New Class of Materials For Plastic Solar Cells

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Type: Scientific

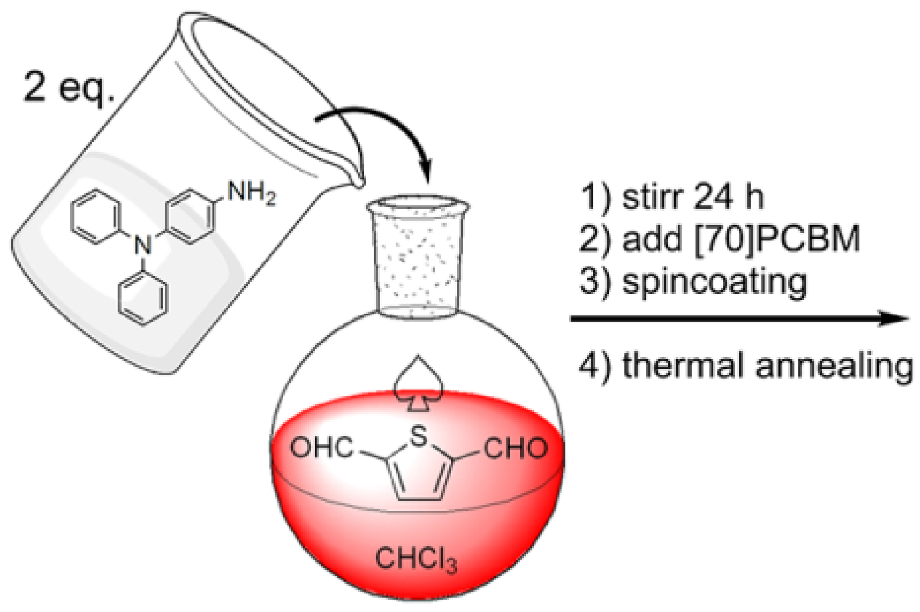
Aerospace Engineering

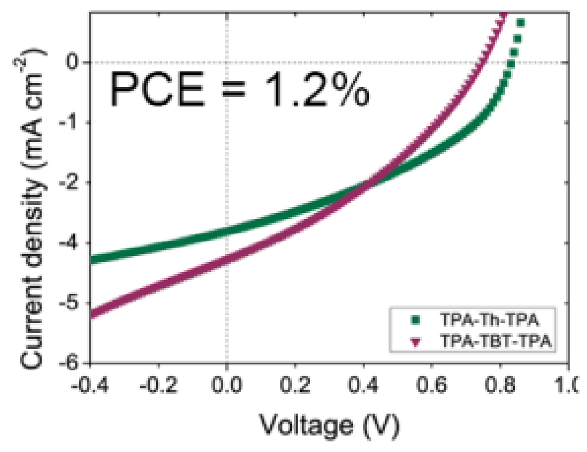
Background

Organic or “plastic” solar cells use organic materials mostly in the form of small molecules and polymers, to convert solar energy into electric energy. These semiconductive organic molecules have the ability to absorb light and induce the transport of electrical charges.

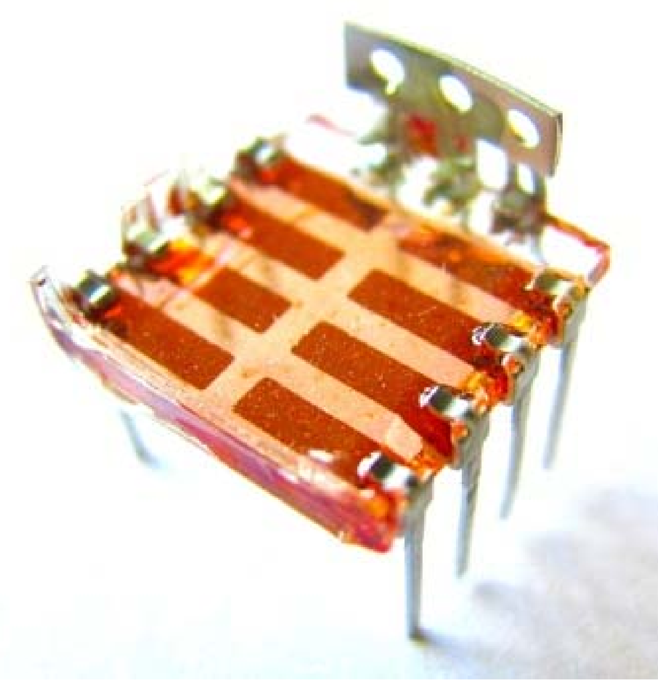
Advantages Plastic vs Silicon Solar Cells

- Ease and cost of fabrication
- Flexible and light weight
- Customisable design
- Intergratable and wearable
- Diffuse lighting
- Very little material required (thickness ~1·10^{-7} m)

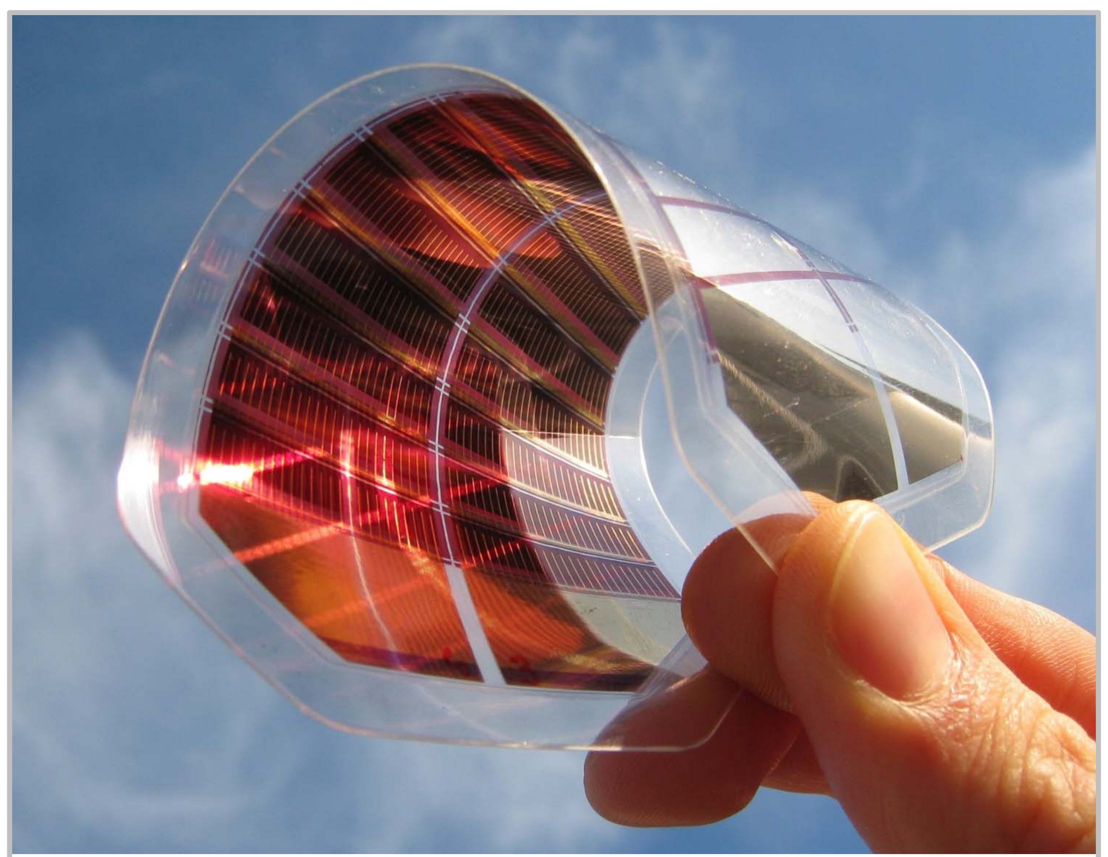




Small-molecules are prepared in a simple one-pot reaction and directly prepared from the reaction mixture, without any form of workup.



8 solar cells on a single glass slide for testing



Example of flexible organic solar cell

Step-growth vs Conventional Chemistry

Conventional Chemistry

- × Expensive catalysts
- × Small scale
- × Many side products
- × Demanding reaction conditions

VS

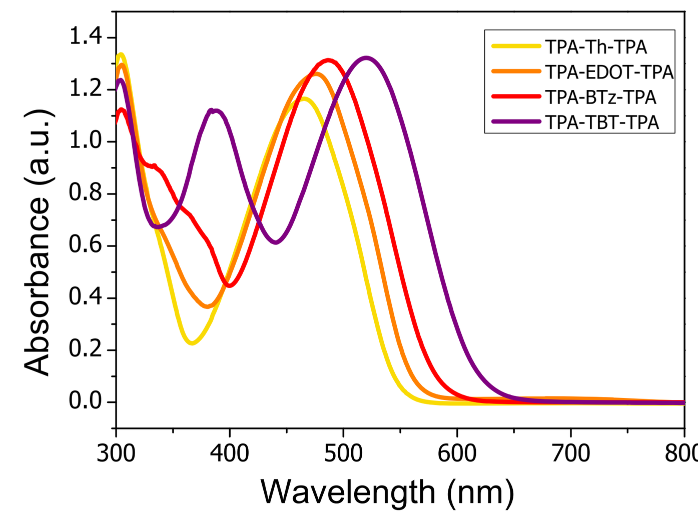
Condensation Chemistry

- ✓ Cheap, easy and robust
- ✓ Catalyst-free
- ✓ Water as only side product
- ✓ Stable materials

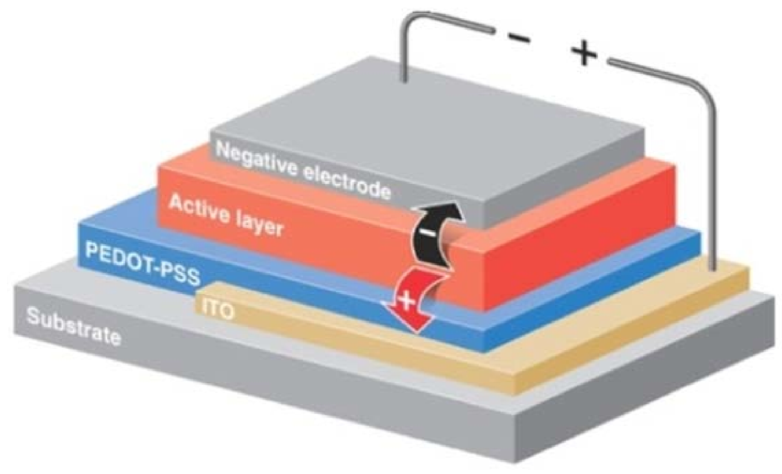
Condensation Chemistry

We use clean and easy chemistry for preparing conjugated small molecules that can be used in solar cells.

The small-molecules are synthesized by stirring an amine (**1**) and a dialdehyde (**2**) together in solution. No catalysts, high temperatures or other “exotic” reaction conditions are required to prepare the product in high yields. **The only by-product that is formed is water**. Therefore purification of the small-molecule is not required, making the reaction environmentally friendly compared to other chemistries.



Absorption spectrum of the different small molecules



Standard organic solar cell device architecture

Photovoltaic properties

The active layer is spincoated from a solution, resulting a layer thickness of 70 nm. Three out of the four small-molecules show efficiencies exceeding 1%.

Small-molecule	V_{oc} (V)	J_{sc} (mA/cm²)	FF (%)	PCE (%)
TPA-Th-TPA	0.83	3.7	39	**1.2**
TPA-EDOT-TPA	0.72	3.8	38	**1.0**
TPA-BTz-TPA	defect	-	-	-
TPA-TBT-TPA	0.75	4.5	34	**1.2**

One-pot preparation

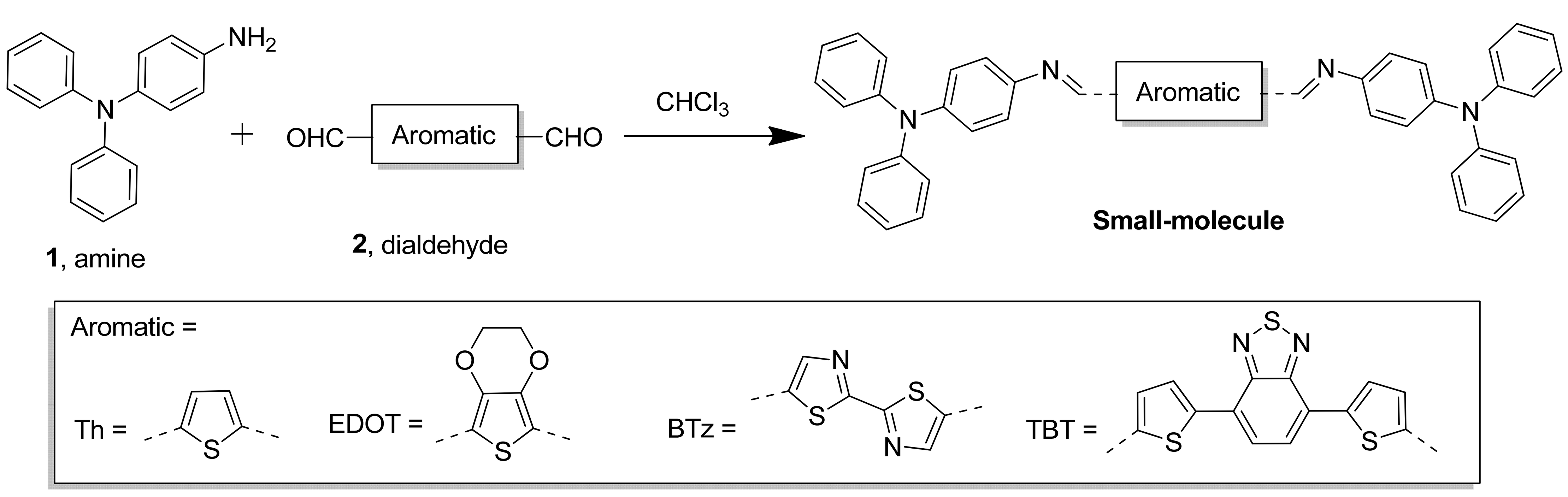
We also demonstrated that this chemistry enables the fabrication of **solar cells directly from the reaction mixture** without any product workup.

Because azomethine chemistry is easy, clean and proceeds under near ambient conditions we believe that this approach has the ability to reduce materials and production costs of organic photovoltaic devices.

Progress and Objectives

Step-growth materials still have a long way to go before they can compete with state-of-the-art PV technologies, however, our work shows that **there is potential for these materials** as photovoltaics. Their ease of synthesis and processing warrants further research.

Recently we have published the results presented here. This series of materials results in the best performing devices within their class of materials known in literature.



Synthesis and molecular structures of four small-molecules. Different structures result in different colors and therefore absorb different parts of the solar spectrum

Small-molecules in solution. conc: 3 mg L^{-1}

Related publications

- Micheal E. Mulholland, Daminda Navarathne, Michiel L. Petrus, Theo J. Dingemans, William G. Skene “Correlation of on-substrate prepared electrochromes with their soluble processed counterparts – towards validating polyazomethines as electrochromes in functional devices”, Journal of Material Chemistry C, 2014, Submitted
- Michiel L. Petrus, Ricardo K.M. Bouwer, Ugo Lafont, Stavros Athanasopoulos, Neil C. Greenham and Theo J. Dingemans "Small-Molecule Azomethines: Organic Photovoltaics via Schiff Base Condensation Chemistry", Journal of Materials Chemistry A, 2014, Accepted
- Michiel L. Petrus, Ricardo K.M. Bouwer, Ugo Lafont, D.H.K. Murthy, René Kist, Marcus Bohm, Yoann Olivier, Tom J. Savenije, L. D. A. Siebbeles, Neil C. Greenham, and Theo J. Dingemans, (2013) “Conjugated poly(azomethine)s via simple one-step polycondensation chemistry: synthesis, thermal and optoelectronic properties”, *Polymer Chemistry* , 2013, **4**, pp 4182-4191
- This research forms part f the research program of the Dutch Polymer Institute (DPI), Project #717

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