Neuromorphic Computing and Water & Energy Sustainability

Environmentally Stable and highly Conductive Organic Transparent Electrodes Laminated with Graphene

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01. Motivation

Conjugated Polymer Materials

- Li–ion Battery
- Solar Cells
- OLED

- Solution Based Fabrication
- Organic Thin-Film
- Flexibility
- Light Weight
- Low Cost
- Transparency

Large area deposition
Environmental degradation of organic film

- Motivation:
  - Humidity
  - Mechanical Stress
  - Thermal Degradation
  - UV Exposure

- Factors:
  - \( H_2O, O_2, H_2 \) and other active chemical species
  - Cracking and debonding
  - Surface weathering
  - Photochemical reactions
  - Defect evolution in nanomaterial layers

- Performance, Lifetime, Sustainability

Diagram shows the degradation process with arrows indicating the effects of different factors on the organic film.
Innovative Idea

Impermeability of graphene


Graphene layer used protective means
03. Graphene Lamination Process

Highly conductive PEDOT:PSS with graphene barrier

- PDZ: A mixture of PEDOT:PSS (Clevios PH 1000), 5 wt% DMSO, and 0.05 wt% Zonyl
- GL-TE: Graphene Laminated Transparent Electrode
- Graphene-PDZ assembly layer can be directly laminated on PET substrate.
03. Graphene Lamination Process

Highly conductive PEDOT:PSS with graphene barrier

a) Photograph of as-synthesized, flexible GL-TE film (Transparency & large area dep.)
b) Sheet resistance (black squares) and transmittance at 550 nm (gray circles) of GL-TEs as a function of the number of PDZ coating cycles.
Characterization of GL-TE

Stability tests under unfavorable environmental agents

- Graphene layer can be acting as role of highly effective environmental barrier

- **a**, **b**) UV stability and Relative humidity test according to the resistance change while the samples were exposed to the radiation of an Xe lamp at 254 nm wavelength and humidity 80% respectively.

- **c**) The change of sheet resistance of a function of the increasing temperature from 25 °C to 210 °C. GL-TE film shows the more thermal stability than PDZ film between room temperature and ~150 °C before PET substrate shrinkage occurs.
04. Characterization of GL-TE

Stability tests under unfavorable environmental agents

- Bending & Stretchability test– Enhancement of mechanical properties

a) Responsive resistance of GL-TE film as a function of bending cycle. The response of GL-TE film was measured during bending the TE with 7.6% strain.

b) Comparison resistance of the PDZ/PUA (red circles) and GL-PDZ/PUA (black squares) films as a function of applied tensile strain.

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Environmentally stable and highly conductive GL-TE

- We developed a new method for improving the lifetime and the operational and thermal stability of organic thin-film materials while maintaining high conductivity and mechanical flexibility.

- The merits of GL-TE are as follows:
  a) Direct transfer of graphene layer
  b) Tight interfacial binding & free of wrinkles and air gaps
  c) The laminated films exhibit an outstanding room-temperature hole mobility of $\approx 85.1 \text{ cm}^2\text{ V}^{-1}\text{s}^{-1}$
  d) Environmentally stable properties against high mechanical/thermal stress, humidity, and ultraviolet irradiation
  e) Appropriate work function energy value $\sim 5.12 \text{ eV}$
  f) Considering the use of flexible organic electronics for our-door applications
Thank you.