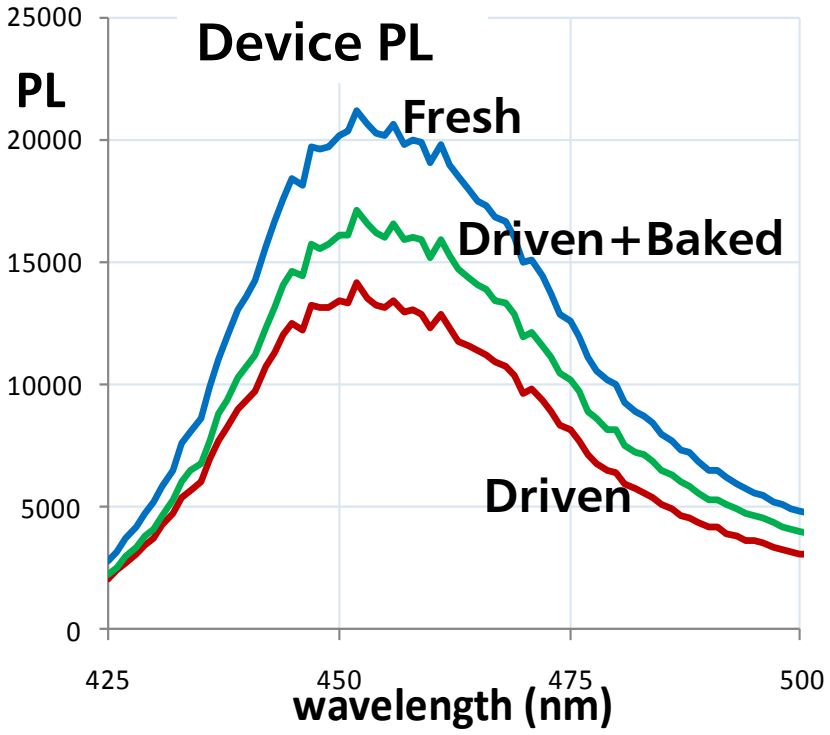


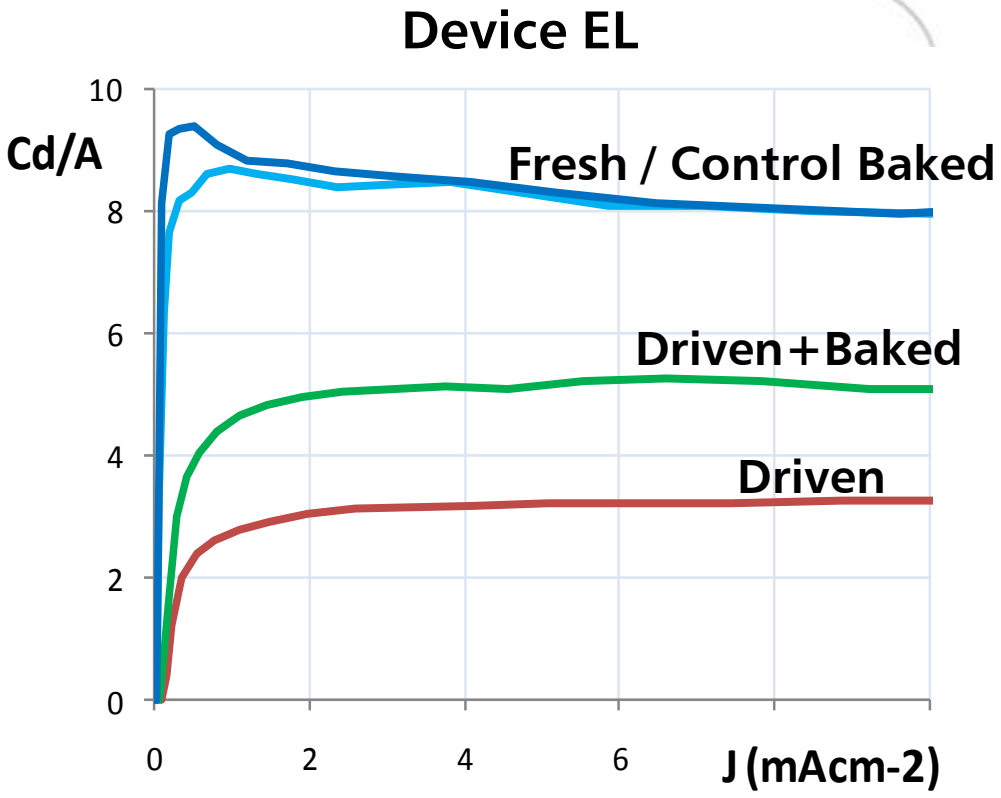
→ UV generated excitons can generate PL quenching sites
→ Improved LEP materials are more stable to excitons

→ Excitons cause degradation

Recovery of PL decay

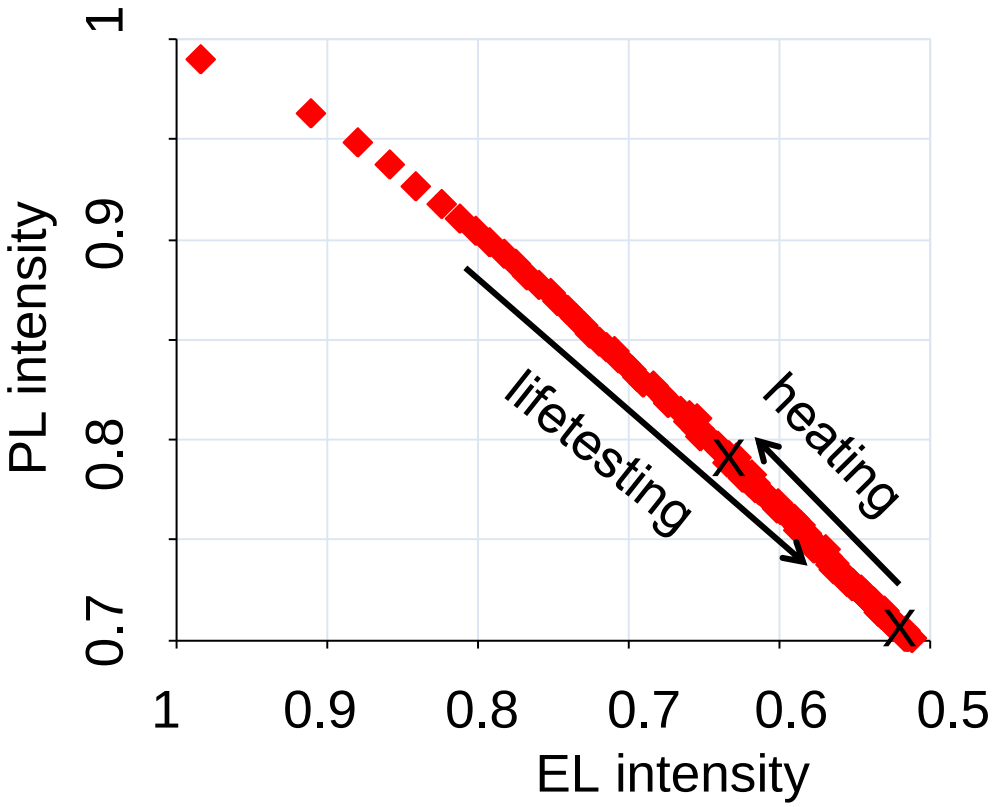
iL:LEP = Model materials





→ PL decay can be split into 'permanent' and 'recoverable' components
→ ~40% of EL and PL decay at T50 can be recovered by baking!!

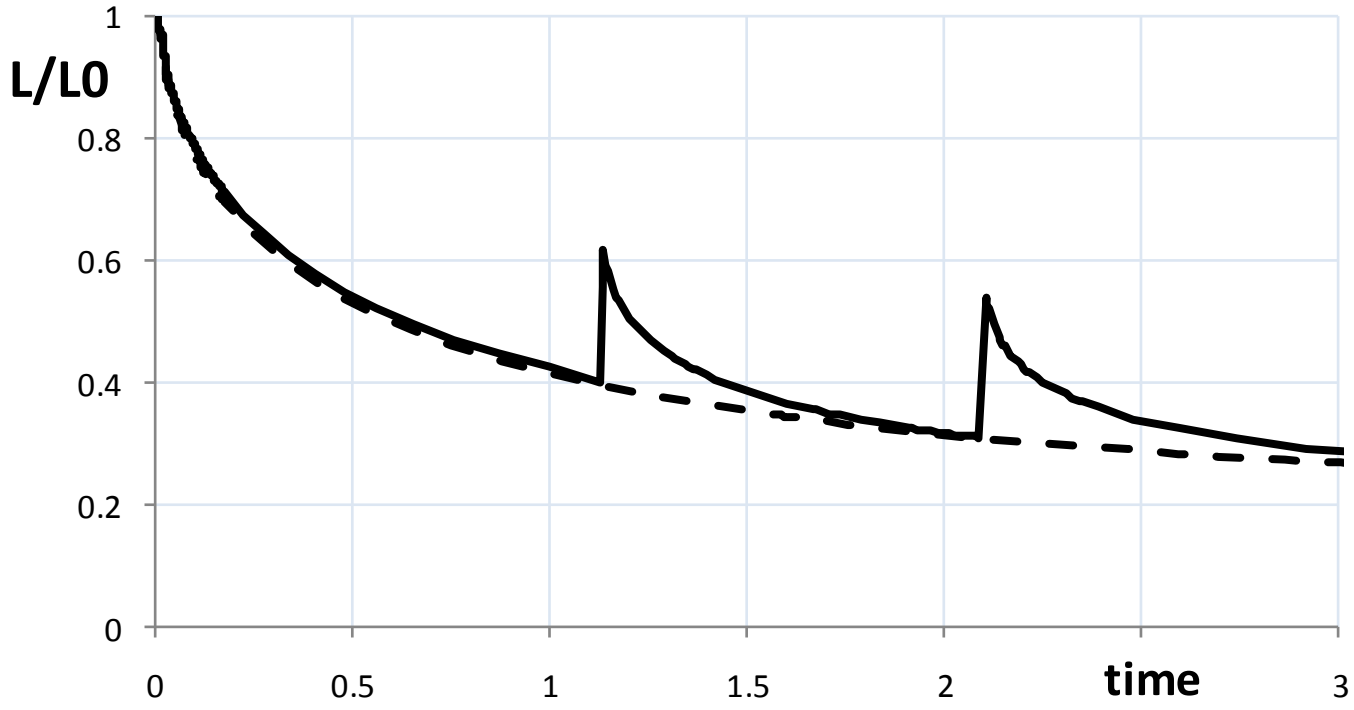
EL vs PL decay



- Baking the device recovers the PL and EL
- Consistent with all of the EL drop being explained by PL drop
- Improved materials set give more PL recovery

Reversibility of EL decay

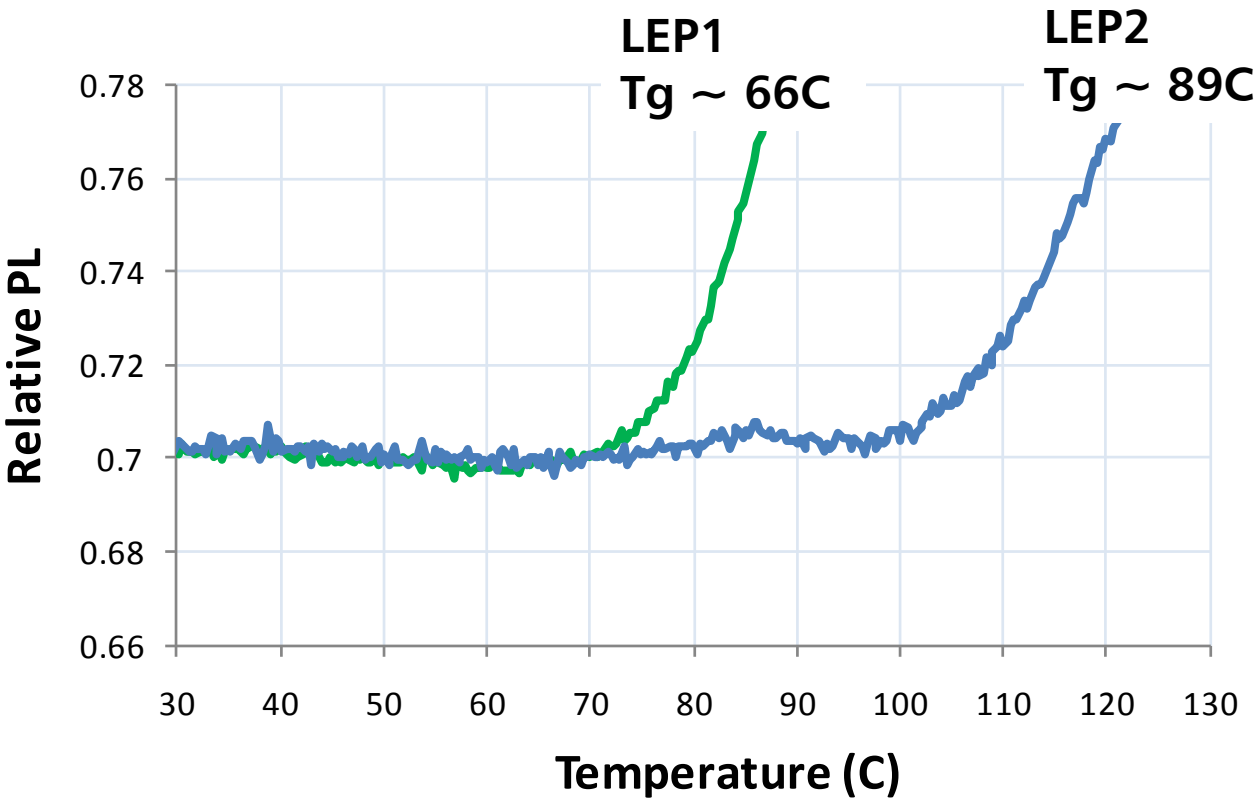
iL:LEP = Model materials



→ In this model system, permanent component dominates

→ Recoverable component of decay is truly recoverable – thus component of the degradation can really be 'healed'

Tg dependence of PL recovery

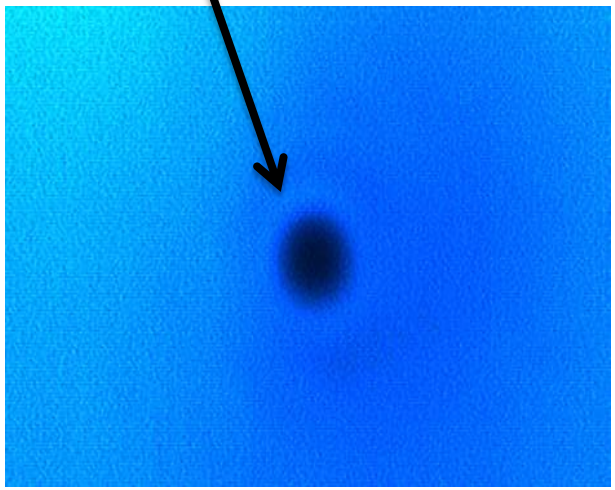


Threshold / activation temperature for PL recovery is the LEP Tg

PL recovery in UV degraded films

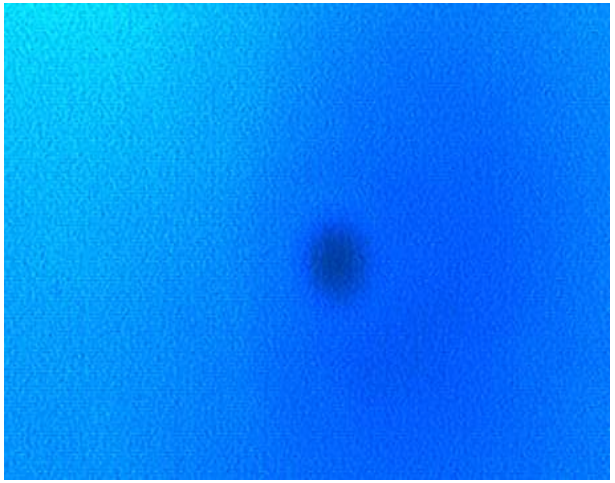
iL:LEP = improved materials

PL degraded area from UV laser illumination



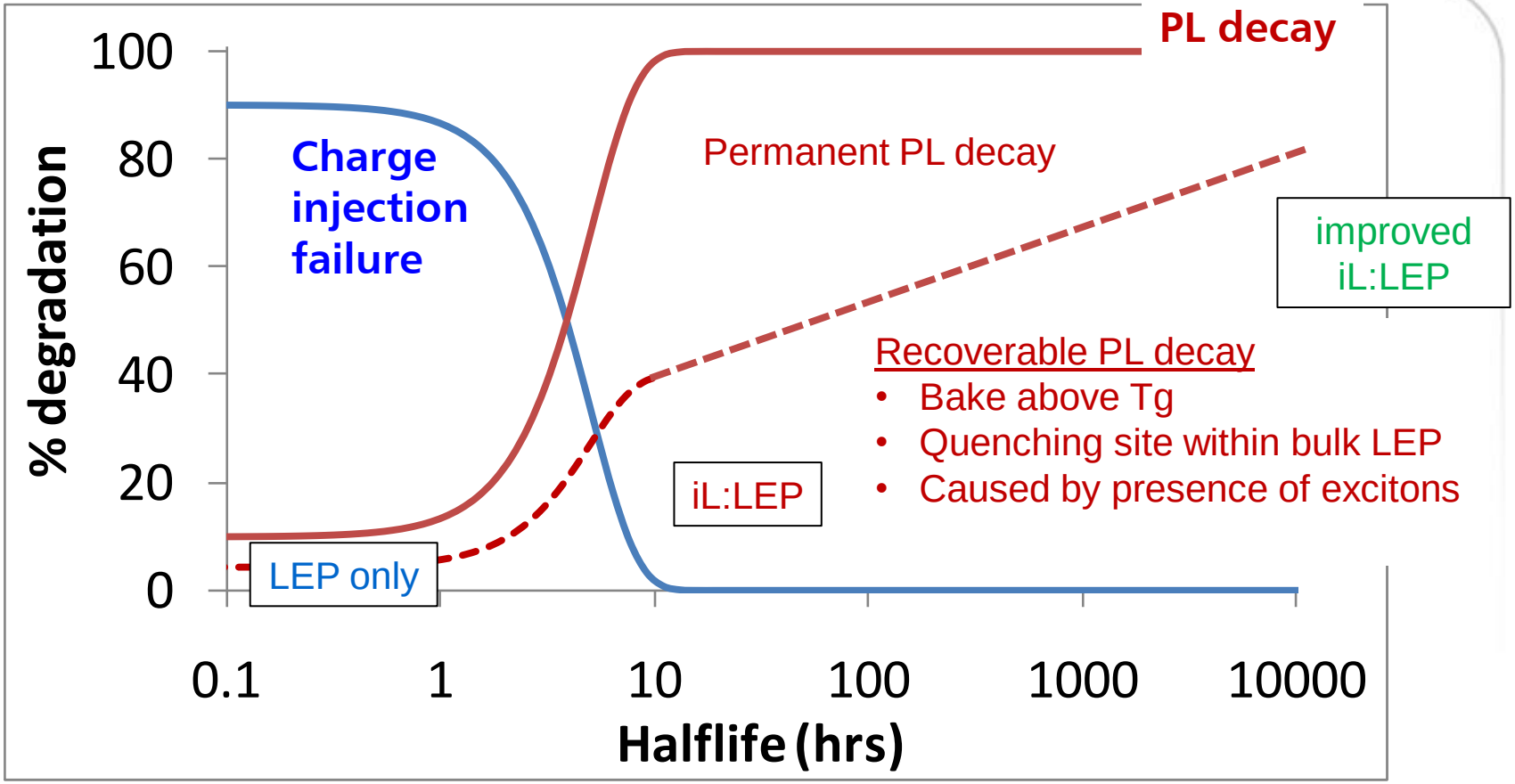
Bake Above Tg

Significant recovery of PL in degraded area



Significant recoverable PL is also observed in UV degraded films

Summary: P-OLED stability



- **Understanding the reversible PL decay is key to improving P-OLED lifetimes**
- **Model materials set show similar but vastly accelerated degradation mechanism**
- **Optical excitation provides a simple model for understanding fundamental mechanisms**