"Low band gap" polymers for near infrared light-emitting diodes

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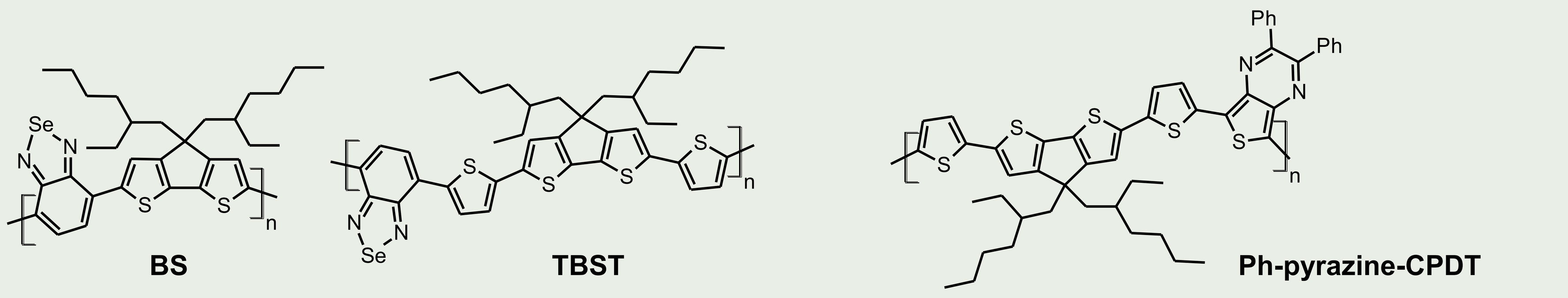
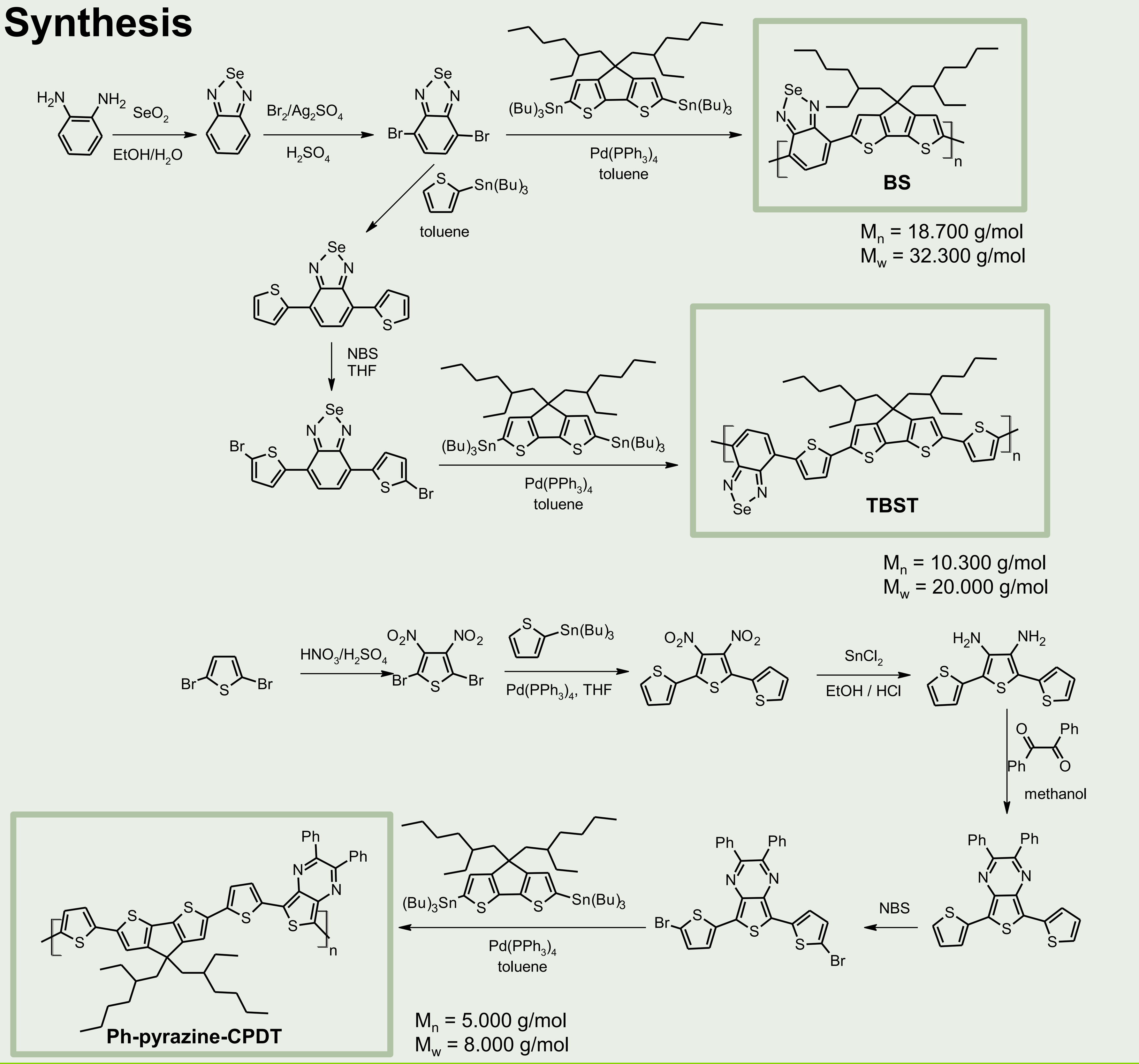
Introduction

Recently, polymeric materials with absorption and emission in the near infrared have attracted attention for their potential use in photovoltaic devices[1], photodetectors[2] and light-emitting diodes[3].
Here we present the synthesis and characterization of three different low band gap polymers for applications in near infra-red light emitting diodes.

Se-containing polymers — thienopyrazine based polymer



Synthesis



BS: M_n = 18.700 g/mol, M_w = 32.300 g/mol

TBST: M_n = 10.300 g/mol, M_w = 20.000 g/mol

Ph-pyrazine-CPDT: M_n = 5.000 g/mol, M_w = 8.000 g/mol

Photoluminescence of Se polymers

- Solution PL shows NIR emission.
- PL efficiency of films <1 %
- Blends with F8BT show emission peaks in visible and NIR.
- Increasing TBST concentration increases NIR component to >50%.
- PL efficiency of blended films (concentration 5%):
  2 ± 0.5 % for BS
  4 ± 1 % for TBST
- High PL efficiency of blends compared to pure material films likely to be due to a reduction in aggregation.

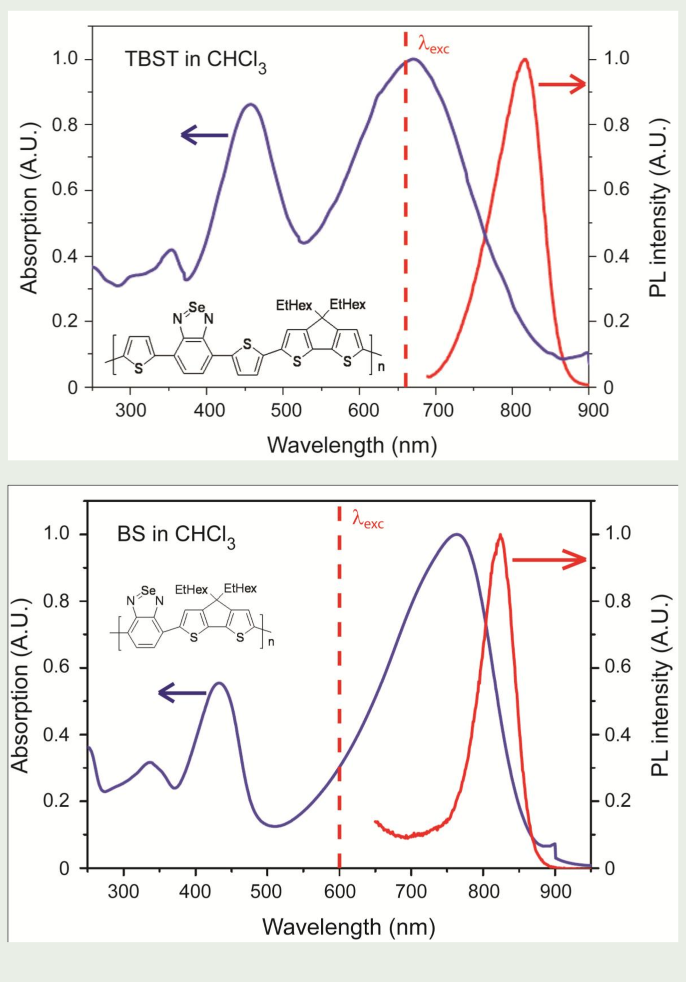


Figure 2 – Solution absorption and PL of BS and TBST.

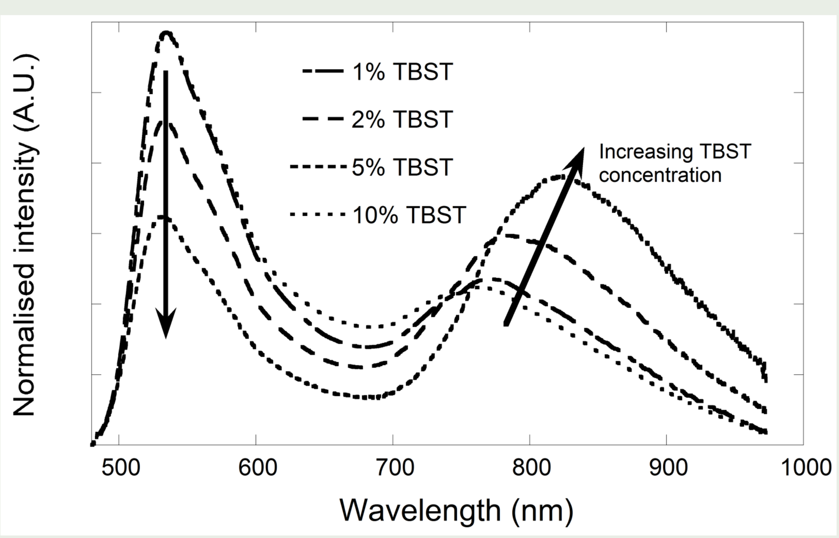


Figure 3 – PL of blended films of F8BT and TBST plotted for different TBST concentrations. λexc = 325nm

	η_{PL} in NIR (%)
BS	< 1 %
TBST	< 1 %
F8BT : BS (5%)	2 ± 0.5
F8BT : TBST (5%)	4 ± 1

Table 1 – Photoluminescence efficiencies of the polymers and blends with F8BT

Light-emitting diodes (Se polymers)

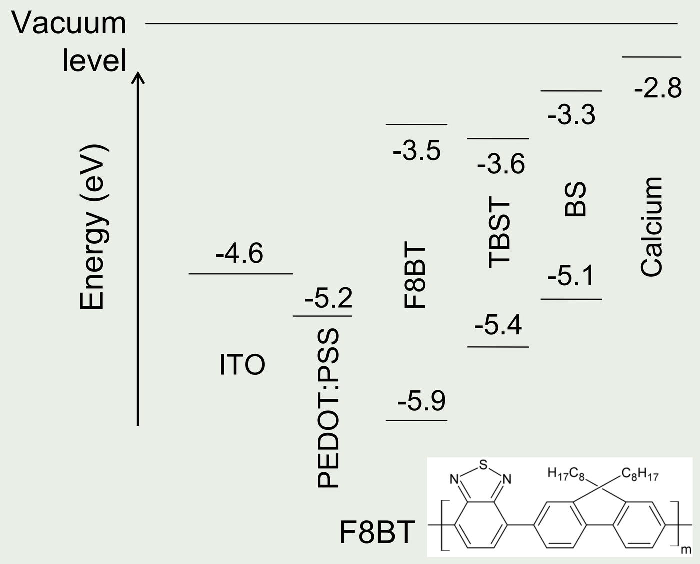


Figure 5 – (Top) Energy levels of the materials inside the devices. (Bottom) chemical structure of poly(9,9'-dioctylfluorene-alt-benzothiadiazole), F8BT. →

ITO / PEDOT:PSS / Active layer / Ca / Al

- PEDOT:PSS hole injection layer (~80 nm thick).
- Active layer is a blend of F8BT, BS, TBST or a blend of F8BT with BS or TBST (5%) (~90 nm thick).
- Spin-coated from a 2 % (wt/wt) solution of the blend in toluene.

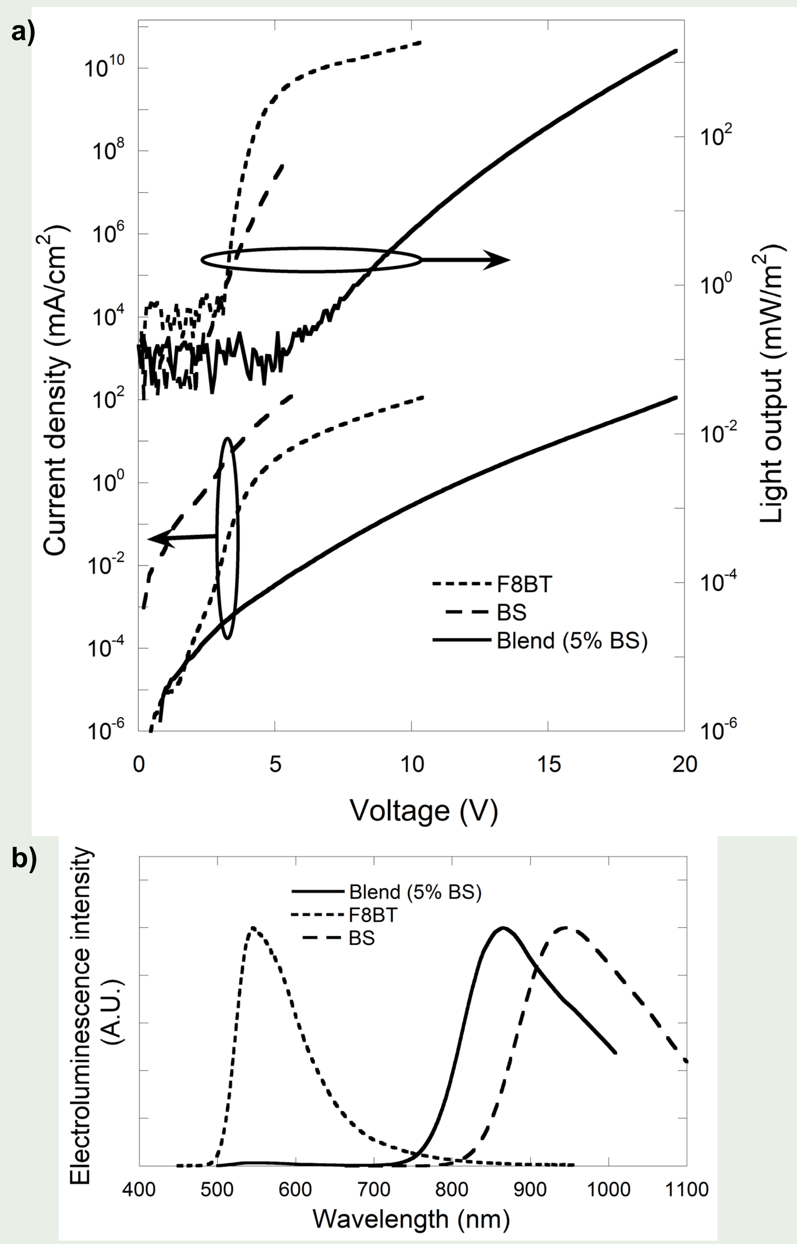


Figure 6 – **a)** IVL characteristics of devices incorporating BS. **b)** EL spectra of these devices.

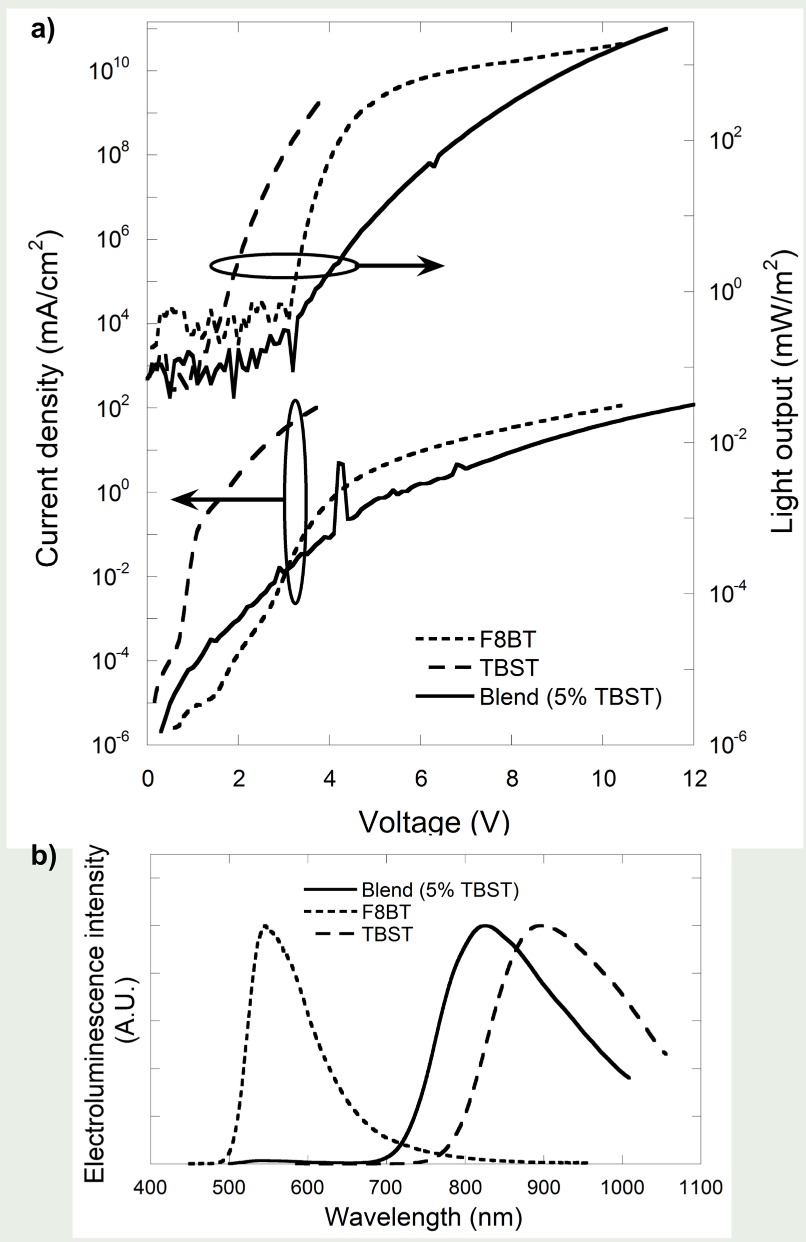
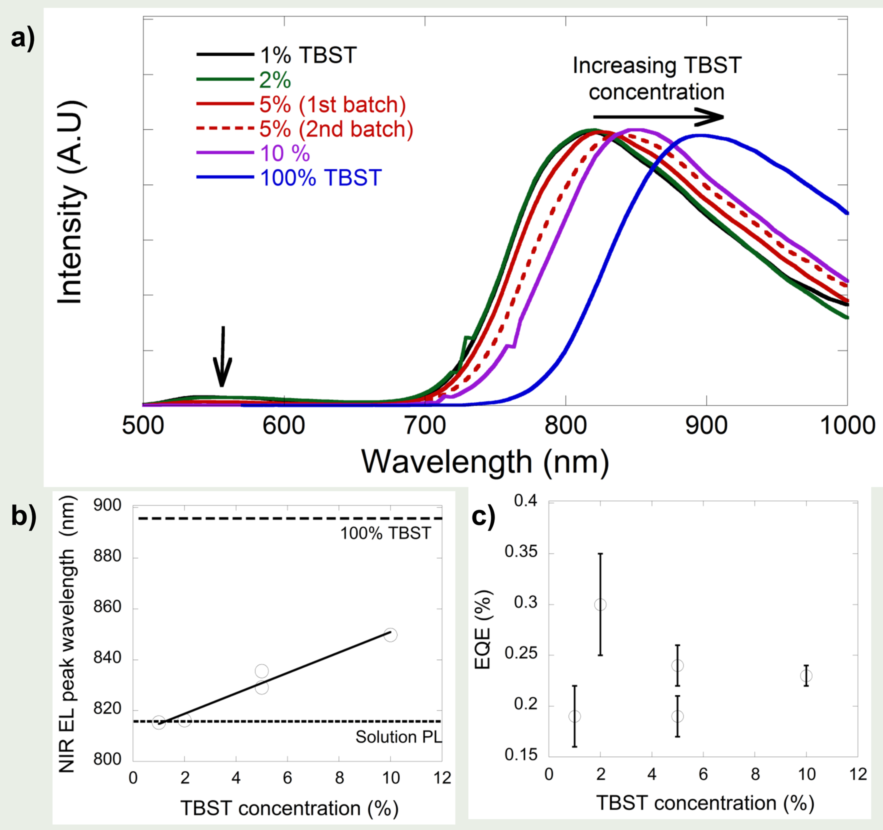


Figure 7 – **a)** IVL characteristics of devices incorporating TBST. **b)** EL spectra of these devices.

- NIR emission observed.
- Efficiency of single polymer-based devices low.
- Blend-based devices show higher efficiencies and higher light turn-on voltages (V_{on}(L)).
- Blue-shift of spectrum of blend-based devices and higher efficiencies indicate reduced aggregation compared to single polymer –based devices.

	V_{on}(L) [at 0.2 mW/m²]	EQE_{EL} (%)	L_{max} (mW/m²)	EL in NIR (%)
F8BT	3.1 ± 0.1	0.49 ± 0.14	2800 ± 1200	-
BS	2.9 ± 0.2	0.00036 ± 0.00007	55 ± 21	-
TBST	1.3 ± 0.2	0.026 ± 0.004	410 ± 70	-
F8BT : BS (5%)	7.3 ± 0.2	0.14 ± 0.02	1400 ± 90	99.1
F8BT : TBST (5%)	3.0 ± 0.1	0.24 ± 0.02	3700 ± 800	99.3
F8BT : TBST (2%)	3.5 ± 0.1	0.30 ± 0.05	4800 ± 600	98.3

Table 3 – LED performance parameters.



Varying blend ratio for TBST

- For >2% TBST, EL is red-shifted
  → Aggregation
- At 2% TBST
  - 98.3% of EL from TBST
  - EL similar to solution PL
  - Maximum EQE (0.30 ± 0.05 %)

→ 2 % concentration of the TBST dopant gives optimum performance

Figure 8 – **a)** EL spectra of blended TBST : F8BT devices. **b)** Peak emission wavelength plotted as a function of TBST concentration. **c)** EQE plotted as a function of TBST concentration.

Conclusion

We have synthesised two selenium containing and one thienopyrazine-based low band gap polymers for electronic applications.
The selenium containing polymers were characterised by photoluminescence spectroscopy and tested for NIR-OLED applications. In LEDs, we observed NIR emission in single polymer and blend-based devices (host: F8BT). For the blended devices we observed *0.30 ± 0.05 % EQE for TBST, and 0.14 ± 0.02 % for BS (dopant conc.: TBST 2%; BS 5%).*
Electroluminescence from the host was almost completely quenched in all cases.

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