Technische Universität Dresden

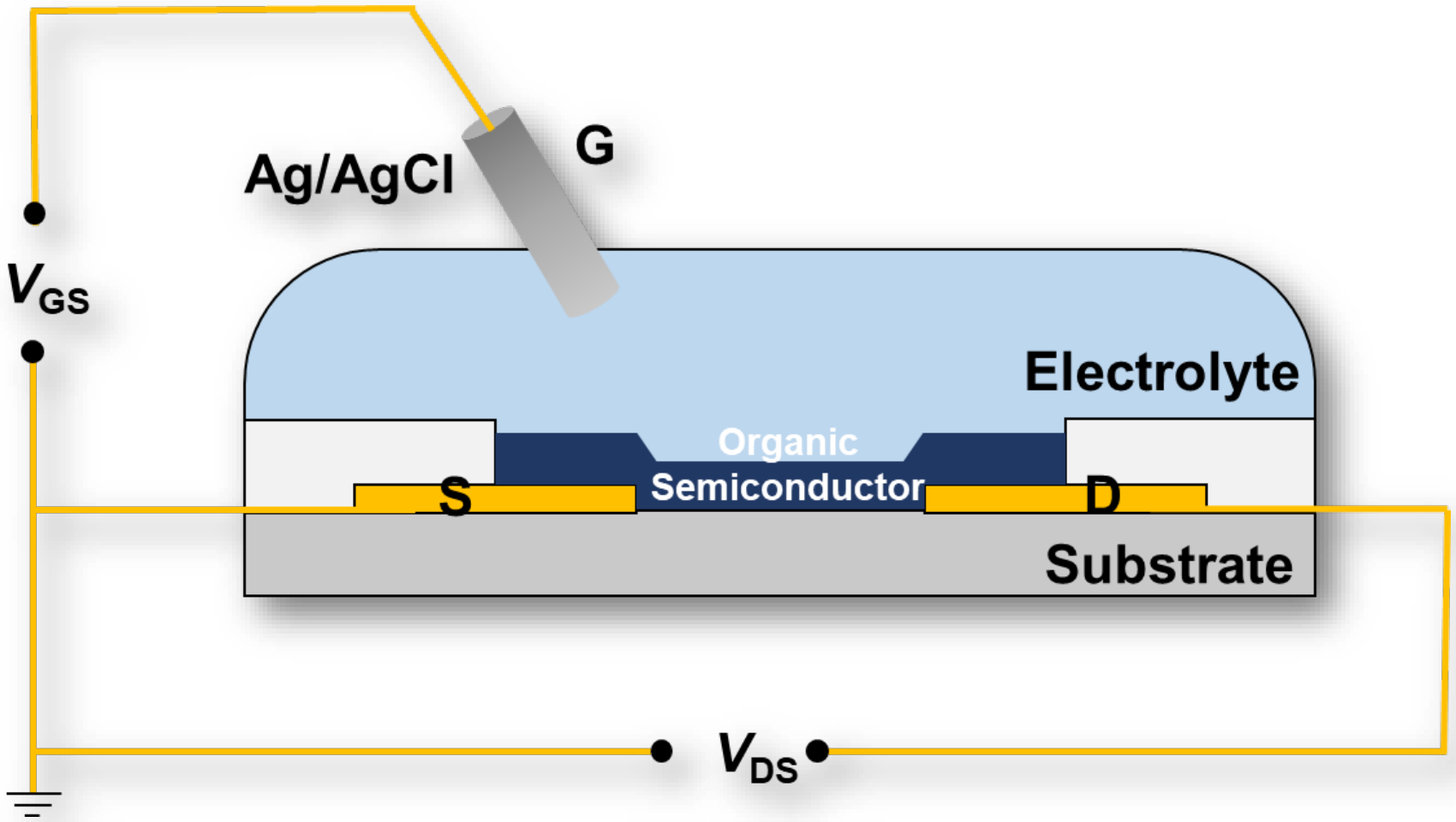
DRESDEN concept

Bioelectronics and Neuromorphic Computing with Organic Electrochemical Transistors

Lecture Summer Term 2026

Hans Kleemann, Peiyun Li
(Dresden Integrated Center for Applied Physics and Photonic Materials)

6. Materials in OECT



- Electrolyte
- **Channel material**
- Electrode (Gate, S&D)
- Encapsulation
- Substrate

6. Materials in OECT

6.1 Electrolyte & Electrode & Encapsulation & Substrate

Electrode:
- S&D,

Au, carbon, conducting polymer…
- Gate

Ag/AgCl, conducting polymer, Au…

Encapsulation:
Parylene C, SU-8…

Substrate:
Glass, SiO_2/Si, PET, PI, PU, parylene, SEBS,…

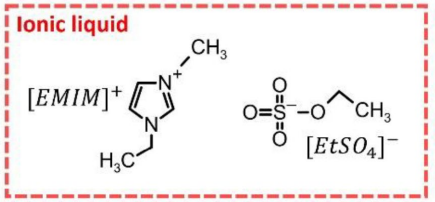
Electrolyte:
- Aqueous

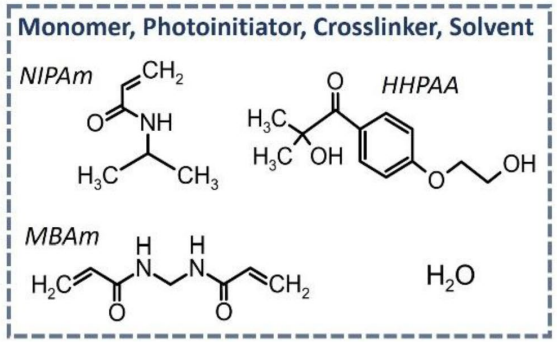
NaCl, KCl, PBS…
- Ion liquid

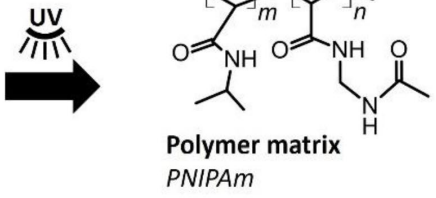
EMIM TFSI…
- Solid state electrolyte

Polymer matrix & ions

Inkjet printed SSE





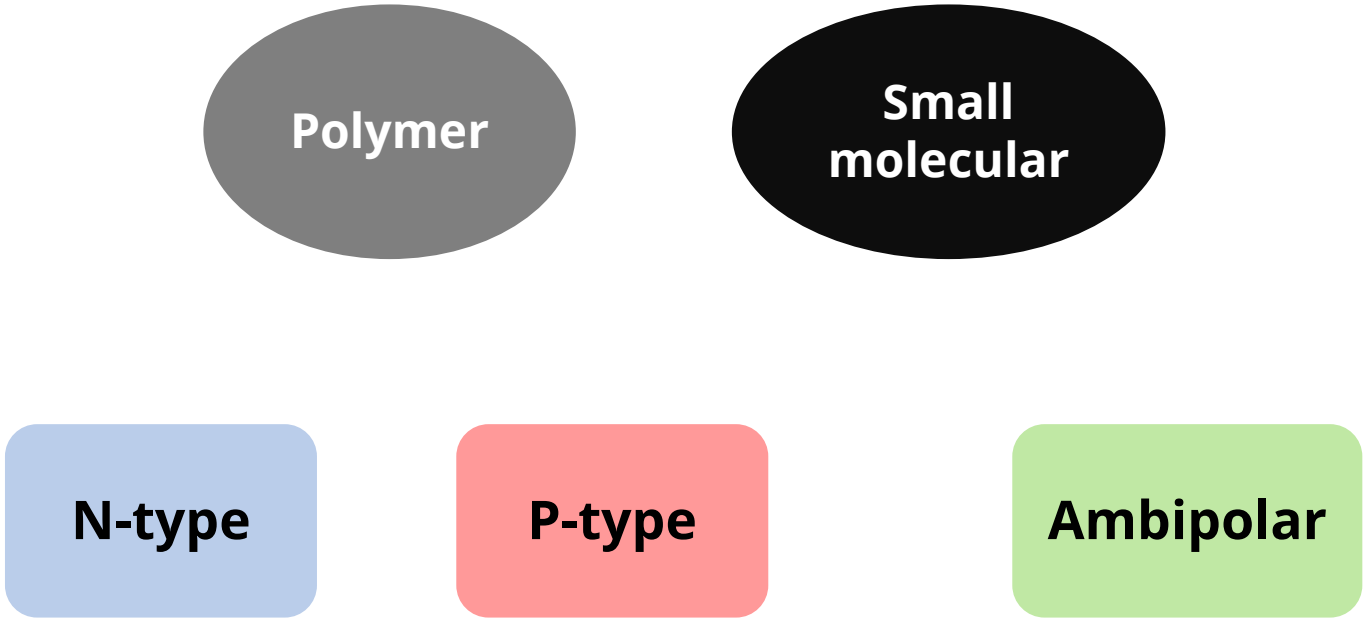


Polymer matrix
PNIPAm

6. Materials in OECT

6.2 Channel

Classification



Depletion/Accumulation mode

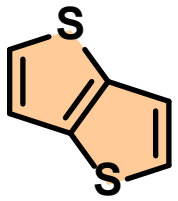
6. Materials in OECT

6.2 Channel

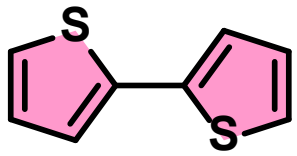
Organic Semiconductor Unit

Donor

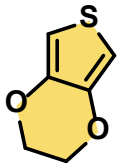
Thiophene



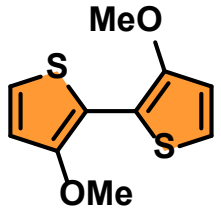
Benzodithiophene



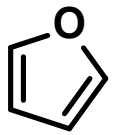
Bithiophene



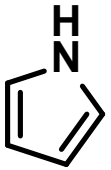
3,4-**e**thylene**di**o**x**y**t**hiophene



dimethoxy-bithiophene

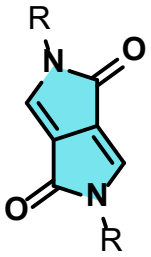


furan

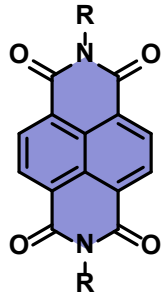


pyrrole

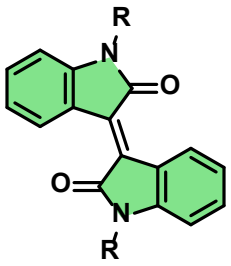
Acceptor



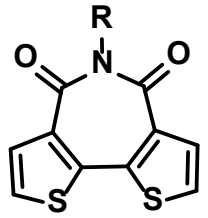
diketo**p**yrrolo**p**yrrole



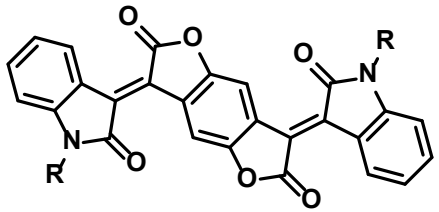
naphthalene **di**imide



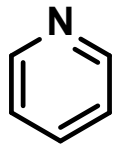
iso**i**n**d**igo



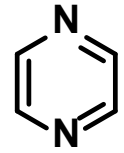
bithiophene **i**mide



BDOPV

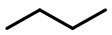


pyridine

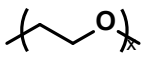


pyrazine

Sidechain



alkyl chain



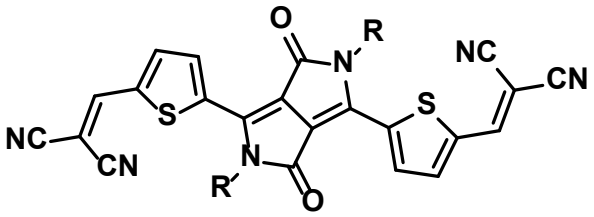
oligo(ethylene glycol) chain

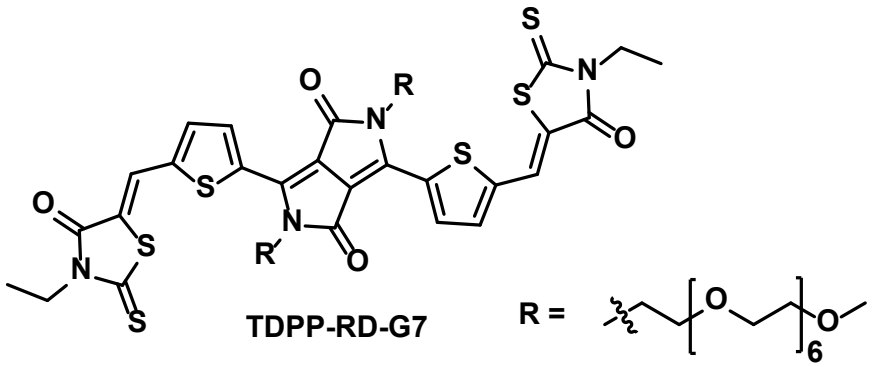
ionic chain

6. Materials in OECT

6.2 Channel

Small molecular

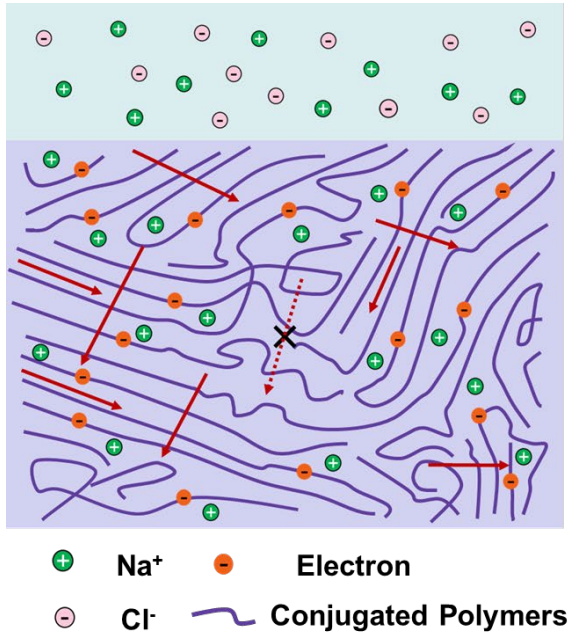


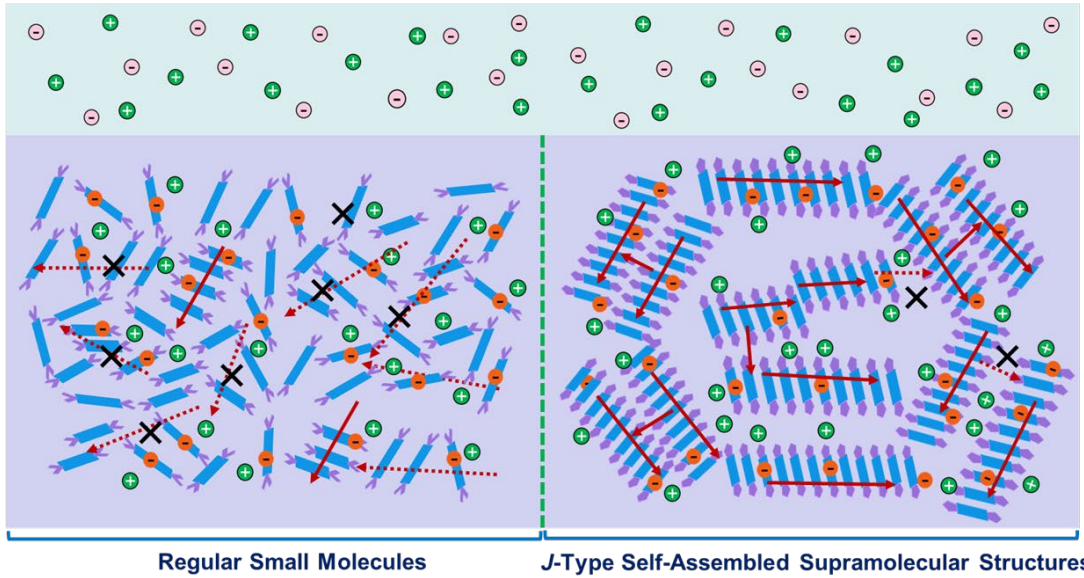


Merit:
- precise chemical structures
- no batch-to-batch variations
- potential high carrier mobilities

Challenges
Poor tolerance to ions

Method
- Improve intermolecular interaction
- Provide stable transport paths for ions and electrons



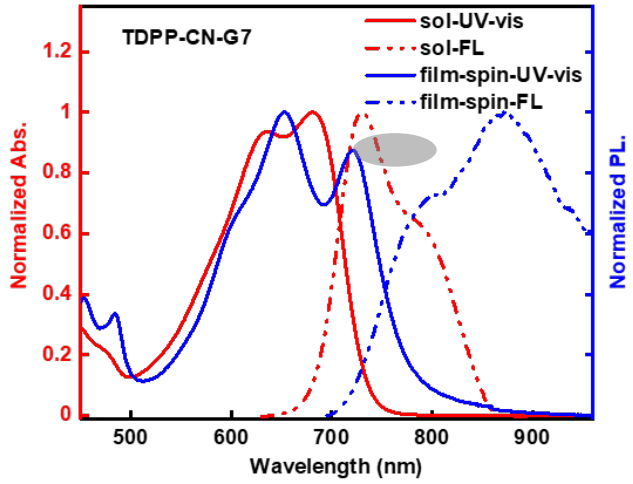


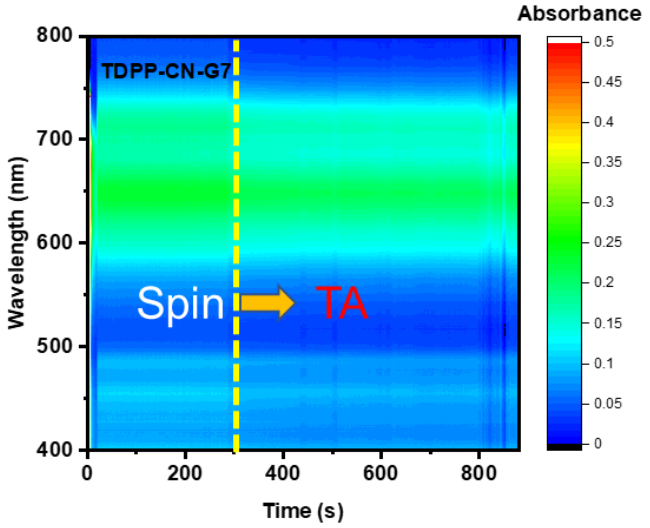
K. Liu#, **P. Li#**, T. Lei*, et al. *Adv. Funct. Mater.* 33, 2300049 (2023).

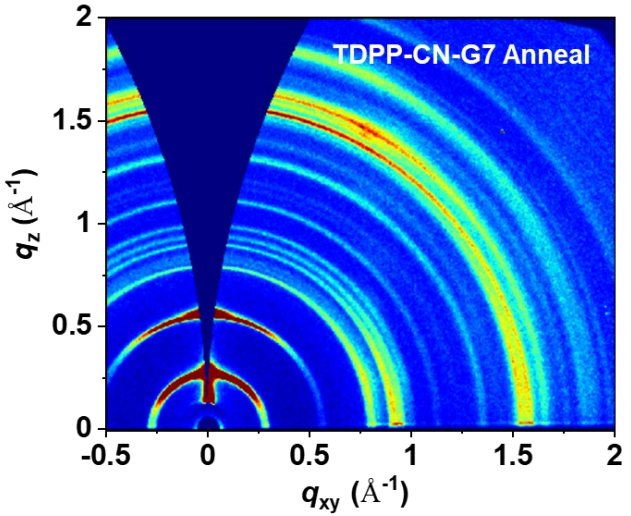
6. Materials in OECT

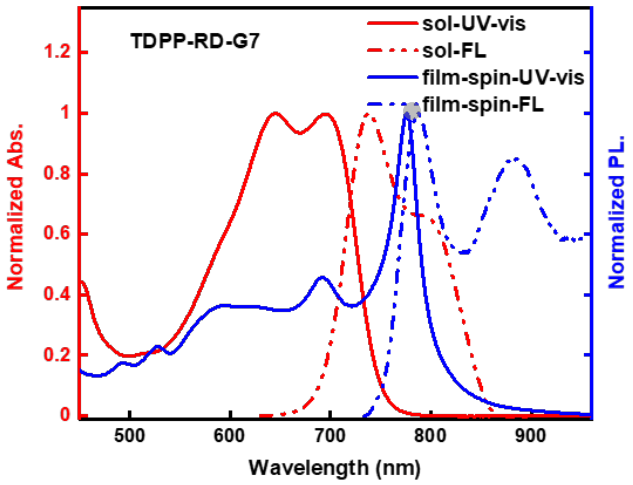
6.2 Channel

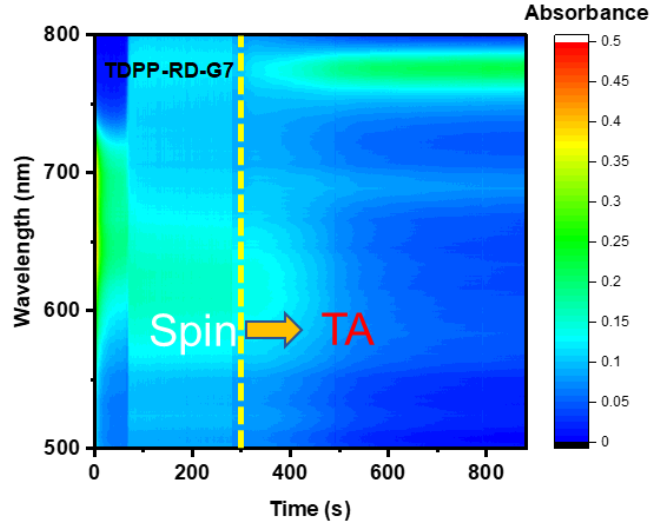
Small molecular

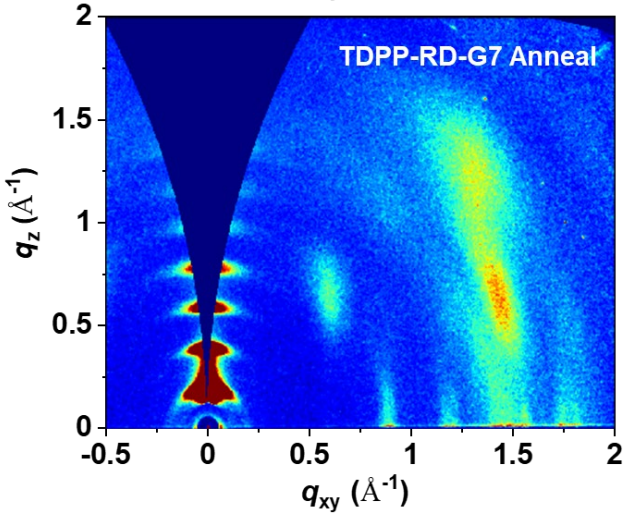












Different Packing

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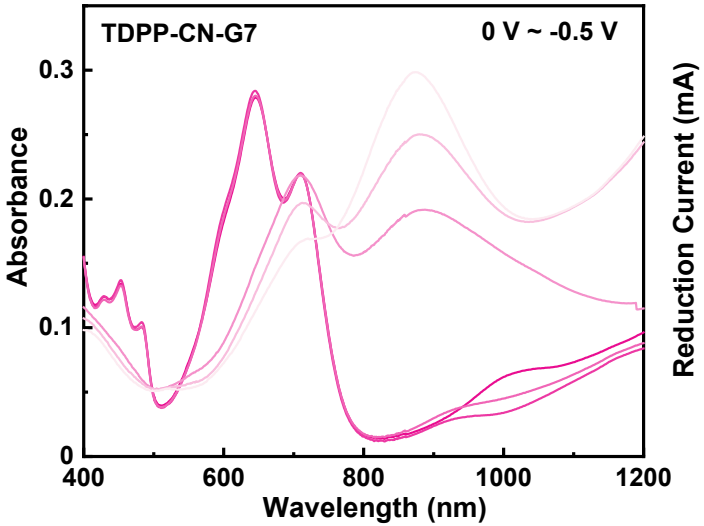
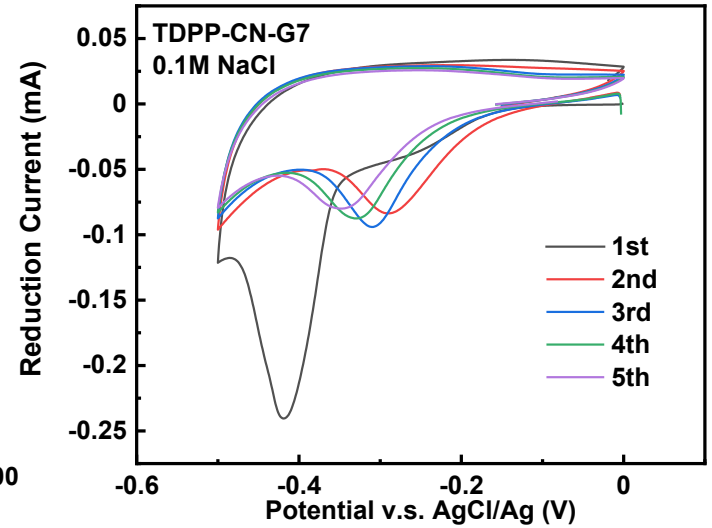
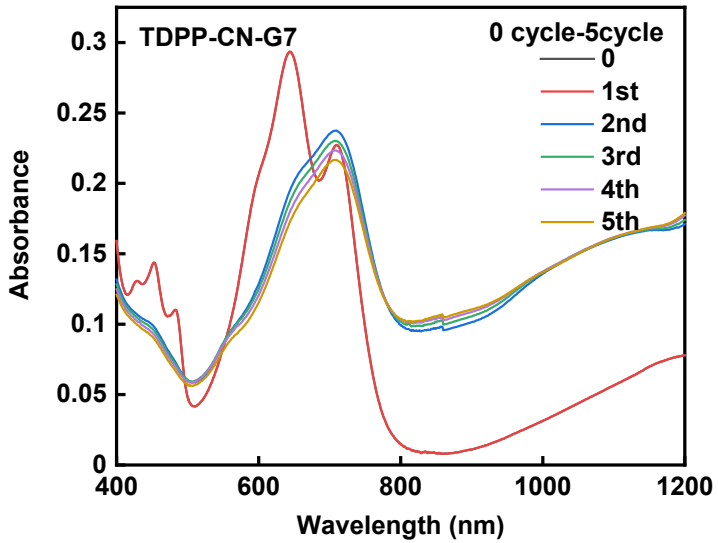
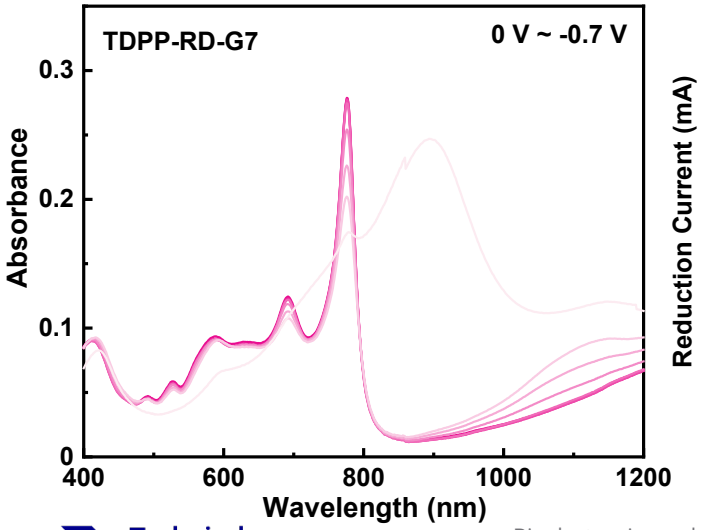
6. Materials in OECT

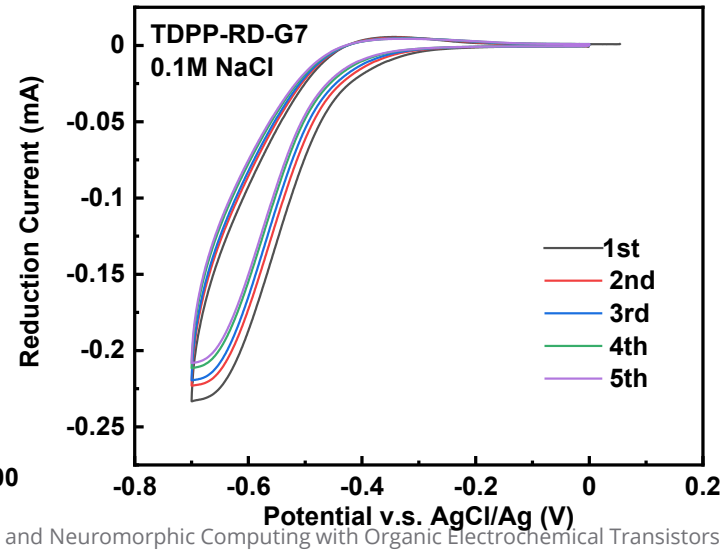
6.2 Channel

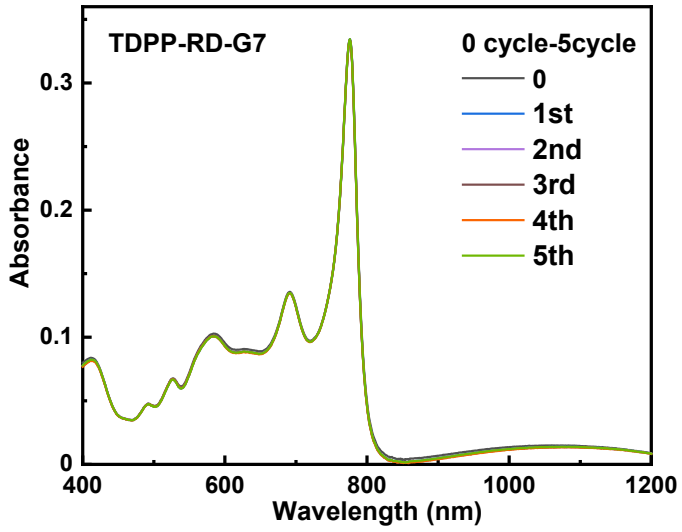












Different electrochemical stability

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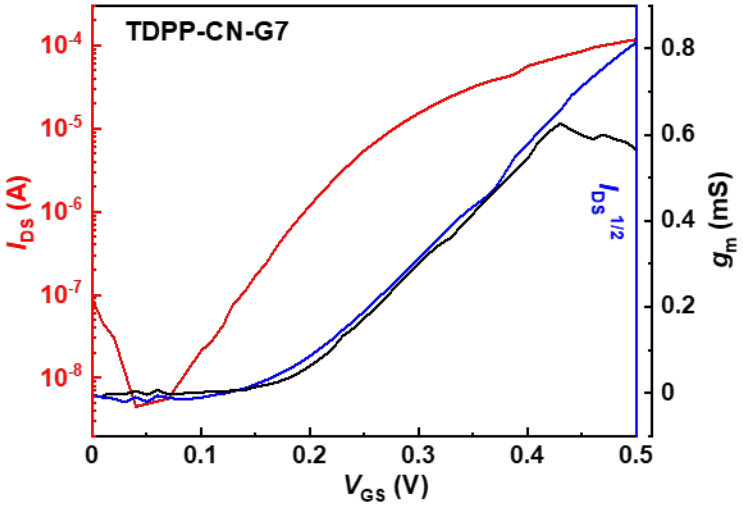
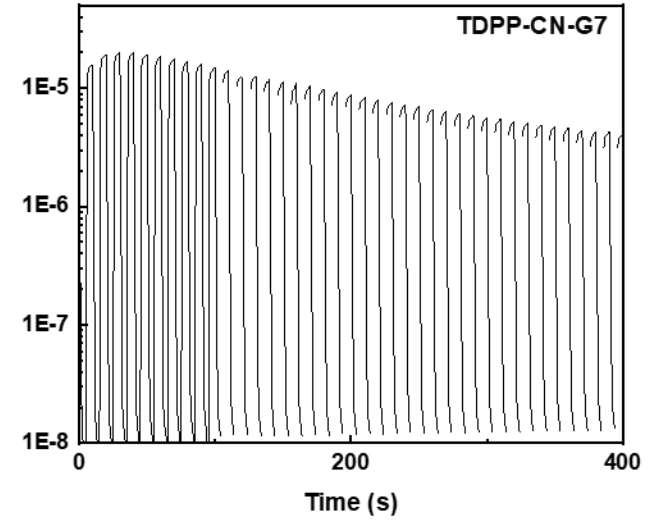
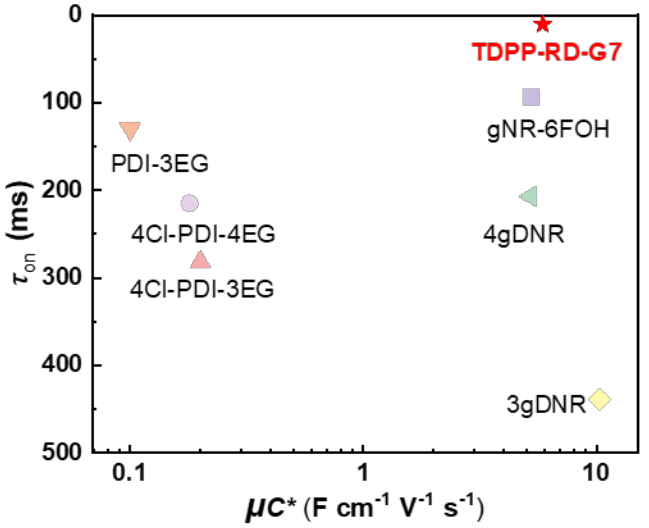
6. Materials in OECT

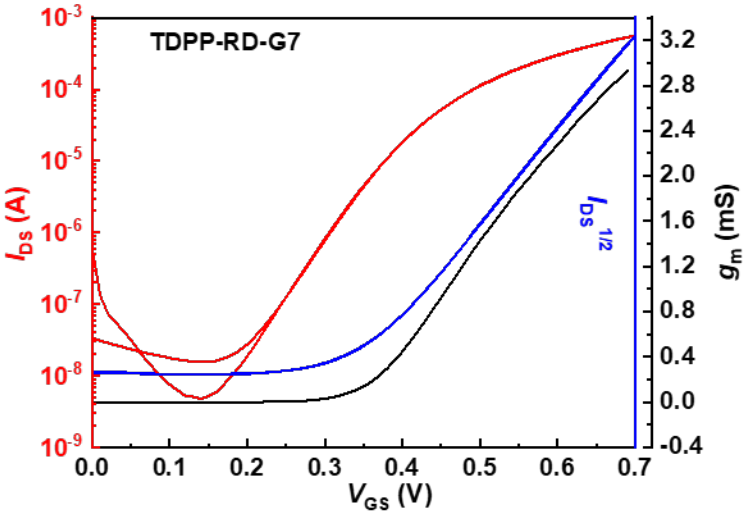
6.2 Channel

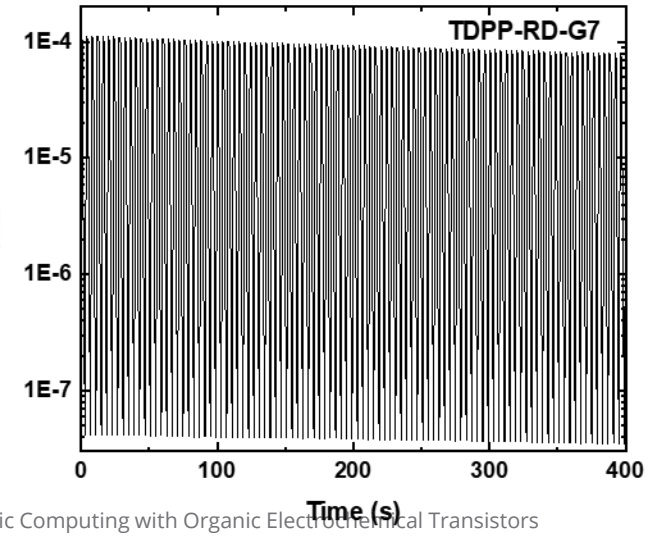


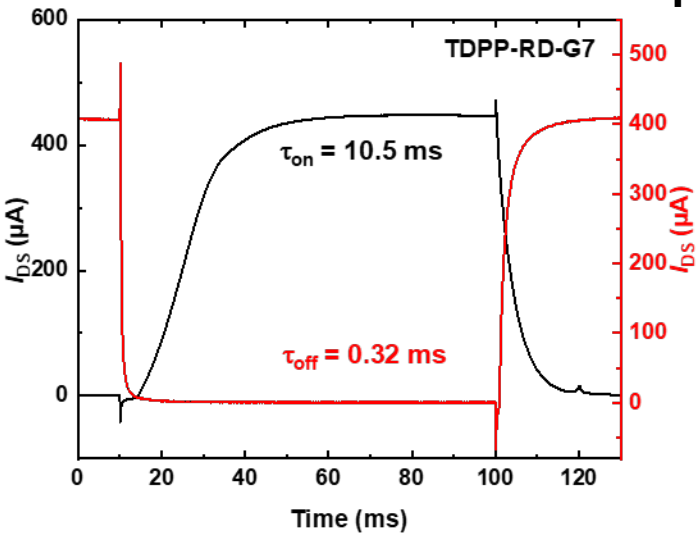




Different OECT performance







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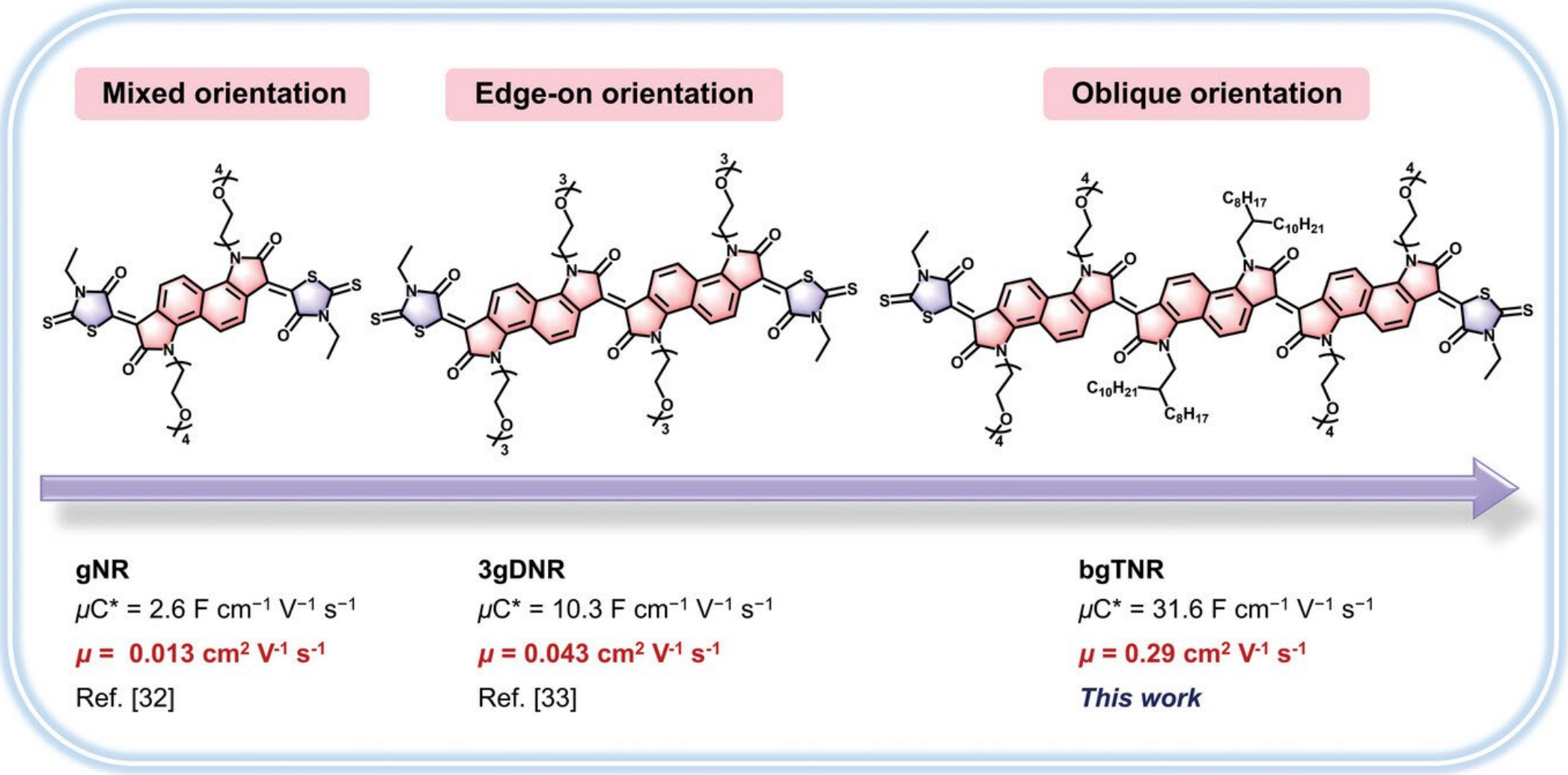
6. Materials in OECT

6.2 Channel

Small molecular



gNR

μC^* = 2.6 F cm^{-1} V^{-1} s^{-1}

μ = 0.013 cm^2 V^{-1} s^{-1}

Ref. [32]

3gDNR

μC^* = 10.3 F cm^{-1} V^{-1} s^{-1}

μ = 0.043 cm^2 V^{-1} s^{-1}

Ref. [33]

bgTNR

μC^* = 31.6 F cm^{-1} V^{-1} s^{-1}

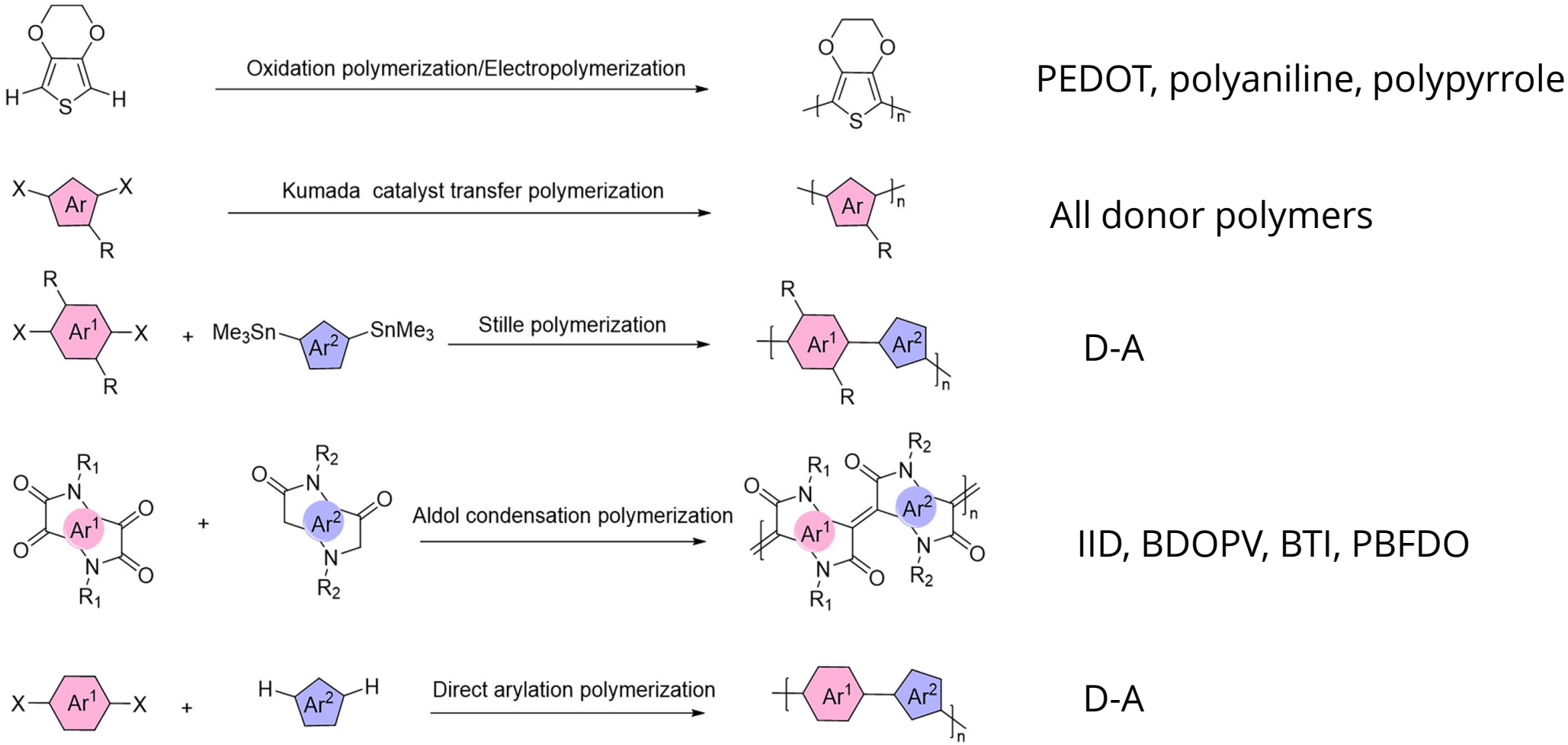
μ = 0.29 cm^2 V^{-1} s^{-1}

This work

6. Materials in OECT

6.2 Channel

Polymerization methods used for OECT polymers



PEDOT, polyaniline, polypyrrole

All donor polymers

D-A

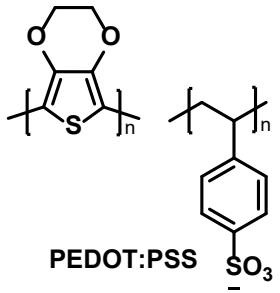
IID, BDOPV, BTI, PBFDO

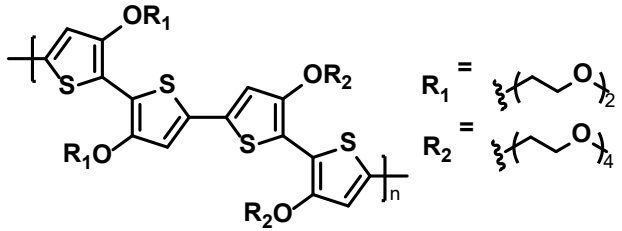
D-A

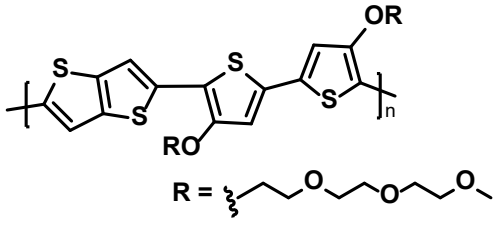
6. Materials in OECT

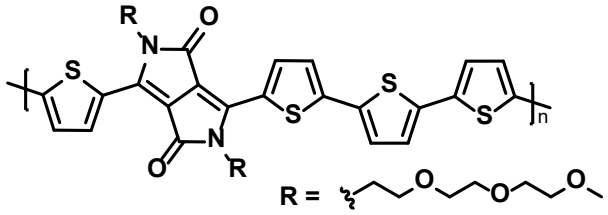
6.2 Channel

P-type polymer

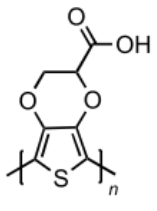


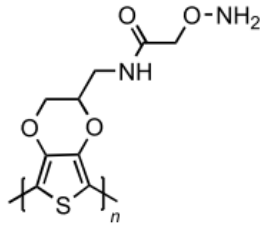


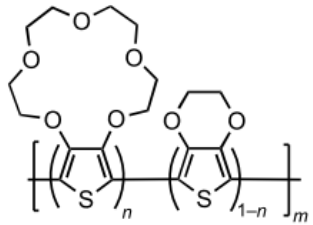


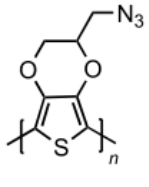


- Crystallinity
- Side chain
- Regioisomeric
- D-A







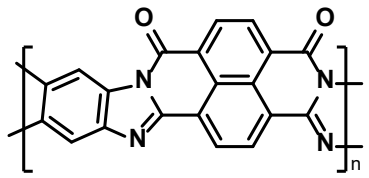


- Functionalization

6. Materials in OECT

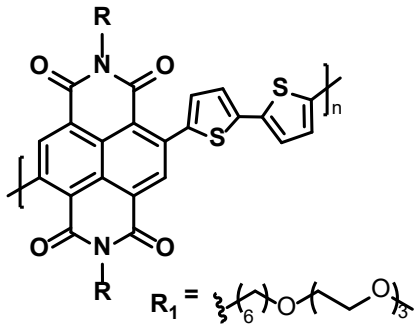
6.2 Channel

N-type polymer



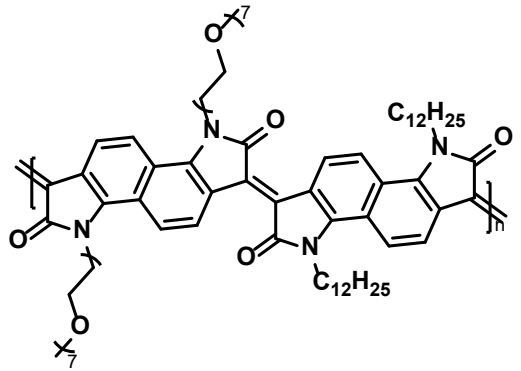
BBL

- Molecular weight



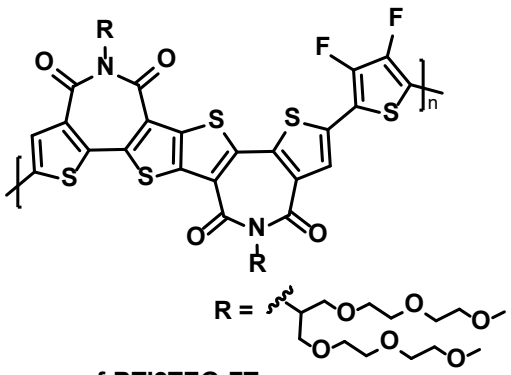
p(C6-T2)

- D-A



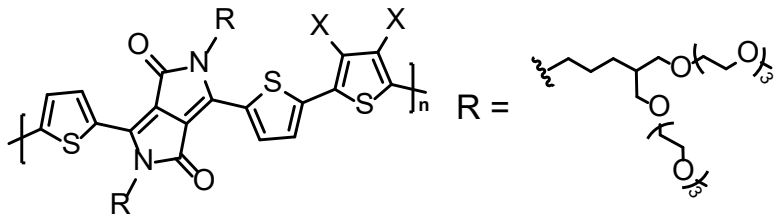
PgNaN

- Side chain



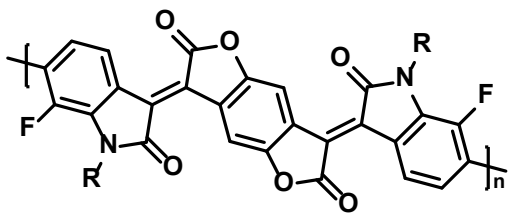
f-BTI2TEG-FT

- D-A

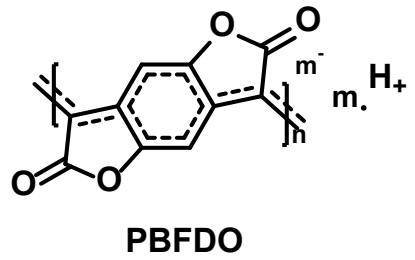


X = H P(gTDPPT) X = F P(gTDPP2FT)

- Doped state engineering



- D-A

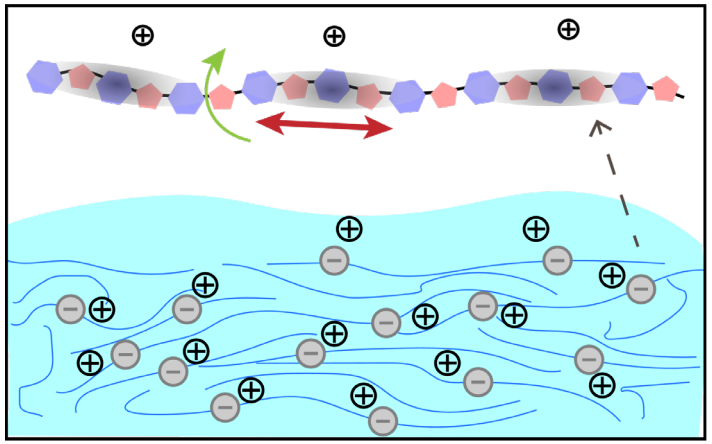


PBFDO

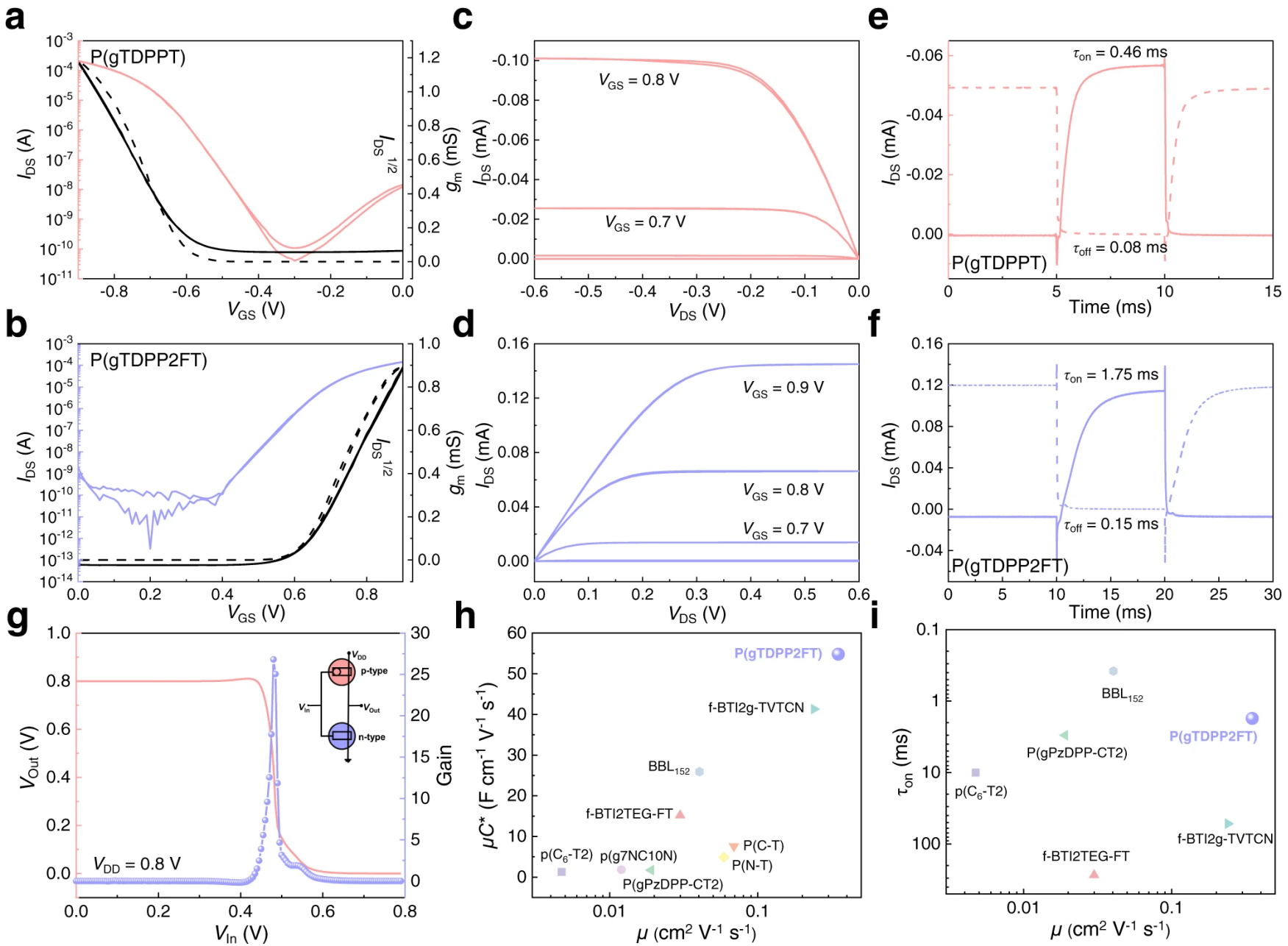
- Depletion mode

6. Materials in OECT

6.2 Channel



- ✓ Uniform charge distribution
- ✓ Stable polaron
- ✓ Enhanced backbone planarity
- ✓ Enhanced conformational stability

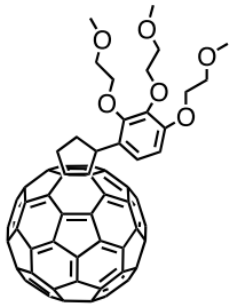


P. Li#, J. Shi#, T. Lei*, et al. *Nat. Commun*, 13, 5970 (2022).

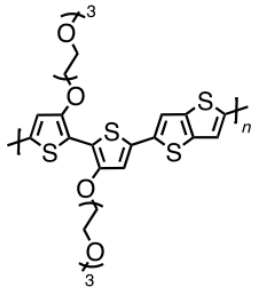
6. Materials in OECT

6.2 Channel

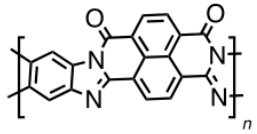
Blend



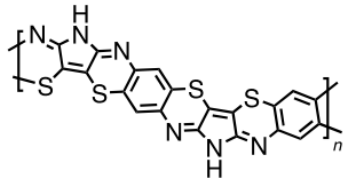
$PrC_{60}MA$



p(g2T-TT)



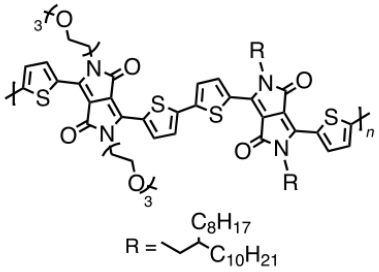
BBL



PBBTL

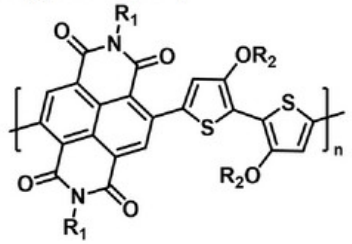
Ambipolar polymer

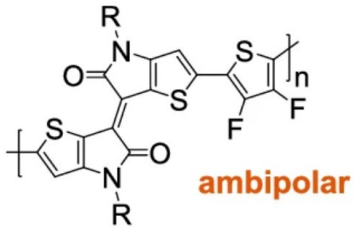
Single component



2DPP-OD-TEG

P(gNDI-gT2)





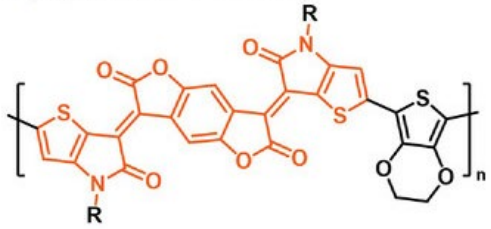
ambipolar

p(TII-2FT)

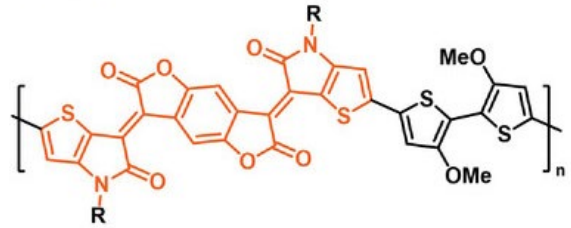
p-μC^*= 158.6 F cm^{-1} V^{-1} s^{-1}

n-μC^*= 147.4 F cm^{-1} V^{-1} s^{-1}

P(bgTBDOPV-EDOT)



P(bgTBDOPV-MeOT2)



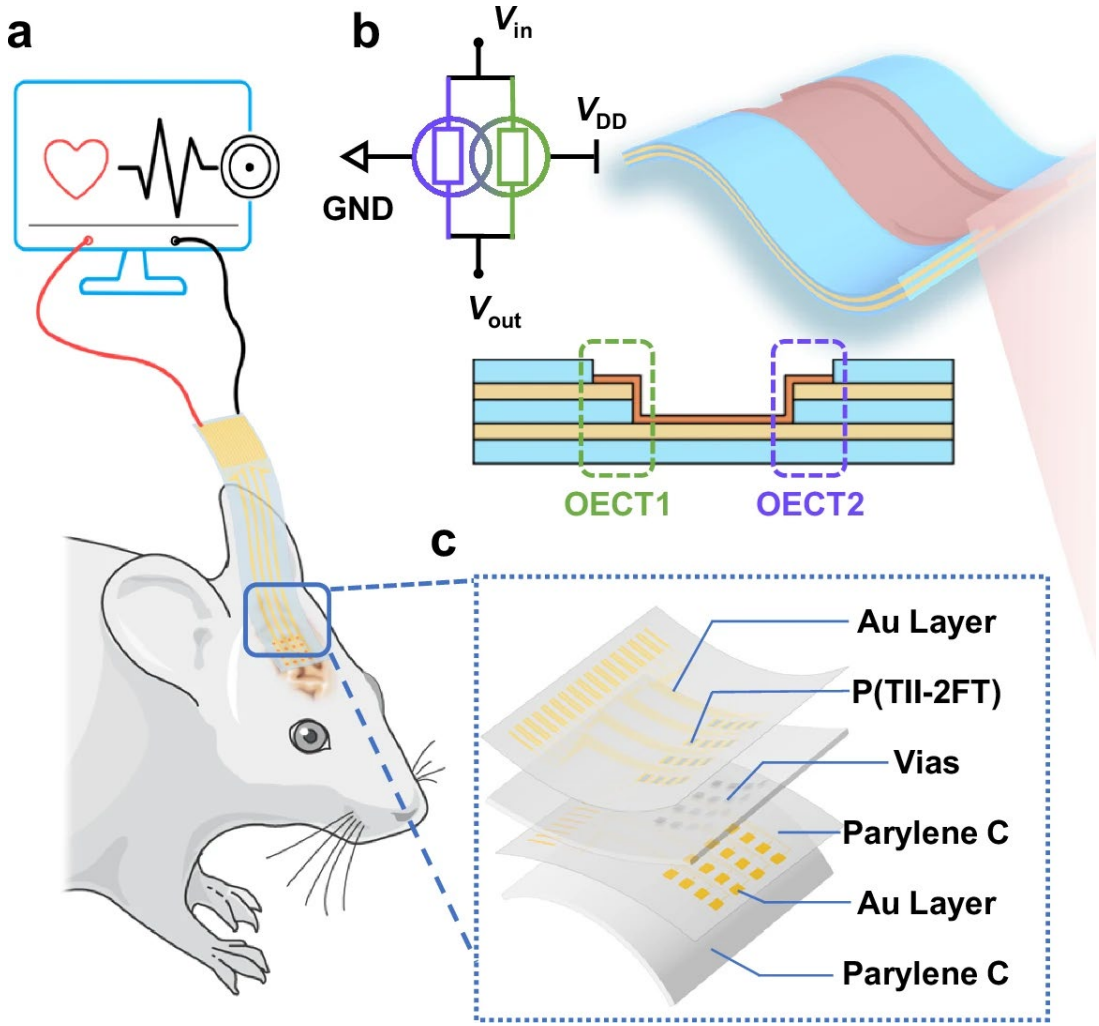
- D-A
- high-spin
- Proquinoidal

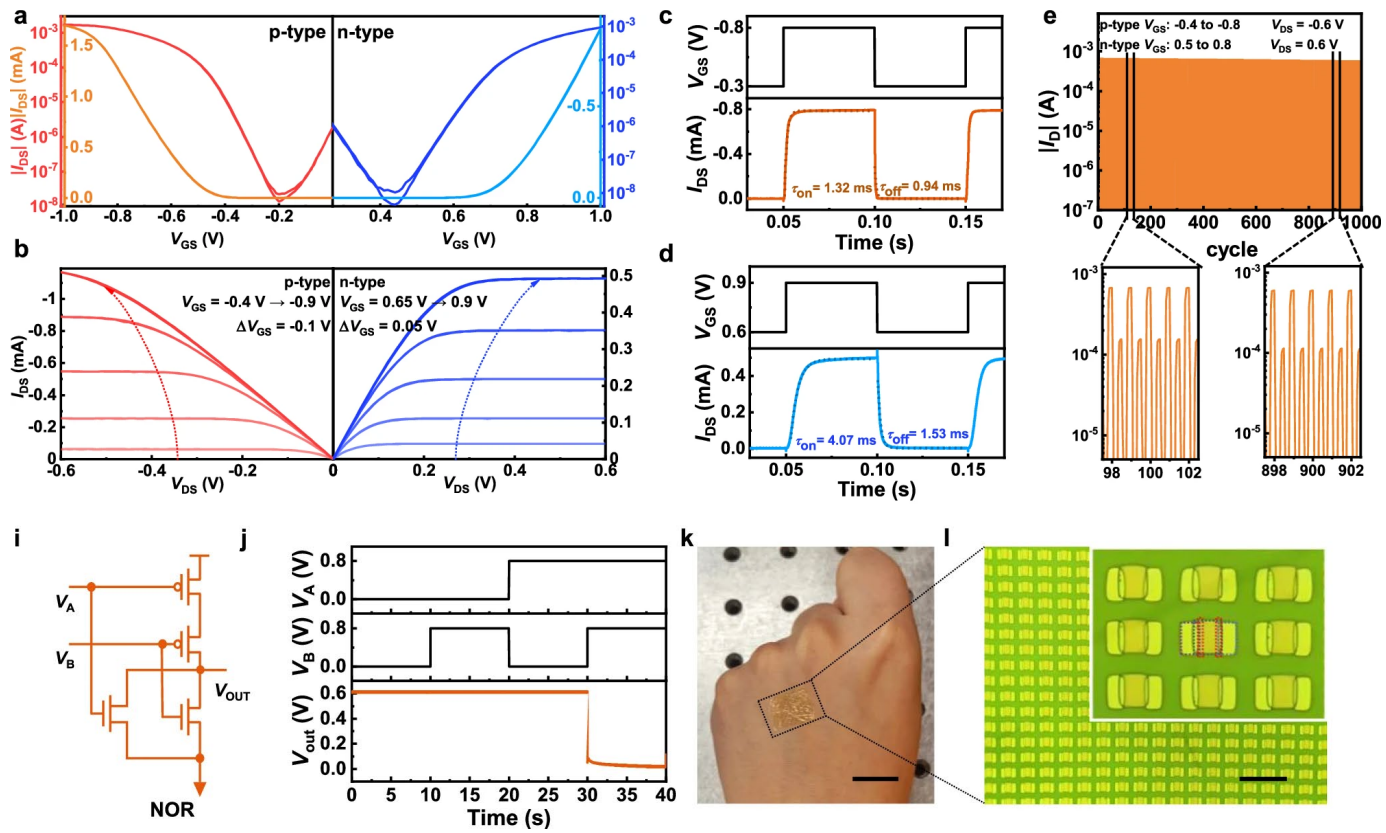
- Balanced p-n transport

6. Materials in OECT

6.2 Channel

Ambipolar polymer



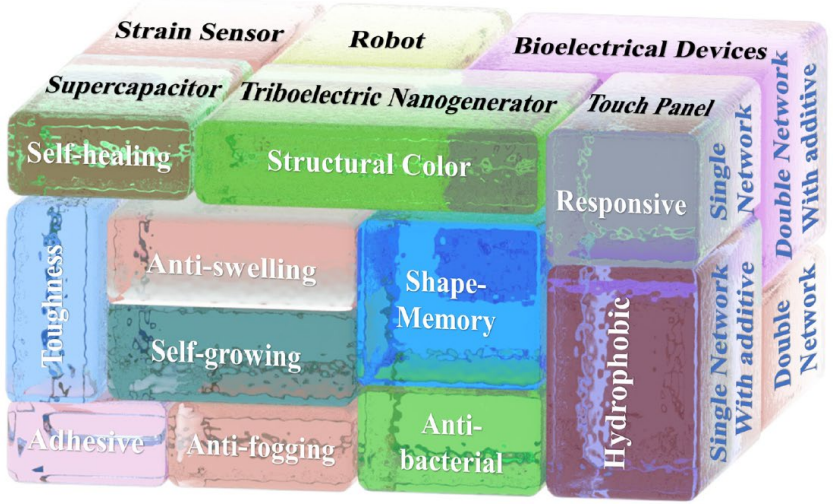


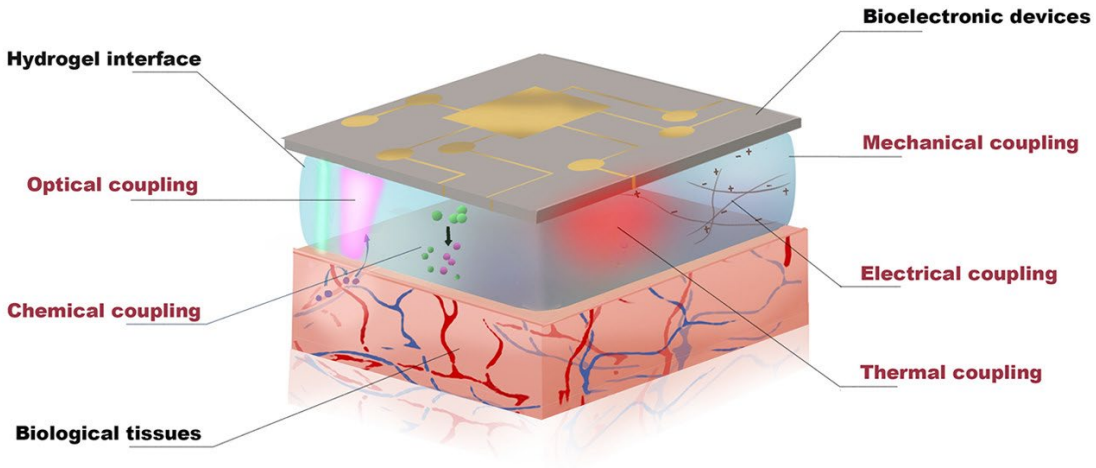
Nat Commun 16, 396 (2025).

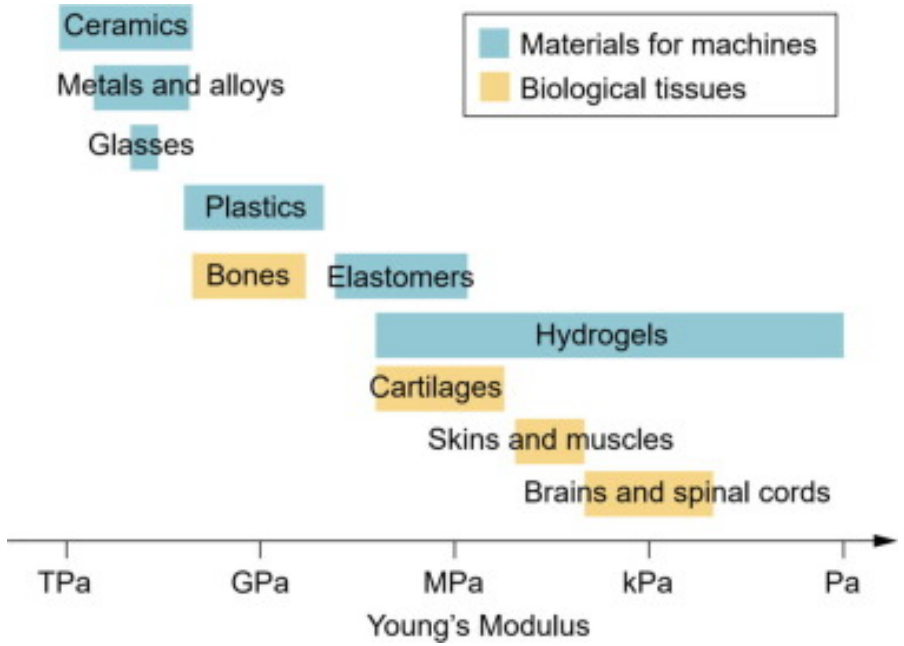
6. Materials in OECT

6.3 Hydrogel

From OMIEC to Semiconducting Hydrogel





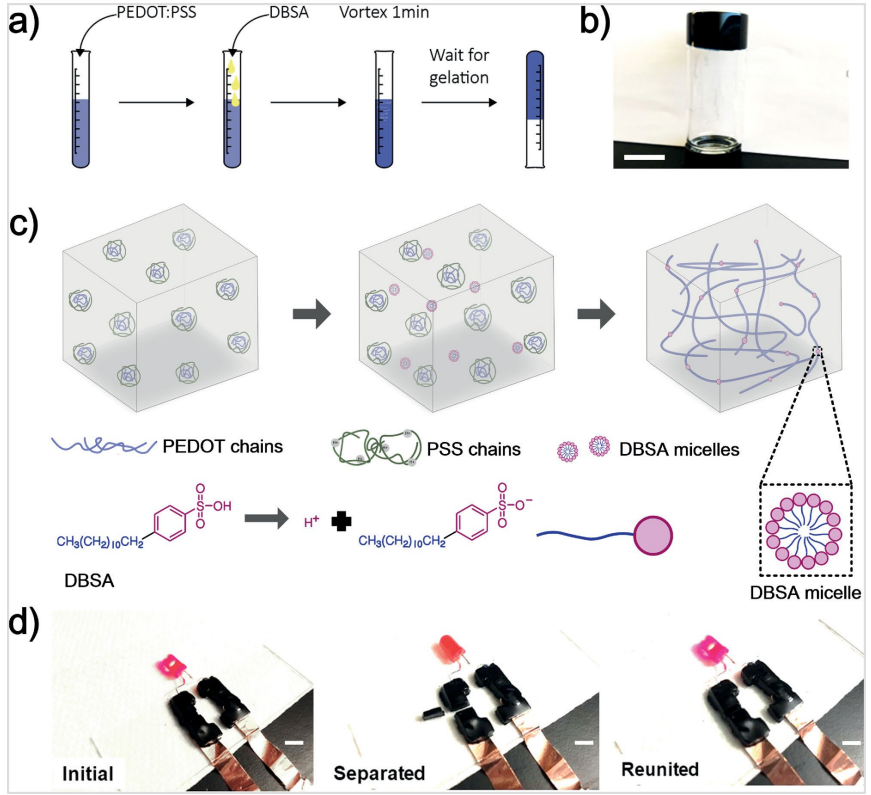


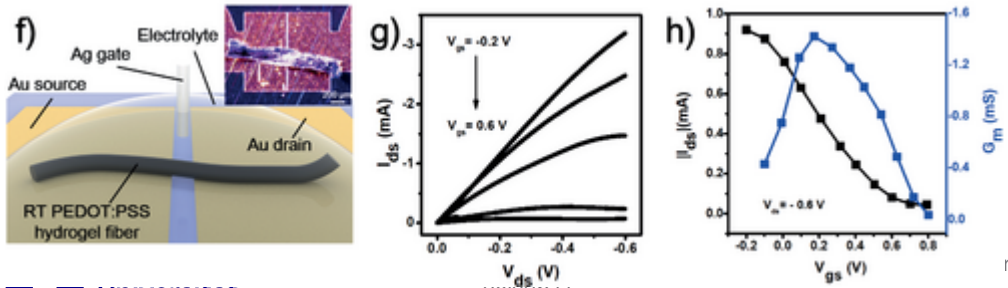
- Mechanical properties
- Multiple functions
- Excellent biocompatibility

Mater. Today, 36: 102-124 (2020). *Acc. Mater. Res.* 2, 1010–1023 (2021).

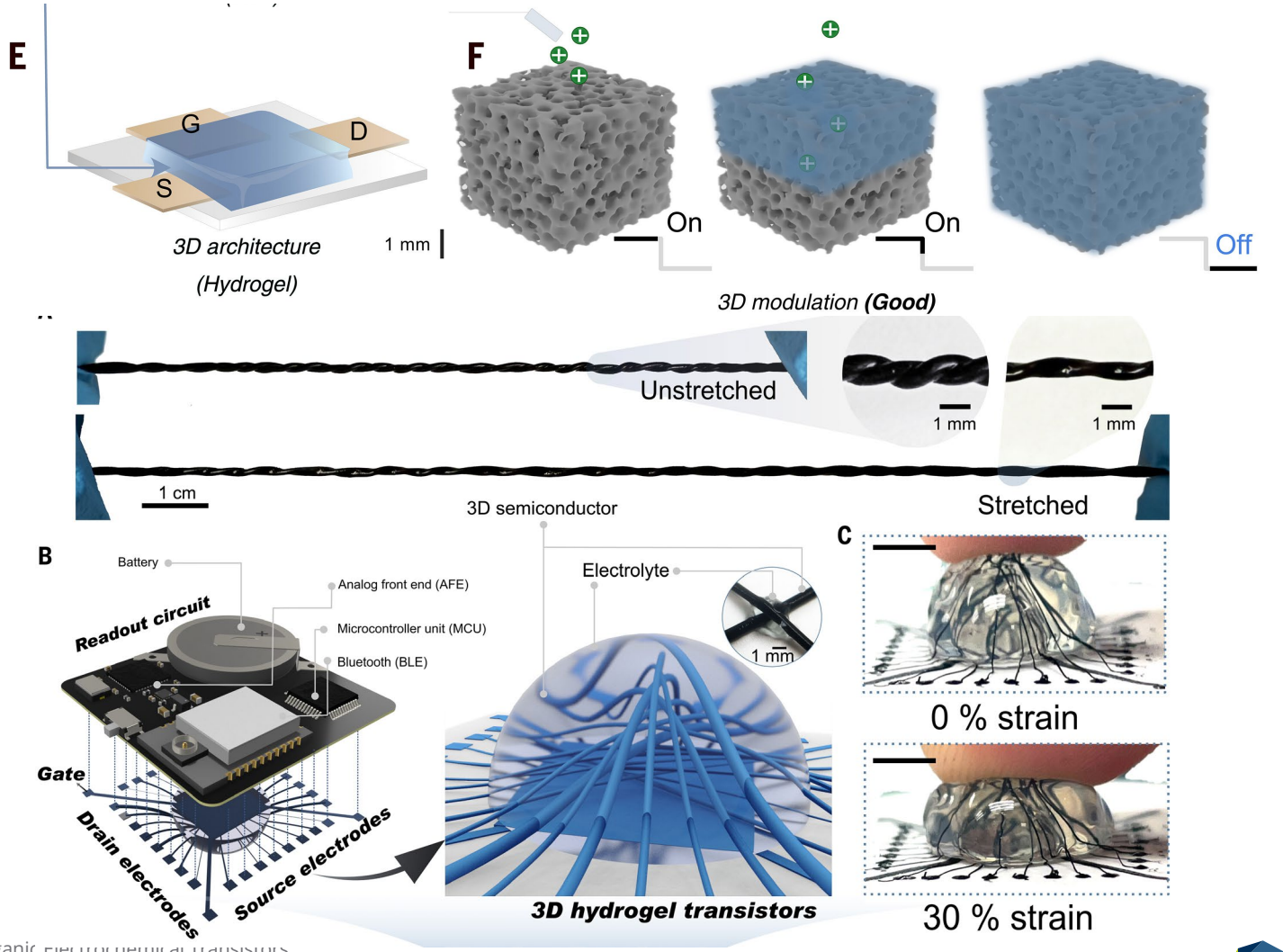
6. Materials in OECT

6.3 Hydrogel





PEDOT:PSS



Adv. Mater. 2020, 32, 1904752

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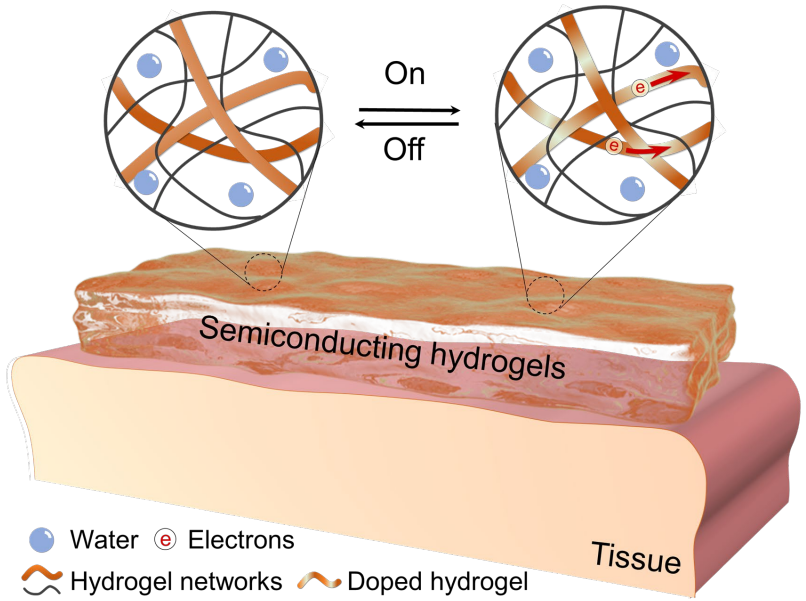
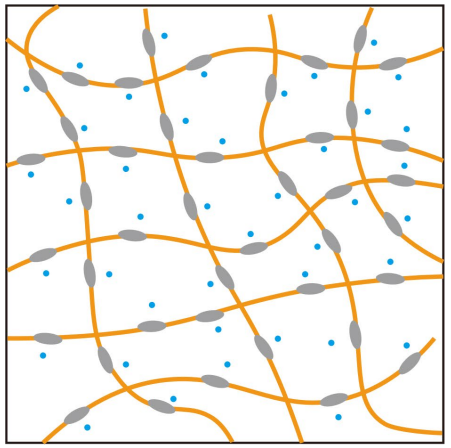
6. Materials in OECT

6.3 Hydrogel

N-type Semiconducting Hydrogel

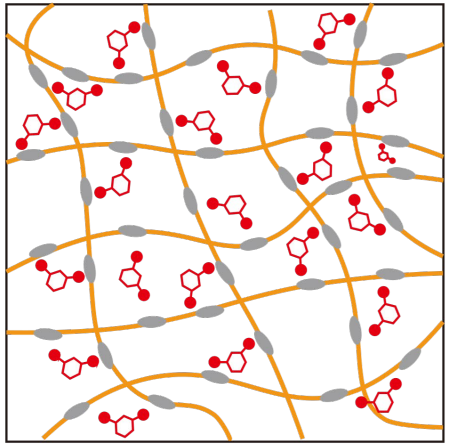




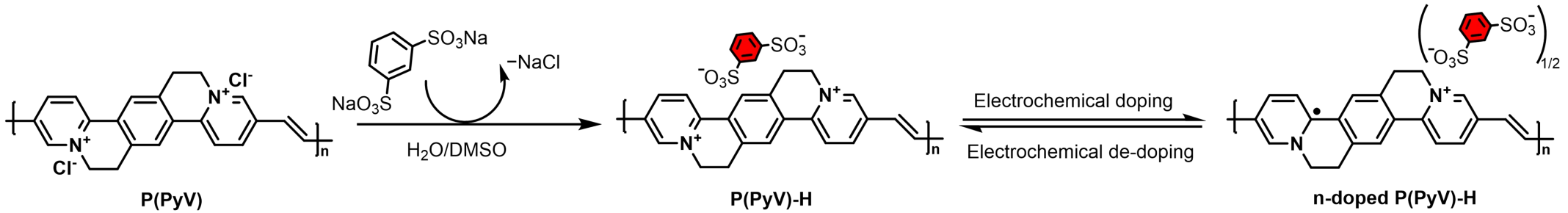
water soluble

Electrostatic crosslinking

DBS^{2-} $P(PyV)^{+}$ Cl^{-}



water insoluble

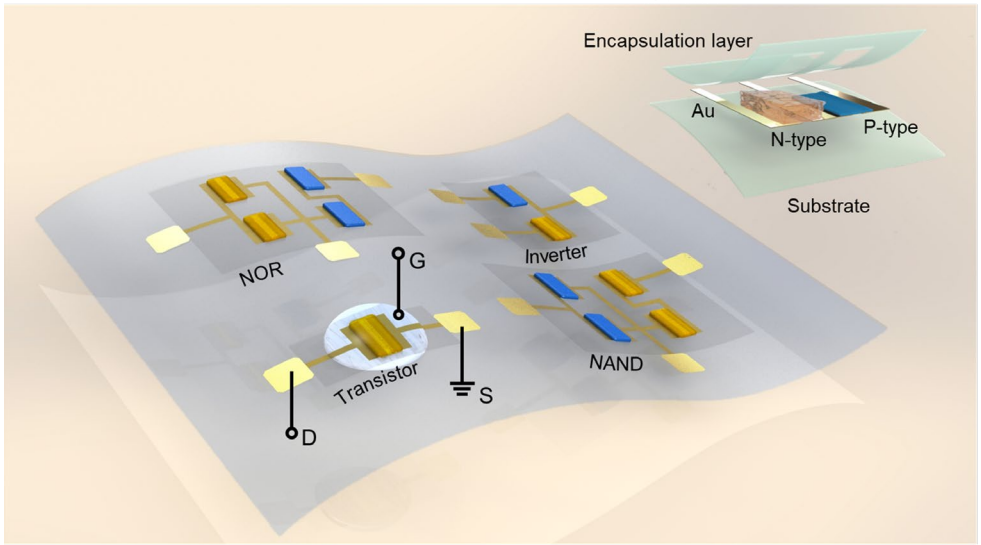


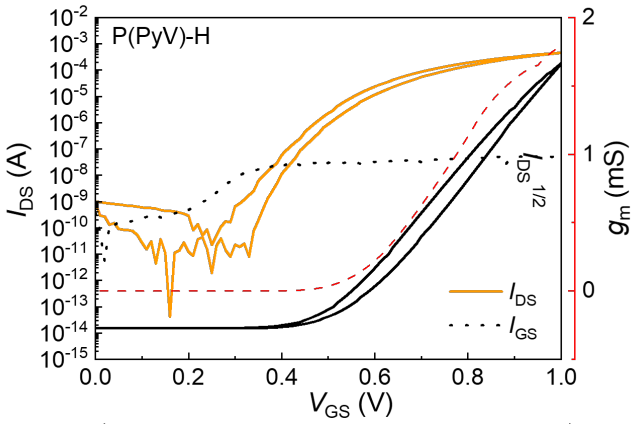
P. Li#, W. Sun#, T. Lei*, et al. *Science*, 384, 557-563 (2024).

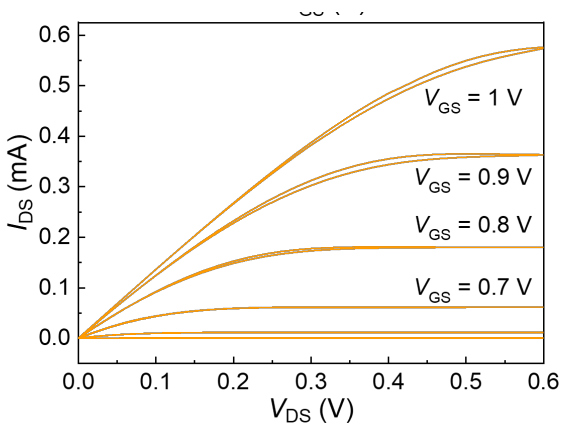
6. Materials in OECT

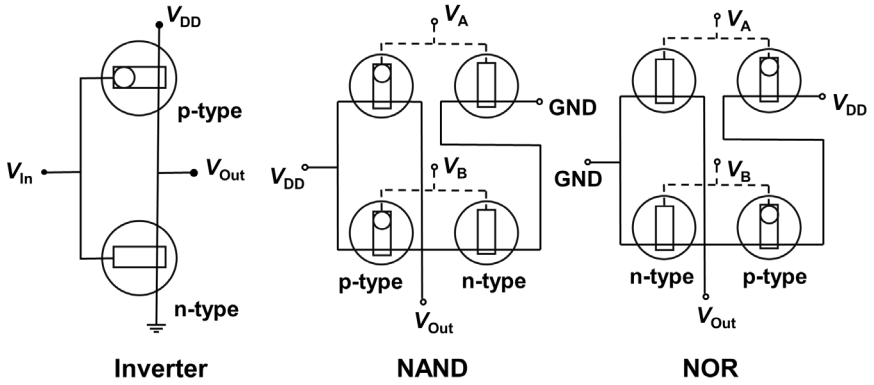
6.3 Hydrogel

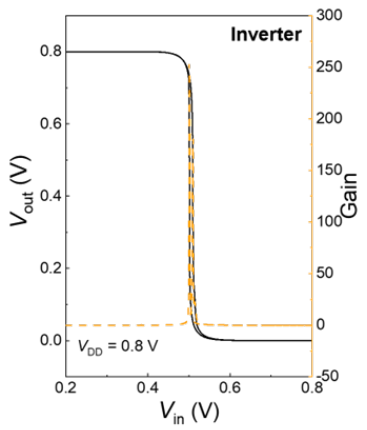
N-type Semiconducting Hydrogel

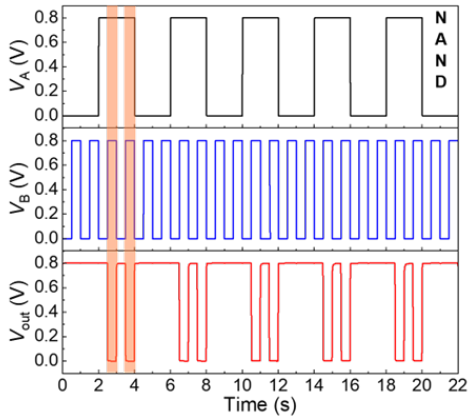


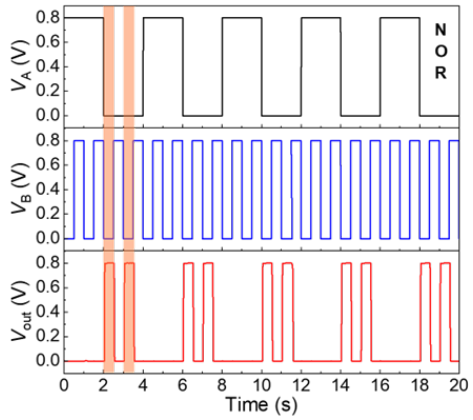










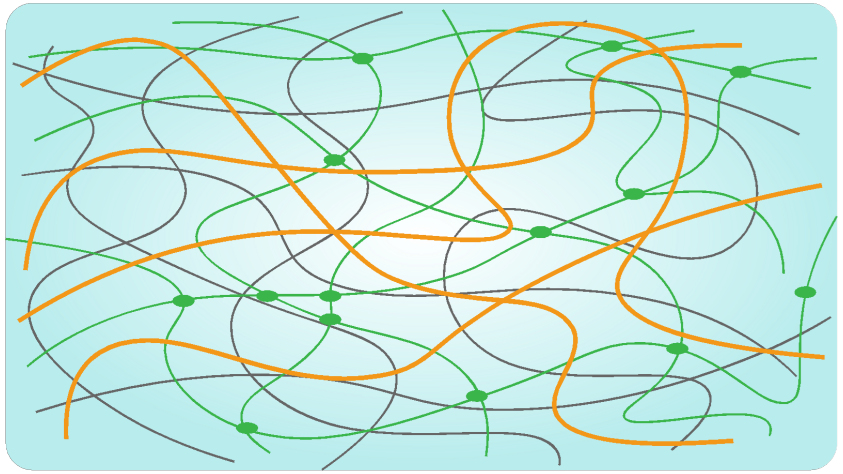


P. Li#, W. Sun#, T. Lei*, et al. *Science*, 384, 557-563 (2024).

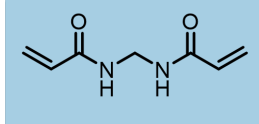
6. Materials in OECT

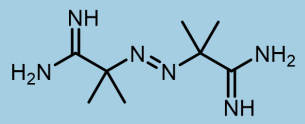
6.3 Hydrogel

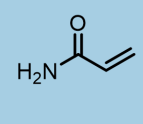
N-type Semiconducting Hydrogel

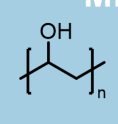


MNH-1

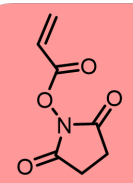

crosslinker

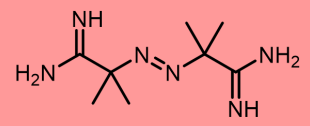

initiator


AM


PVA

MNH-2


AAc-NHS ester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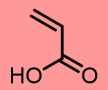
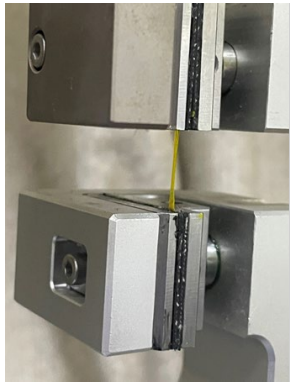
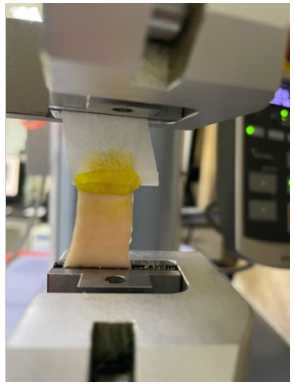
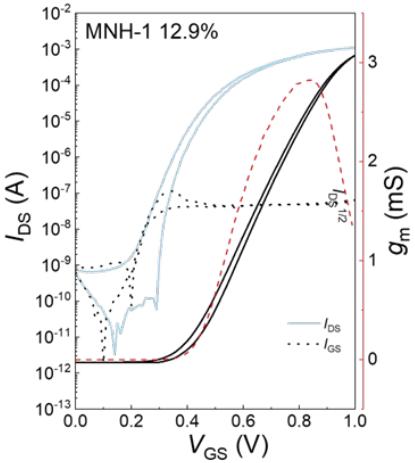
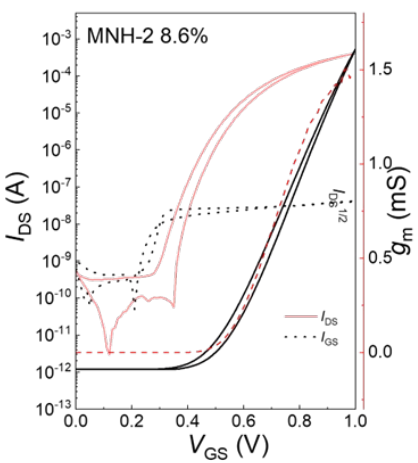

AA

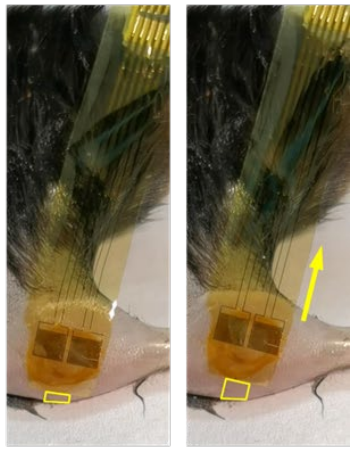
gelatin & gelMA









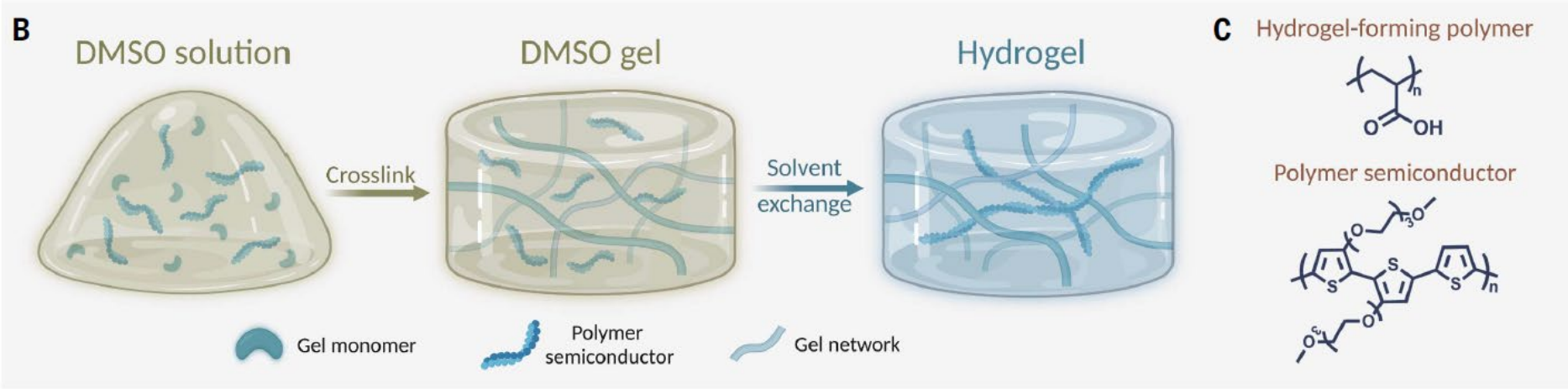


P. Li#, W. Sun#, T. Lei*, et al. *Science*, 384, 557-563 (2024).

6. Materials in OECT

6.3 Hydrogel

Solution exchange



Science 386, 431–439 (2024)