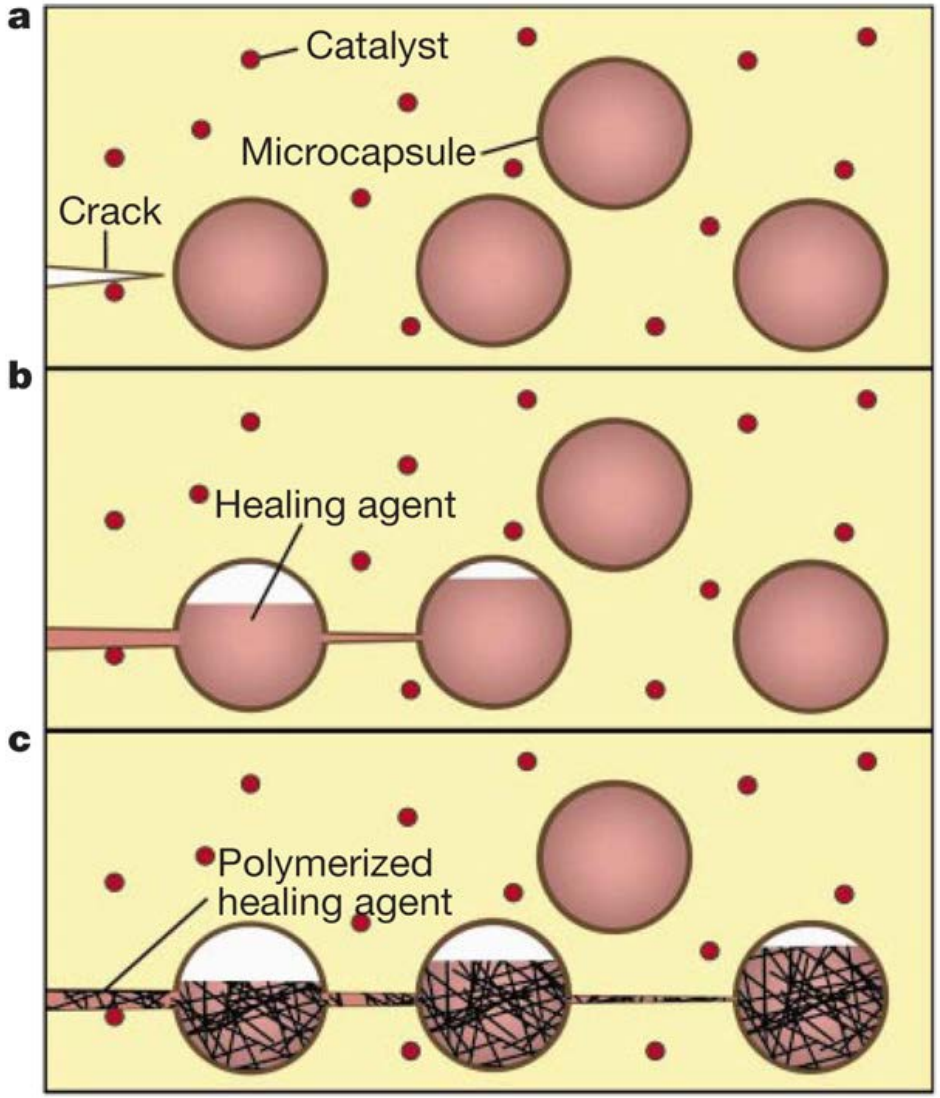
Self-healing Materials

Self-healing can be defined as the ability of a material to heal damages automatically and autonomously, that is, without any external intervention.

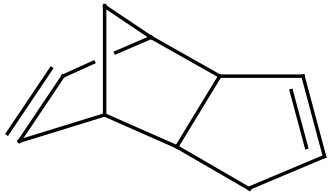
- Autonomic (without any intervention)
  - -Release of healing agent
    - Microcapsule embedment
    - Hollow fiber embedment
    - Microvascular systems

- Nonautonomic (needs an external trigger)
  - -Reversible cross-links
    - Reversible cycloaddition reactions
    - Ionomers
    - Supramolecular polymers

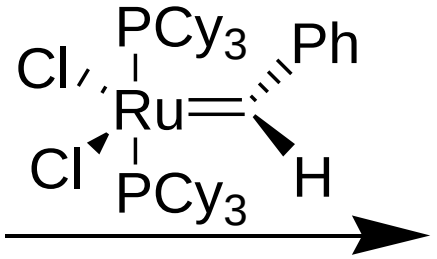
Self-healing via Microsphere Embedment



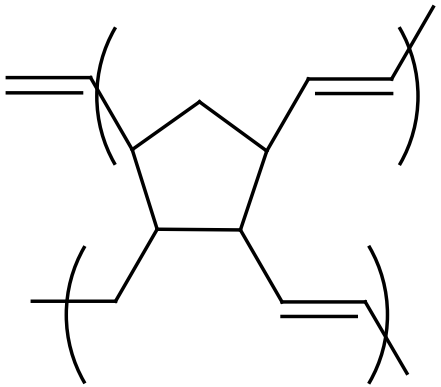
☺ Autonomic healing



DCPD Monomer



Grubbs' Catalyst



Crosslinked Polymer Network

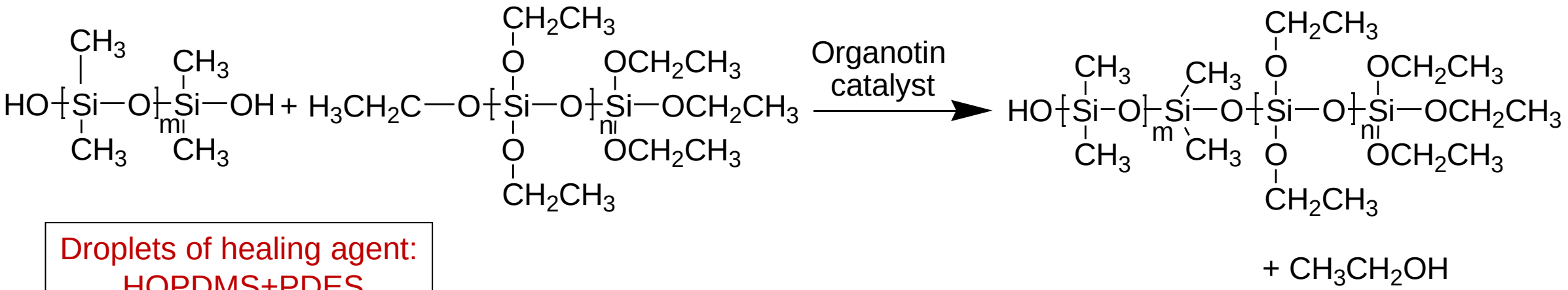
☹ Multiple healing impossible

White et. al. *Nature* **2001,** *409*, 794.

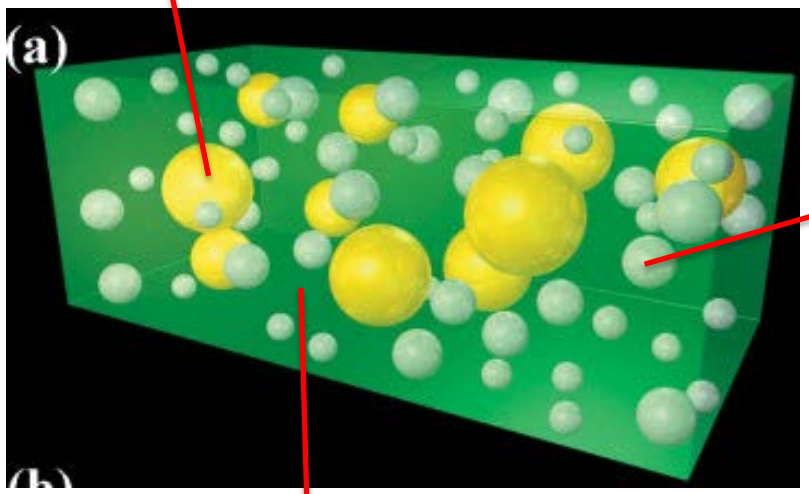
Dual Capsule System

HOPDMS

PDES



Droplets of healing agent:
HOPDMS+PDES

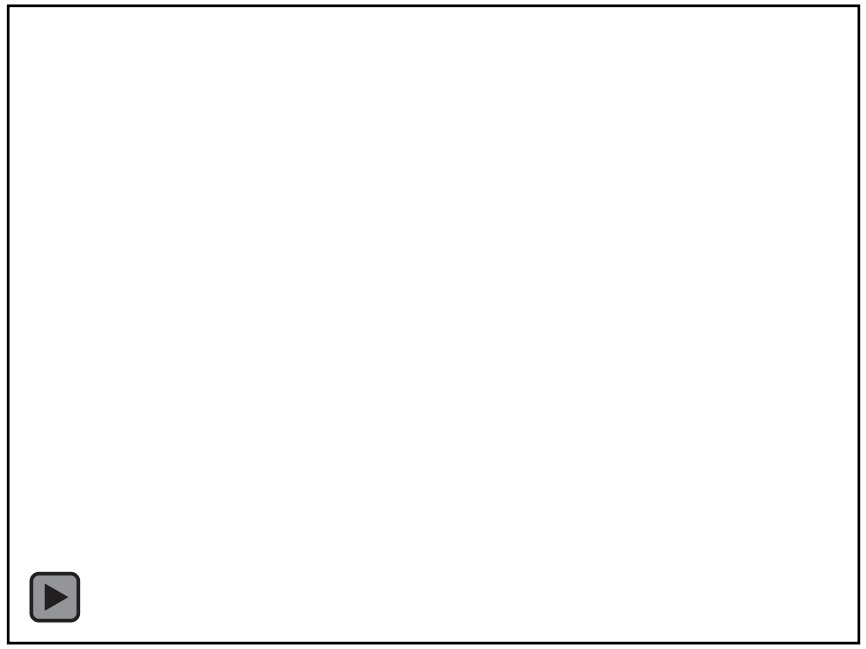


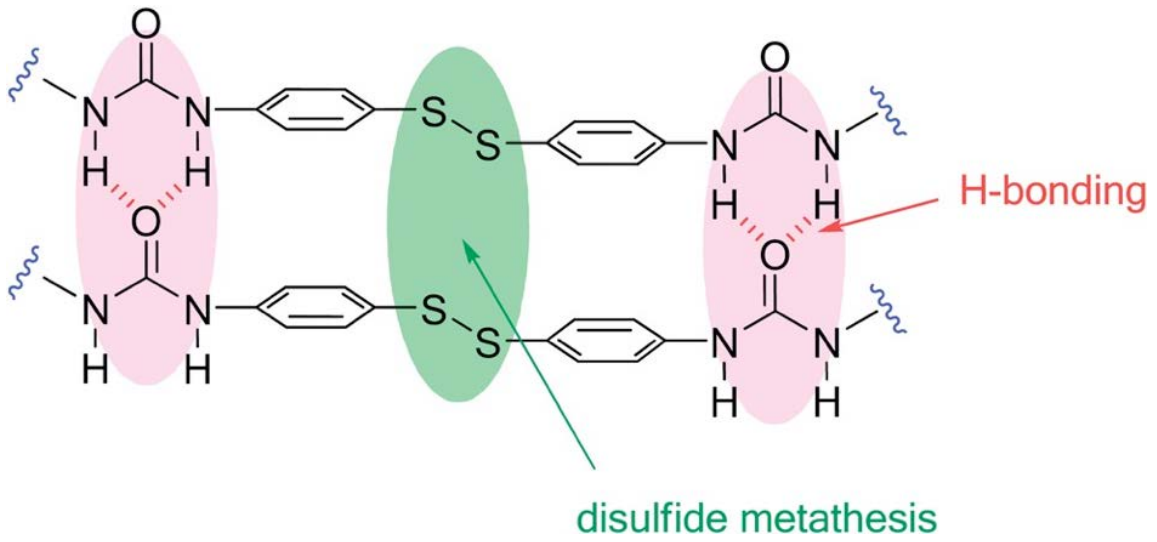
Catalyst: di-*n*-butyltin dilaurate (DBTL), encapsulated in polyurethane microcapsules

Vinyl ester matrix

Cho et al. Adv. *Mater.* **2006**, *18*, 997.

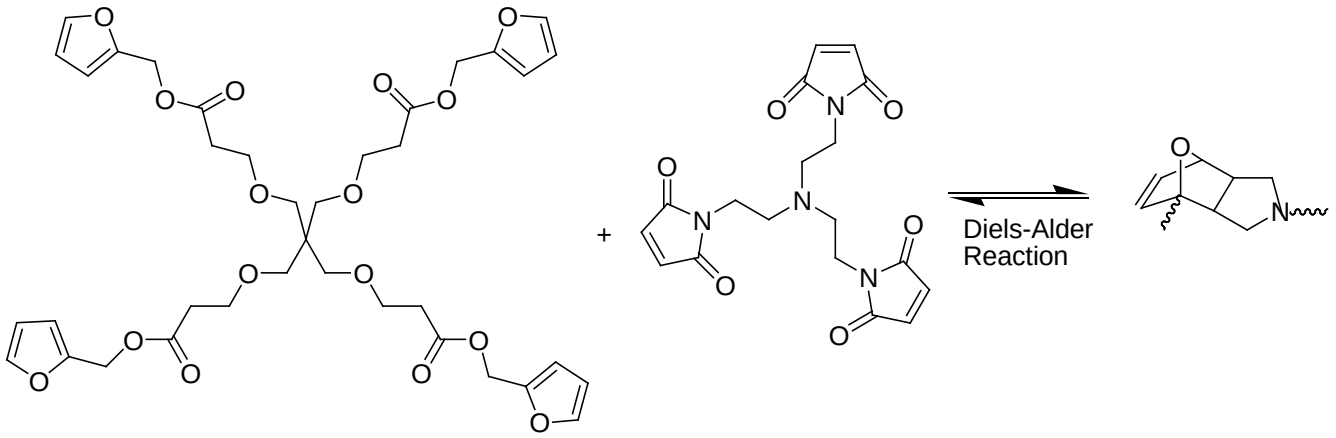
Catalyst free, Room-temp. Self-healing Elastomer





Rekondo et.al. *Mater. Horiz.*, **2014**, 1, 237.

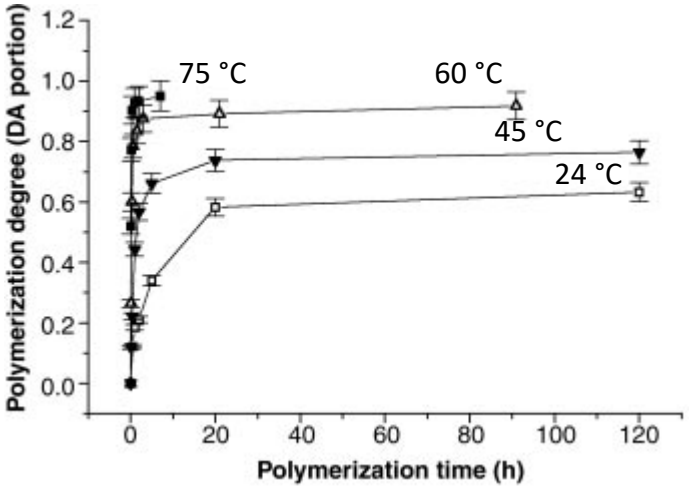
Thermally Cross-linked Self-healing Materials

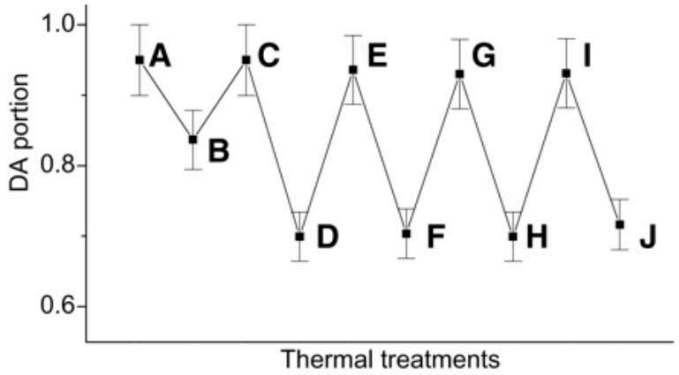


Multifuran

Multi-maleimide

Highly crosslinked
Polymer network





- Multiple cycles of autonomic crack mending
- Uncatalyzed thermal treatment

Chen et. al. *Science* **2002**, *295*, 1698.

Smart, Self-healing Coating

Scratch Resistant Self-healing Coating

New scratches

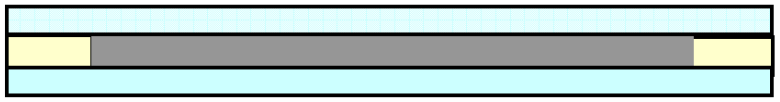
One week later

TOKYO (Dec. 2, 2005)-- Nissan Motor Co., Ltd

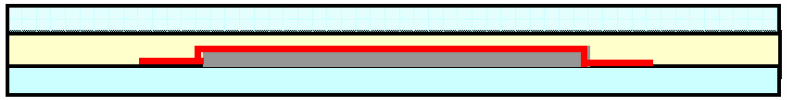
Photovoltaic Devices: Challenges

Protection from moisture / oxygen is needed

Edge Sealant



Laminating Adhesive



: substrate
: adhesive
: display media
: inorganic coating

Polymers used: silicones, epoxies, polyurethanes, acrylates, fluorine containing polymers, etc.

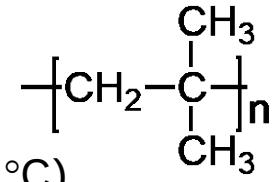
Drawback

- Insufficient barrier properties
- Insufficient oxidative, thermal and UV stability

Objective
To develop self-healing sealant with high barrier properties and stability

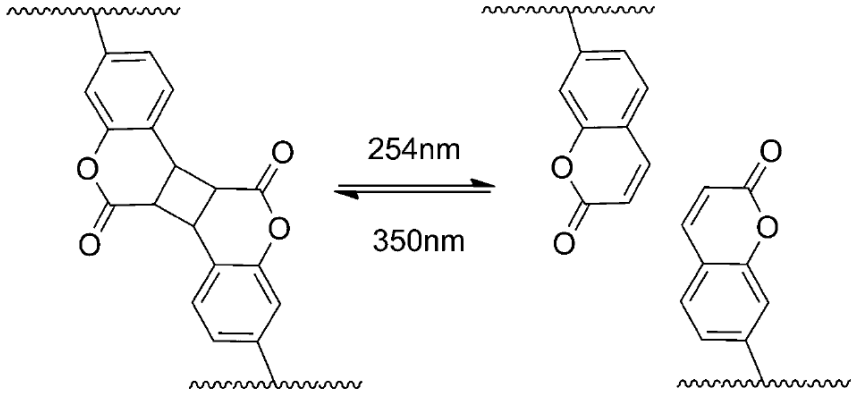
Design Principle

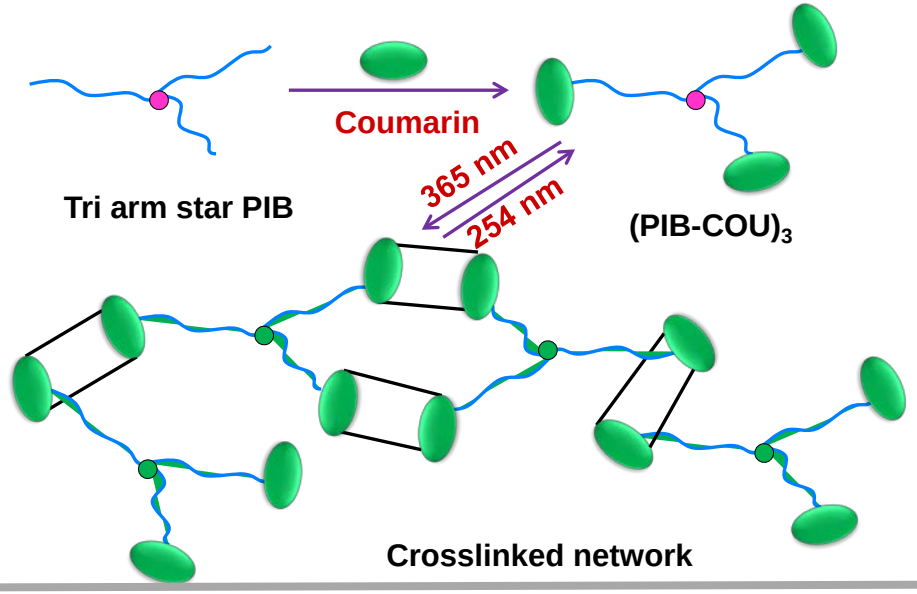
Polyisobutylene



- Flexibility, (T_g ~ -70 °C)
- Thermal and oxidative stability
- Strong adherence to substrate
- Superior damping properties
- Excellent barrier properties
- Chemical and hydrolytic stability

Reversible [2+2] cycloaddition

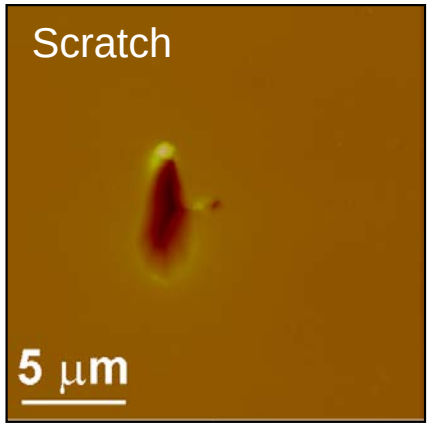


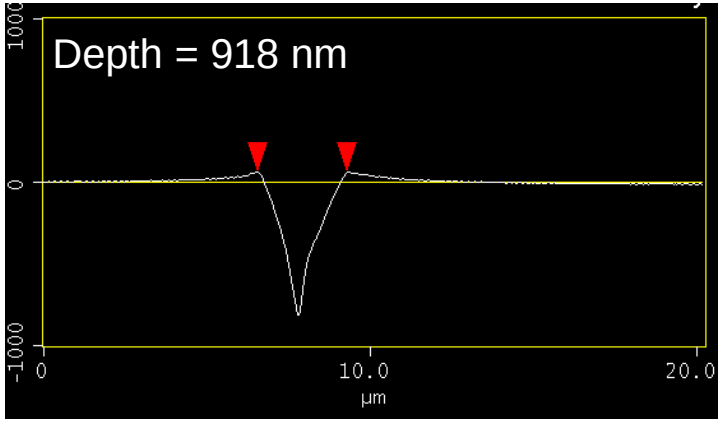


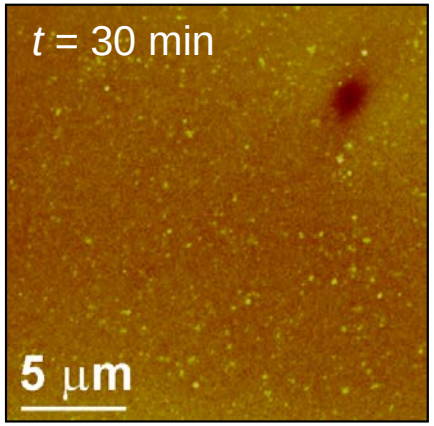
Advantages

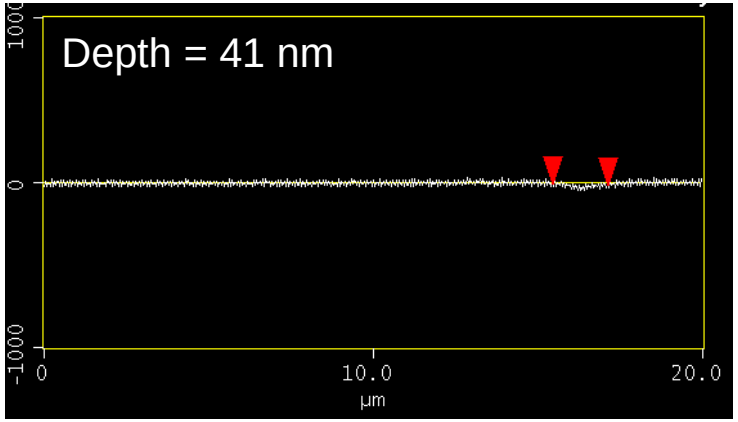
- Solvent less coating
- Exceptional flexibility
- Strong adherence to substrate
- Excellent barrier properties
- Excellent thermal/ UV stability

Photoinduced Self-healing Study

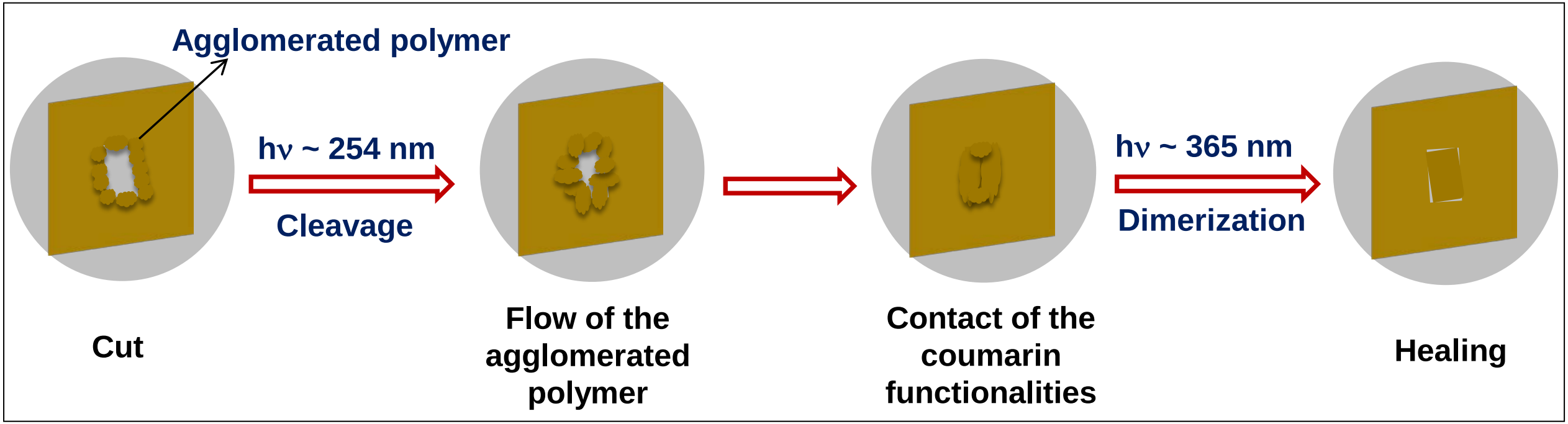




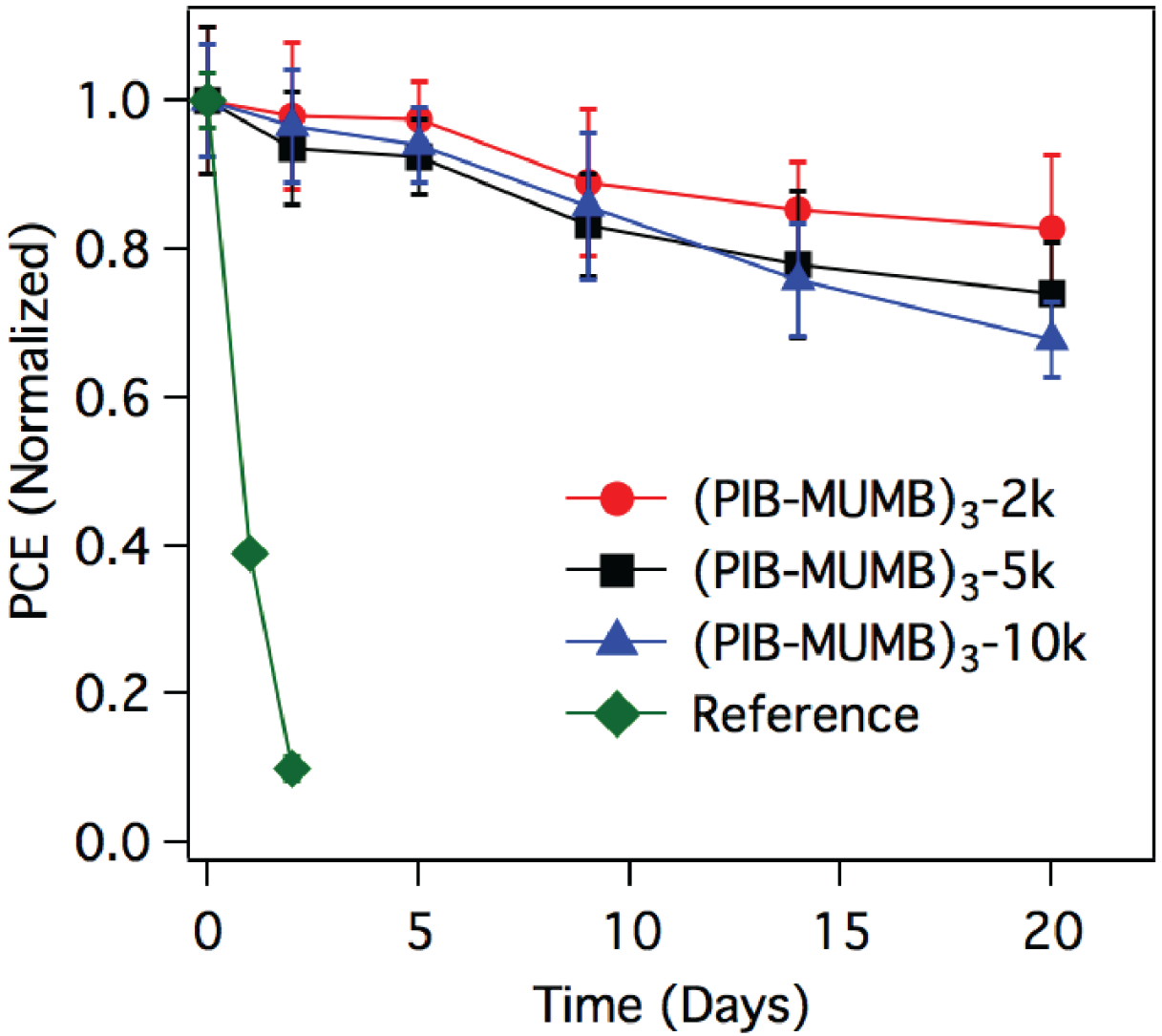


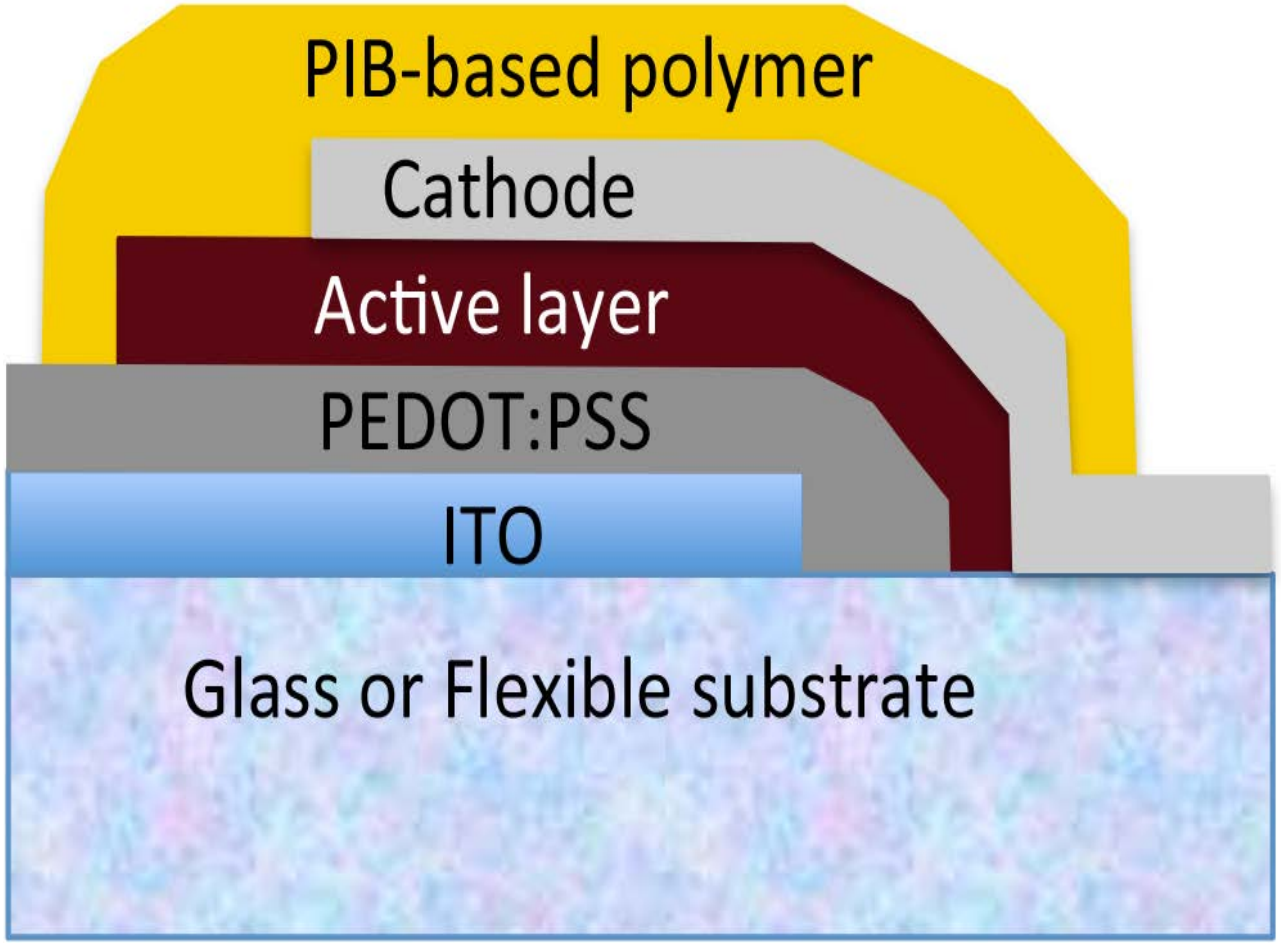


Mechanism of Self-healing



Self-healing Sealant for Solar Cell





Encapsulated Polymer Solar Cell