A sensitizer for energy and fuel production

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Light-to-Energy and Fuel (LEaF) Lab @CNR-ICCOM
Our Research in “Chemistry and Energy”

**DSSCs**
- Design and synthesis of new dyes
- Building-Integrated Photovoltaics
- Fiber-shaped Solar Cells

**LSCs**
- Design and synthesis of new visible light-emitters

**H₂**
- New photocatalysts for H₂ production
- Sustainable electron donors
- Alternative TiO₂ polymorphs

**PSCs**
- Design and synthesis of new hole-transport materials (HTMs)
**D-π-A Structure**

In THF solution

![Graph showing absorption spectrum in THF solution]

On TiO$_2$

![Graph showing absorption spectrum on TiO$_2$]

<table>
<thead>
<tr>
<th>$\lambda_{abs.}$ [nm]</th>
<th>$\varepsilon \times 10^4$ [M$^{-1}$ cm$^{-1}$]</th>
<th>$\lambda_{abs.}$ on TiO$_2$ [nm]</th>
<th>$E_{0-0}$ [eV]</th>
<th>$E_{ox}$ [V]$^a$</th>
<th>$E_{ox}^{-}$ [V]$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>510</td>
<td>9.41</td>
<td>487</td>
<td>2.24</td>
<td>0.99</td>
<td>-1.25</td>
</tr>
</tbody>
</table>

$^a$ vs. NHE
Dye-Sensitized Solar Cells (DSSCs)
Dye-Sensitized Solar Cells (DSSCs) – Transparent thin-film devices

**Simple fabrication:** NO TiCl₄ treatment, NO scattering layer, I⁻/I₃⁻ redox couple;

- Best result $\eta = 7.71\%$ for TTZ5, better than reference dyes D5 and Z907
- Thin TiO₂ films: thickness 5.5 μm / Surface area: 0.25 cm²

![J-V curves](image)

$J_{sc}$ = short-circuit photocurrent density
$V_{oc}$ = open-circuit photovoltage
$ff$ = fill factor
$\eta$ = solar energy-to-electricity conversion yield
$P_{in}$ = power of incident sunlight (generally 100 mW cm⁻²)

$$\eta(\%) = \frac{P_{max.}}{P_{in.}} = \frac{(J_{sc.} * V_{oc.} * ff)}{P_{in.}}$$

Prof. Aldo Di Carlo and Dr. Daniele Colonna, Center for Hybrid and Organic Solar Energy (C.H.O.S.E.)

**Dye-Sensitized Solar Cells (DSSCs) — Transparent thin-film devices**

**Simple fabrication:** NO TiCl₄ treatment, NO scattering layer, I⁻/I₃⁻ redox couple;

- Transparent TiO₂ films: thickness 3.0 μm / Surface area: 3.6 cm²
- Commercial high stability electrolyte (Dyesol HPE)

\[ \text{TTZ5} \]

![J-V curves](image)

![Stability measurements](image)

Prof. Aldo Di Carlo and Dr. Daniele Colonna, Center for Hybrid and Organic Solar Energy (C.H.O.S.E.)

Dye-Sensitized Solar Cells (DSSCs) – Transparent thin-film devices

**Active area (cm²) | J<sub>sc</sub> (mA cm<sup>-2</sup>) | V<sub>oc</sub> (V) | ff (%) | η (%)**

| TTZ5 module      | 226 | 12.4 | 8.72 | 54.0 | 4.86 |
| D35cpdt module*  | 226 | 10.2 | 9.06 | 58.2 | 4.46 |

* Dyenamo Red; https://dyenamo.se/dyenamo_dyes.php

Prof. Aldo Di Carlo and Dr. Luigi Vesce, Center for Hybrid and Organic Solar Energy (C.H.O.S.E.)
Dye-Sensitized Solar Cells (DSSCs) – Fiber-Shaped Solar Cells

Fiber-Shaped Solar Cell in “2 wires configuration”.

High mechanical stability. Suitable for wearable application.

Microscope images of TiO$_2$ coating under mechanical stress at different angle.

Solar Energy Materials and Solar Cells, 2020, 204, 110209

Dr. Alessandra Sanson and Dr. Nicola Sangiorgi, CNR-ISTEC
Dye-Sensitized Solar Cells (DSSCs) – Fiber-Shaped Solar Cells

Standard Irradiation Conditions (SIC) ▼

Diffuse Reflection Irradiation Conditions (DRIC) ▼

η_{max} ≈ 1%
An **organic semiconductor** with a smaller band-gap than TiO₂
- To collect visible light
- To have an easier charge separation

A **sacrificial electron donor (SED)**, ideally derived from renewable feedstock, to reduce the dye
Photocatalytic experiment

- Dye loading: 10 μmol g⁻¹
- 150 W Xe lamp with a cut-off filter at 420 nm
- Time: 20 hours

\[
\text{TON} = \frac{2 \times \text{H}_2 \text{total amount}}{\text{dye loading}}
\]

<table>
<thead>
<tr>
<th>SED: TEOA</th>
<th>SED: EtOH</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂ amount [μmol g⁻¹]</td>
<td>TON</td>
</tr>
<tr>
<td>AD418</td>
<td>4359</td>
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<tr>
<td>TTZ5</td>
<td>3432</td>
</tr>
</tbody>
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Regione Toscana

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