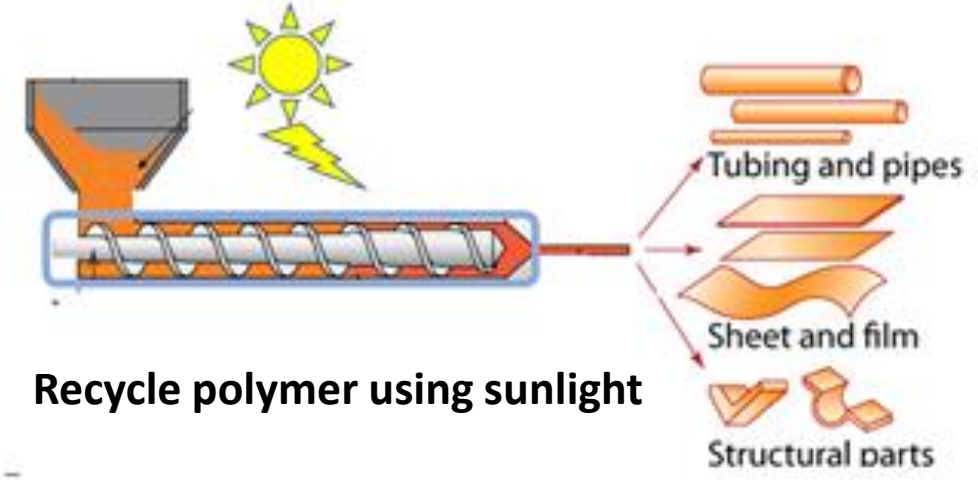
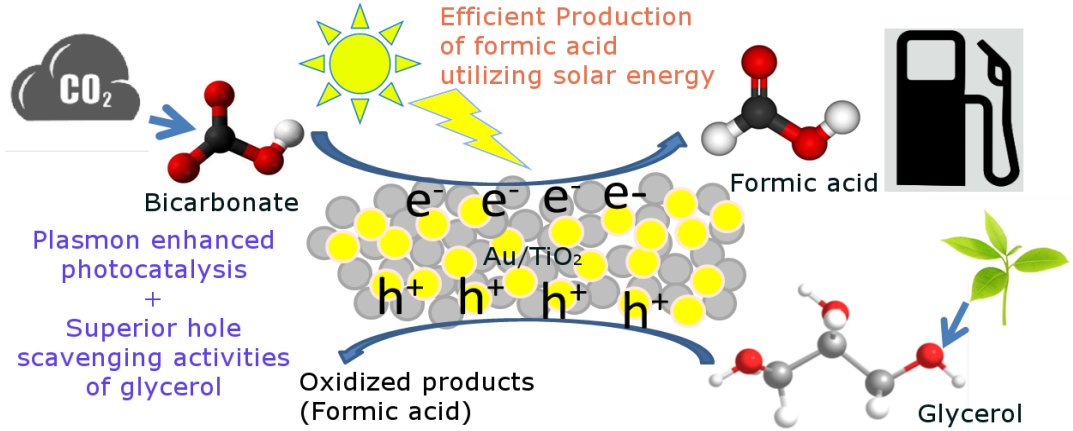
Plasmonics Nanoresearch Laboratory (PI: Dr. Sanchari Chowdhury)

Chemical Engineering

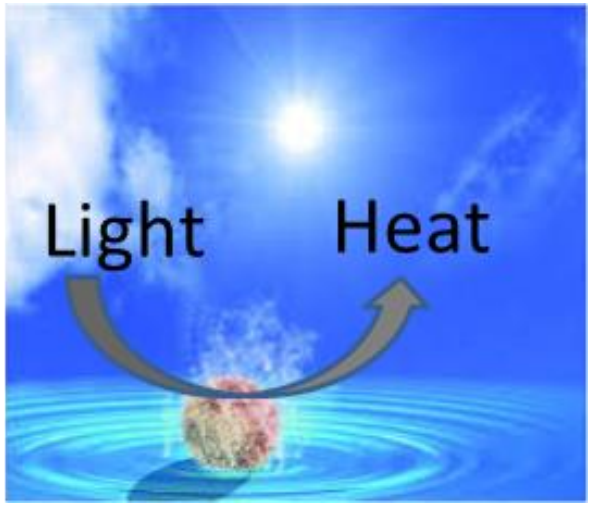
Develop inexpensive and stable materials for efficient conversion of light (sunlight) to useful energy



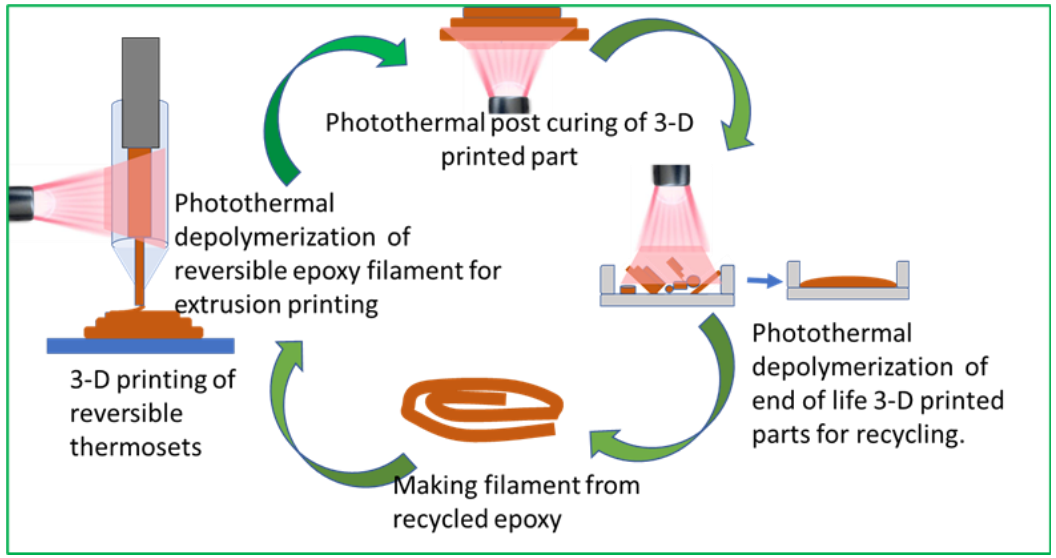
Recycle polymer using sunlight



Drive energy extensive reactions



Evaporate saline water



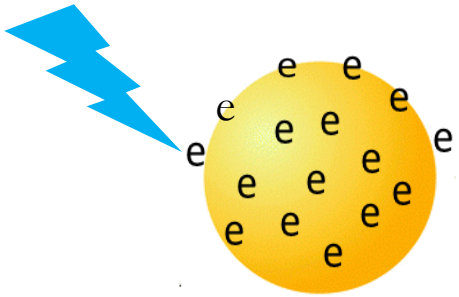
Application of photothermal Materials to Enhance 3-D printing

Research Interests of Our Group

Optically active materials (Absorbs light efficiently)

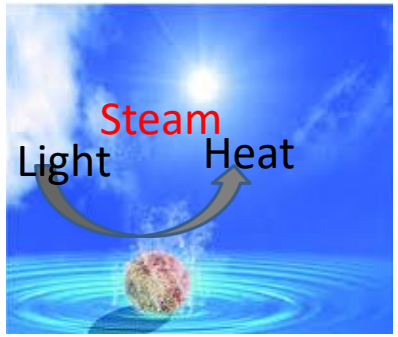
Metallic nanoparticles

Plasmonic Nanostructures

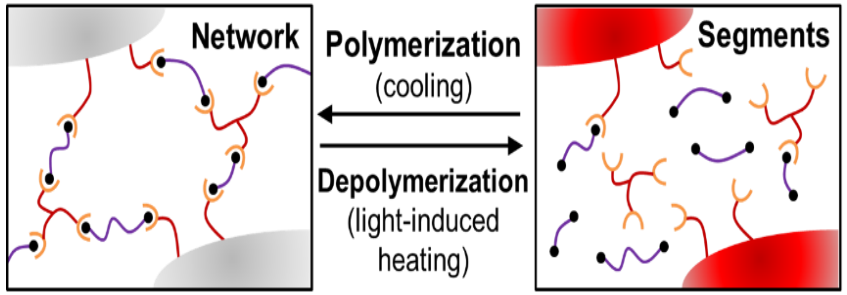


- Concentrate light at the nanoscale (as high as 1000 times)
- Efficiently convert light into heat
- Transfer excited charge/electron to adjacent materials

Generate Localized Heat

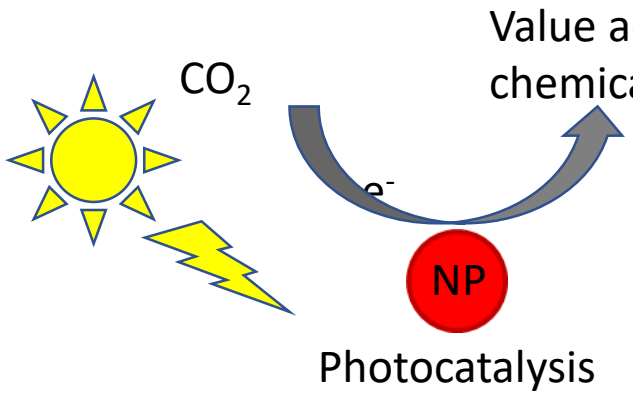


S Chowdhury et al. Nanoscale 12 (18), 10284-10291 (2020)



S Chowdhury et al., A CS Applied Polymer Materials, 2022

Transfer photoexcited charge carriers



S Chowdhury et al .Solar Energy Materials and Solar Cells, 200, 109967 (2019).
*S Chowdhury et al, ACS Sustainable Chem. Eng., **6**, 1872 (2018).*
*S Chowdhury et al .,Journal of CO_2 Utilization, **22**, 117, (2017).*

Development of Recyclable Thermosets for Additive Manufacturing

Goals: Development of recyclable thermosets (epoxy):

- Recycling using solar light;
- Suitable for additive manufacturing (3D printing);
- Comparable strength and stability as conventional epoxies;

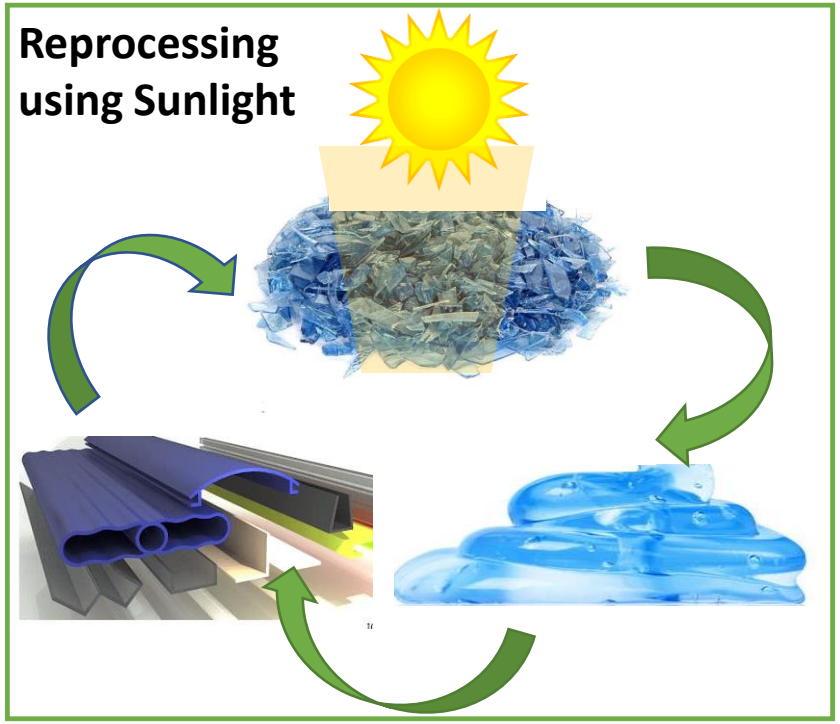
Challenging to recycle/ additive manufacturing

Excellent mechanical properties

Thermal and chemical resistance

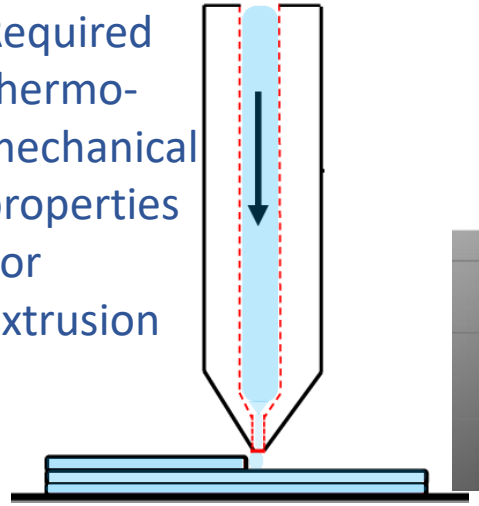
Irreversible crosslinked networks

Reprocessing using Sunlight

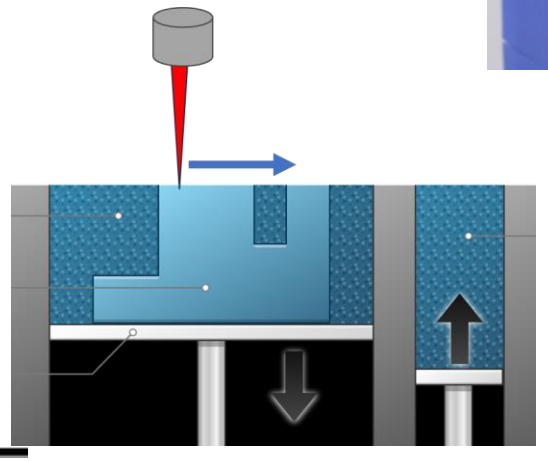


Enhancing additive manufacturing of thermosets

Required thermo-mechanical properties For extrusion



Rapid curing



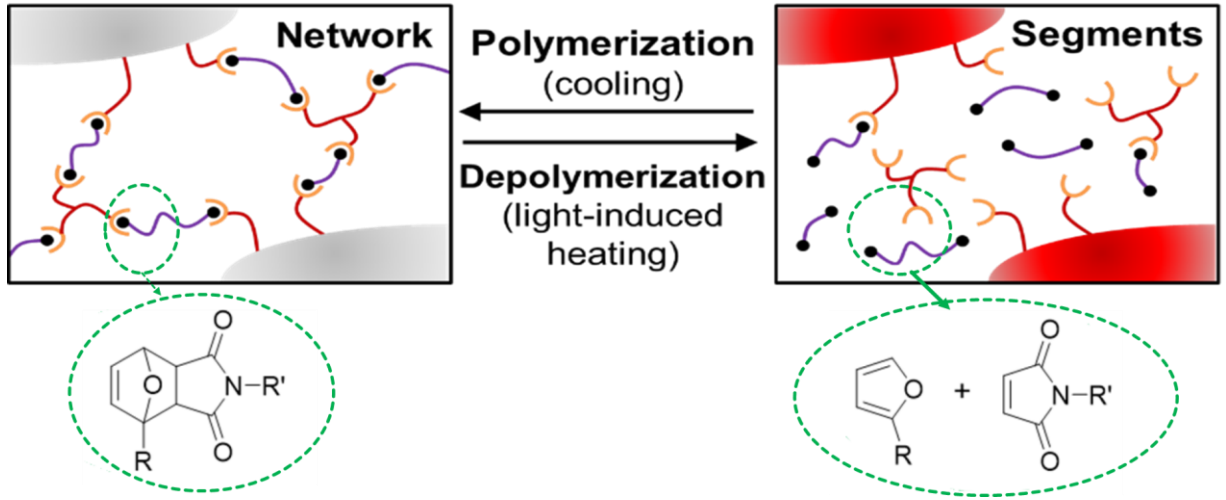
Efficient liquefaction to improve layer by layer adhesion.

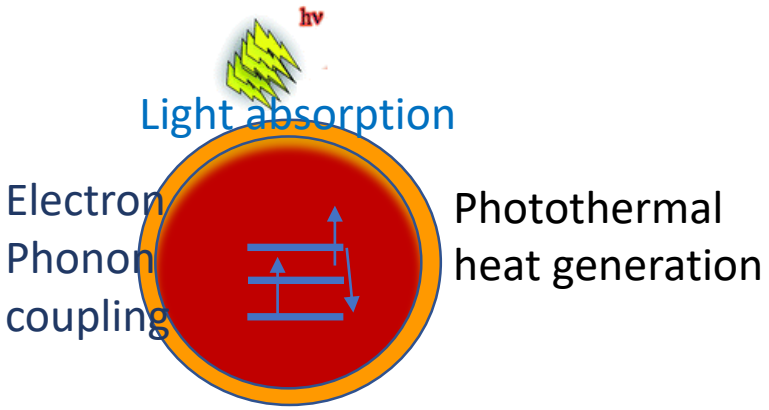
Efficient reversible liquefaction and solidifying (curing) of thermosets using light!

Proposed Strategies

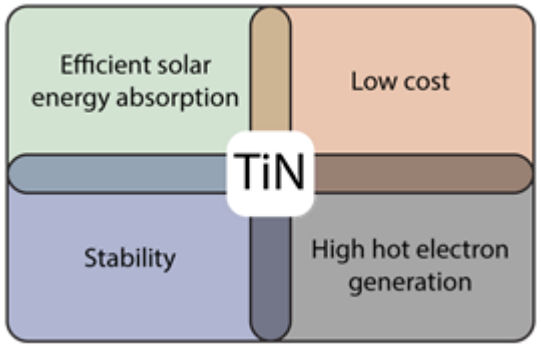
Development of reversible epoxy

- Diels-Alder chemistry
- Addition of photothermal refractory plasmonic nanoparticles (Titanium nitride,TiN)





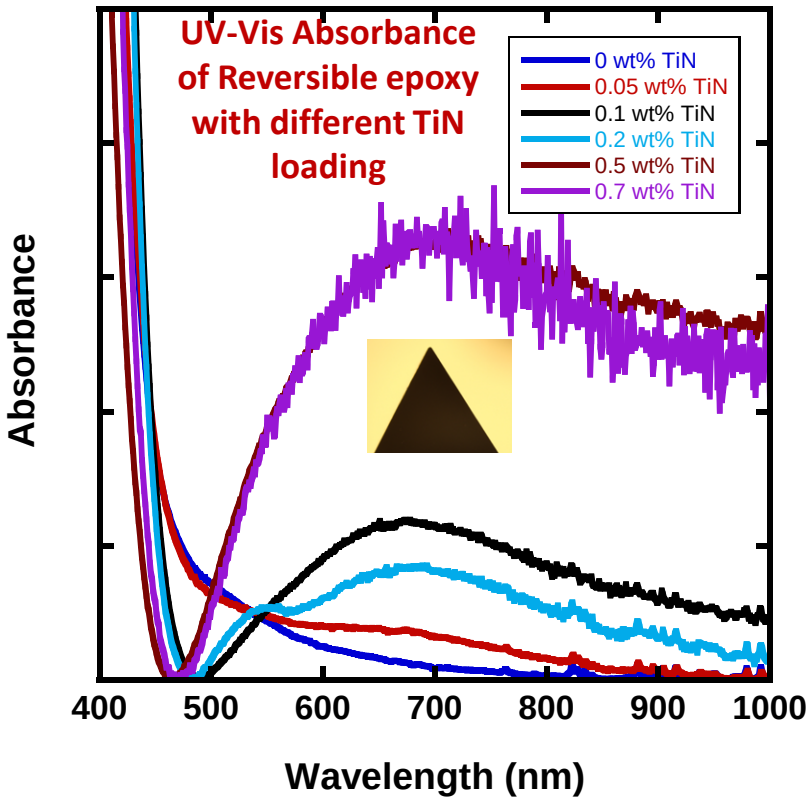
Plasmonic nanoparticles

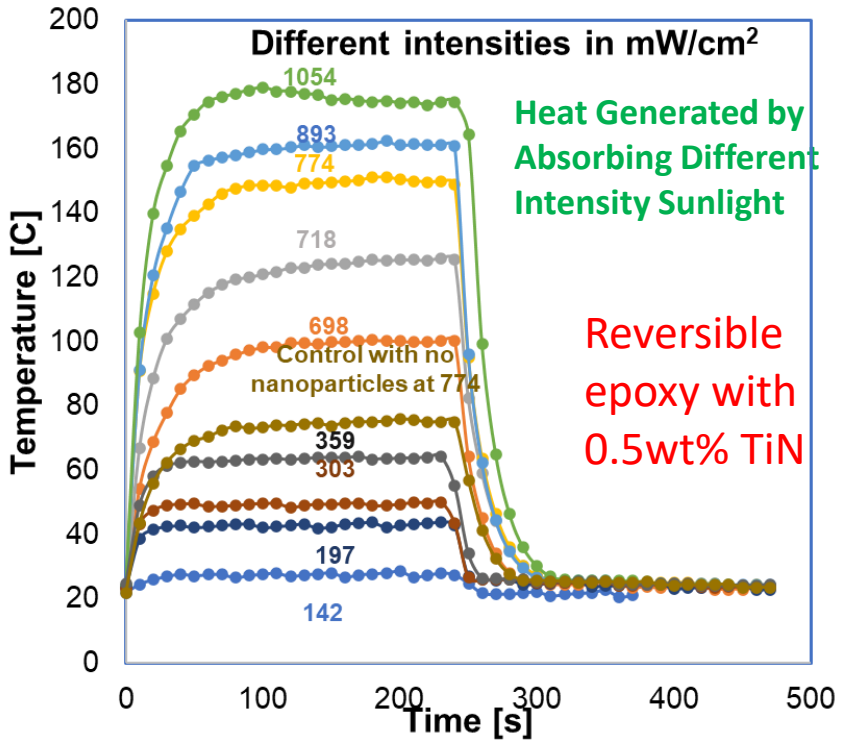


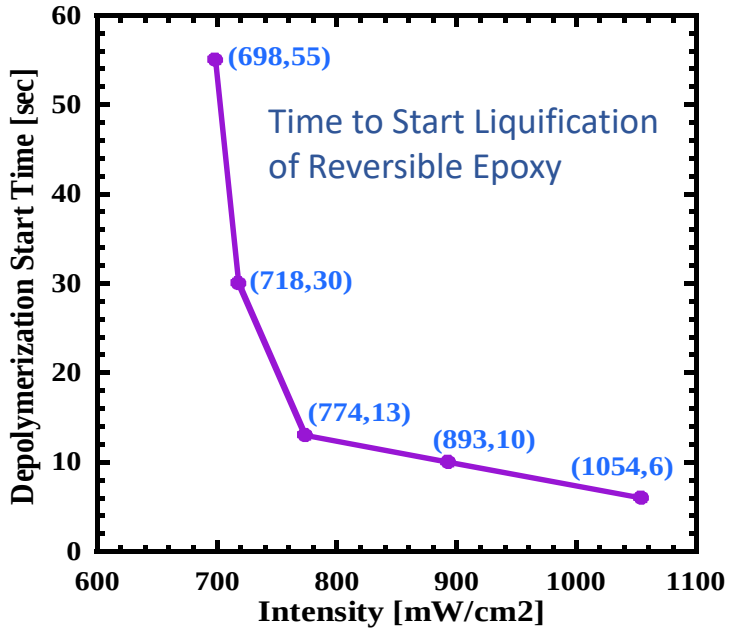
Transition metal nitride
Refractory Plasmonics

- Concentrate electromagnetic field as high as 1000 times at nanoscale
- TiN efficiently and rapidly convert broad spectrum white light to nanoscale heat to initiate the retro Diels-Alder reaction.

Photothermal reversible epoxy composites



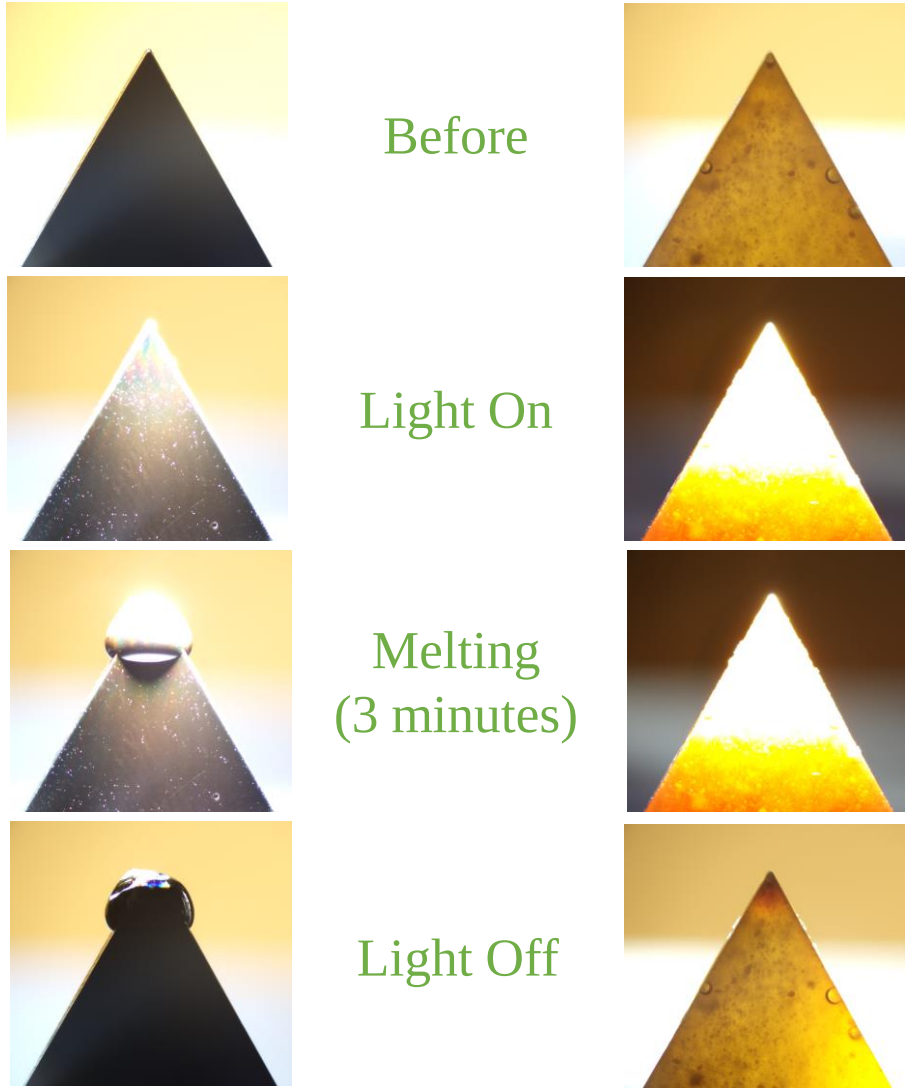


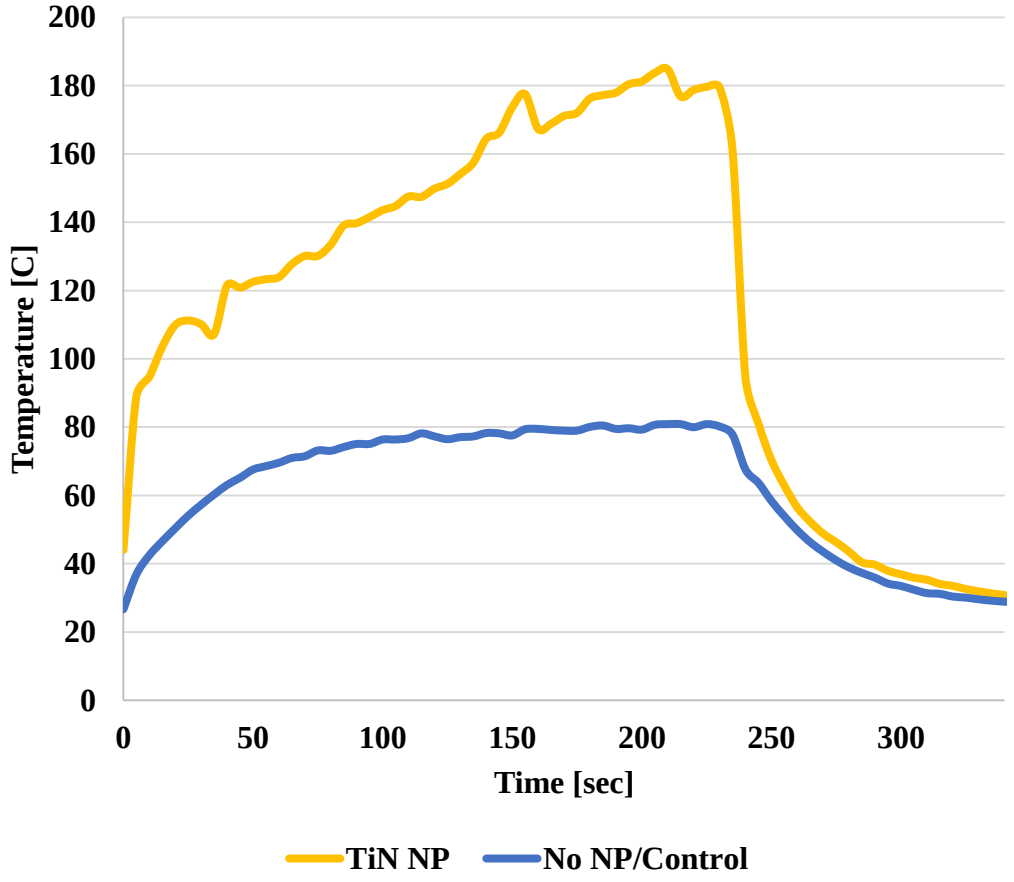


AFM image and Grazing-Incidence Small-Angle X-ray Scattering data confirms average size TiN nanoparticles are ~80 nm confirming good dispersion.

- Even without functionalization of nanoparticles we achieve well dispersion of nanoparticles.
- We functionalize nanoparticles with amine and thiol to improve the loading of nanoparticles in polymer matrix.
- With photothermal nanoparticles the temperature for r-DA reaction (liquefaction) achieved with seven-time sun intensity.
- Liquefaction time decreased with increased light intensity.

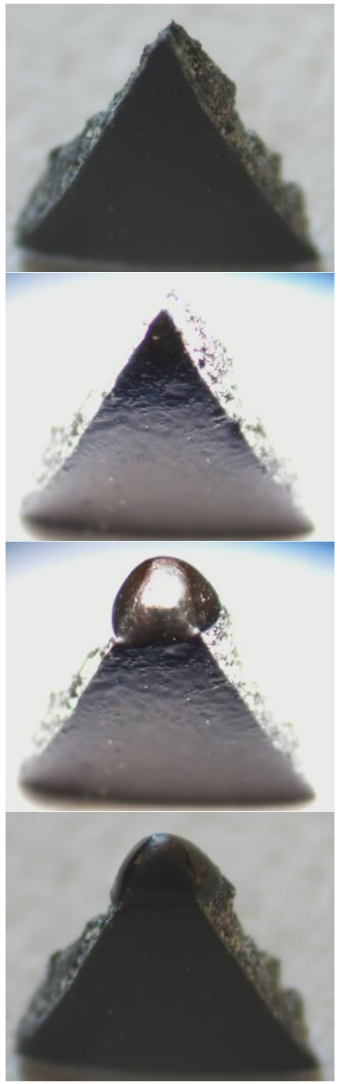
Photothermal nanoparticle/Epoxy vs. Epoxy Same Intensity





Photothermal Nanoparticles/Epoxy vs. Epoxy

774 mW/cm2



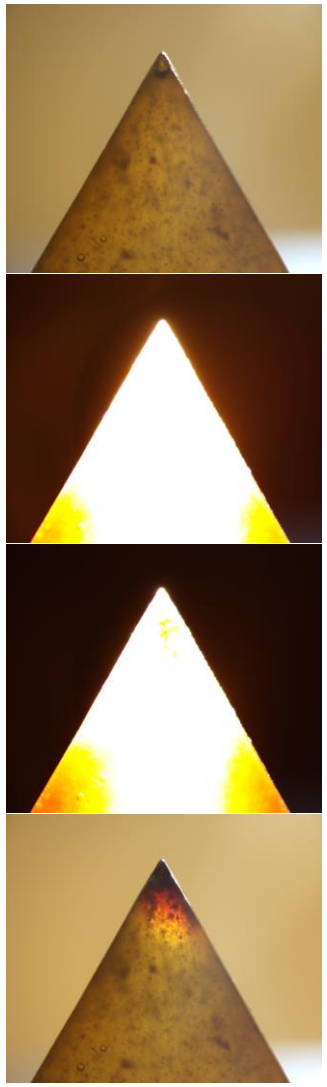
Before

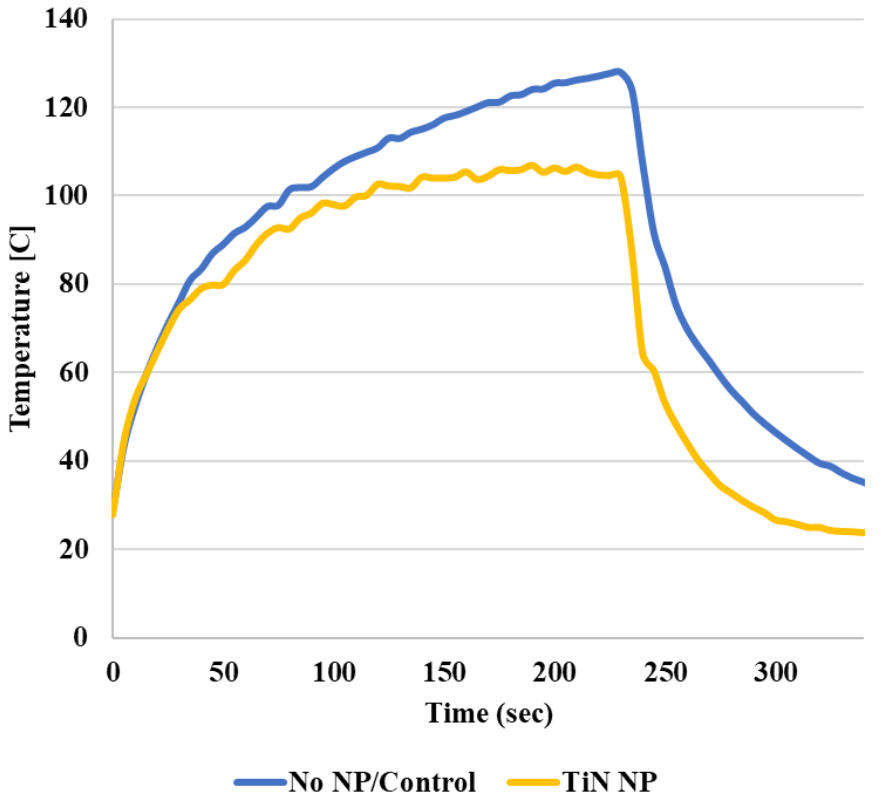
Light On

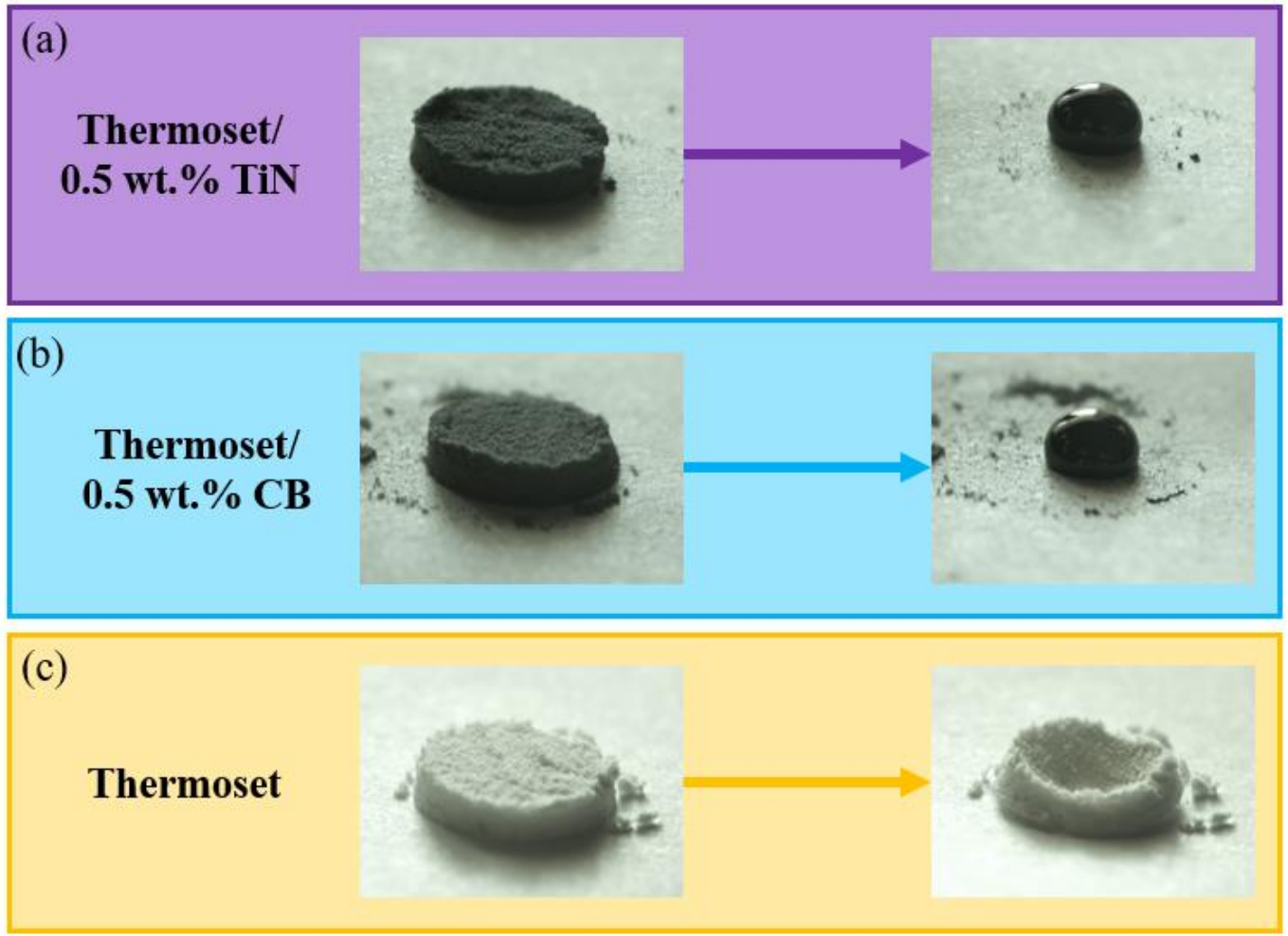
Melting

Light Off

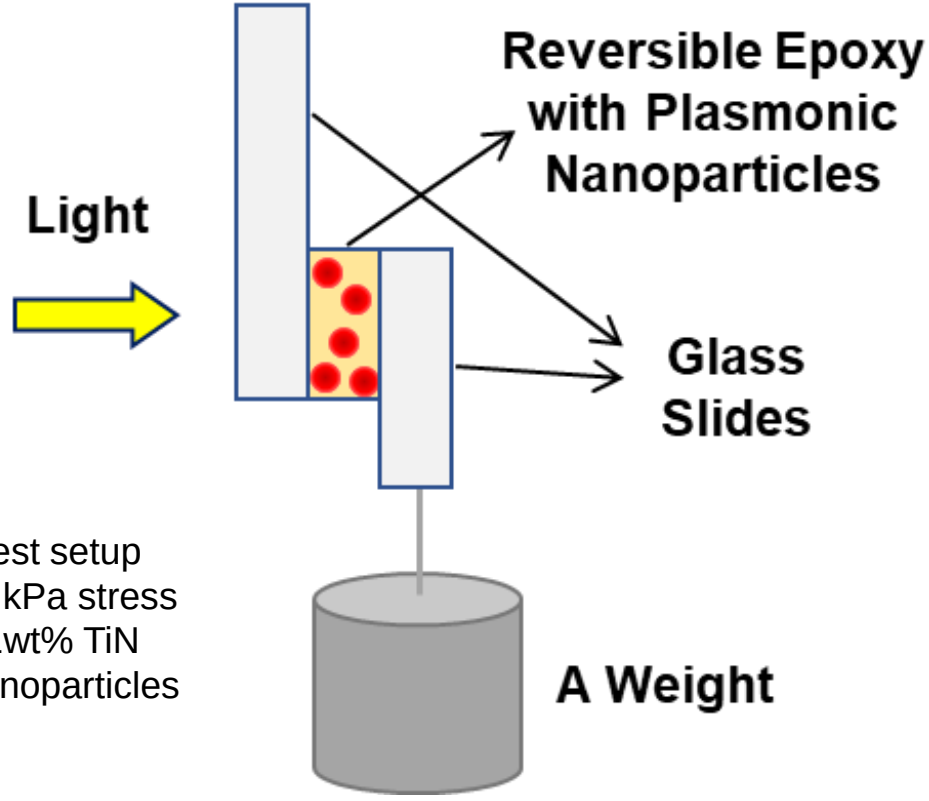
1408 mW/cm2





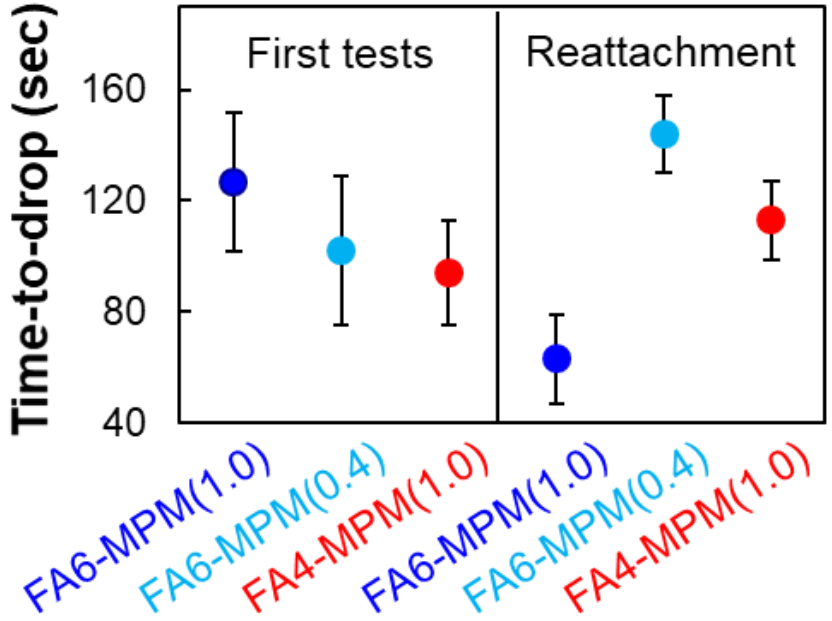

(a)
Thermoset/
0.5 wt.% TiN
(b)
Thermoset/
0.5 wt.% CB
(c)
Thermoset

Light mediated Reversible bonding debonding epoxy adhesive

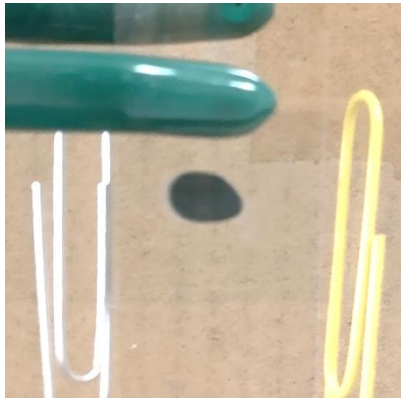


Photothermal drop test setup

- 20 kPa stress
- 0.1wt% TiN Nanoparticles



First test

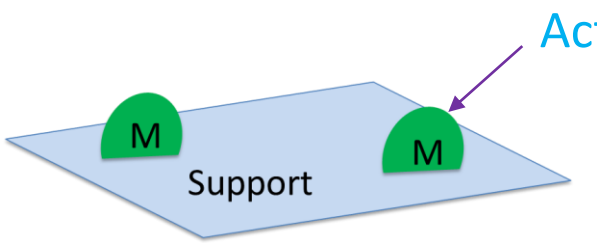


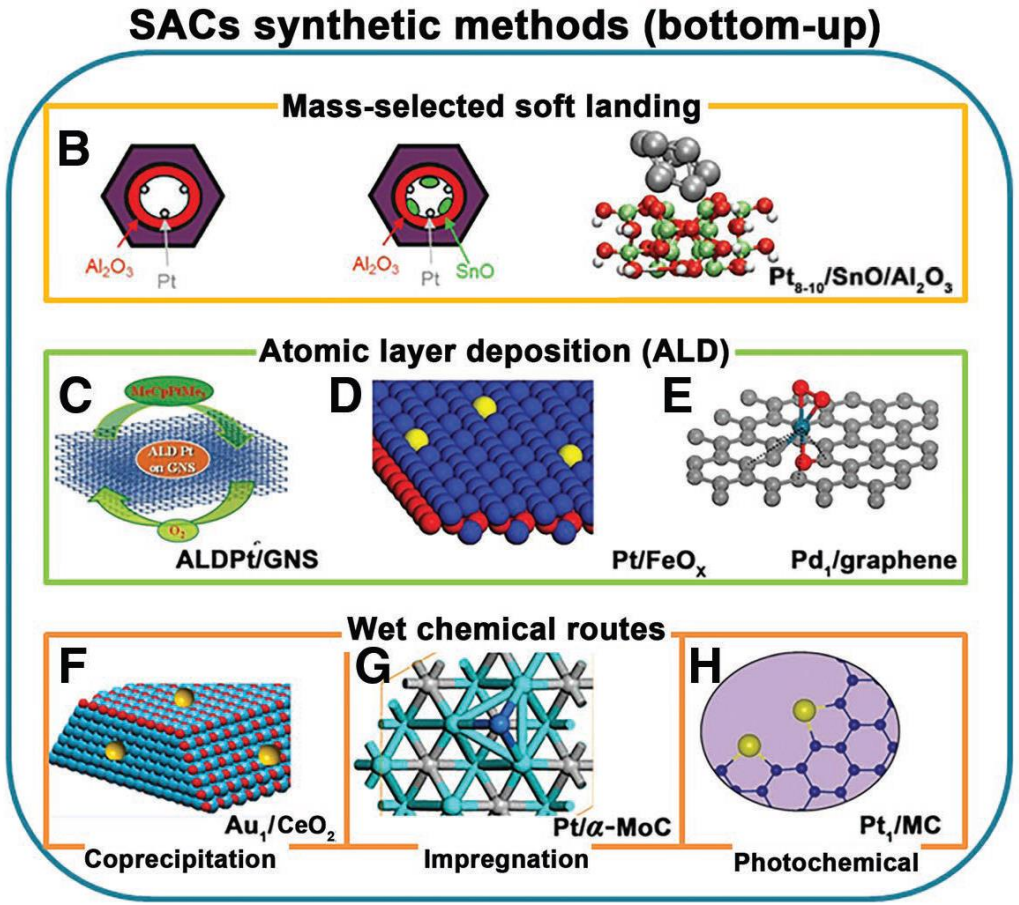
Separated

Reattached sample

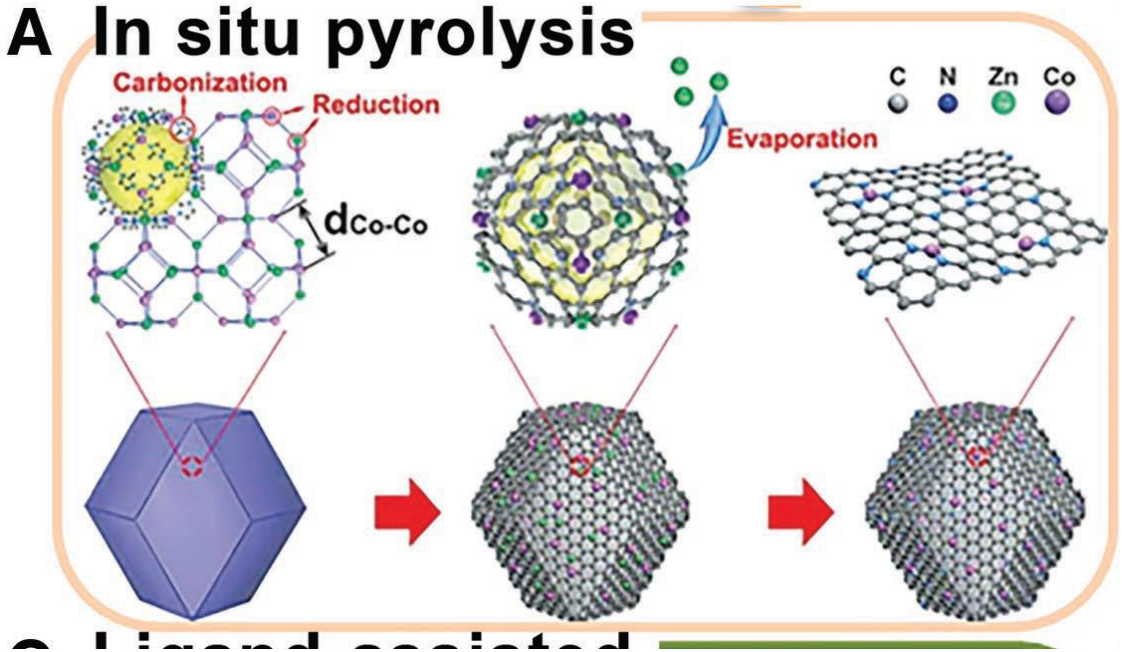
Separated

Single-Atom Catalysts (SACs)





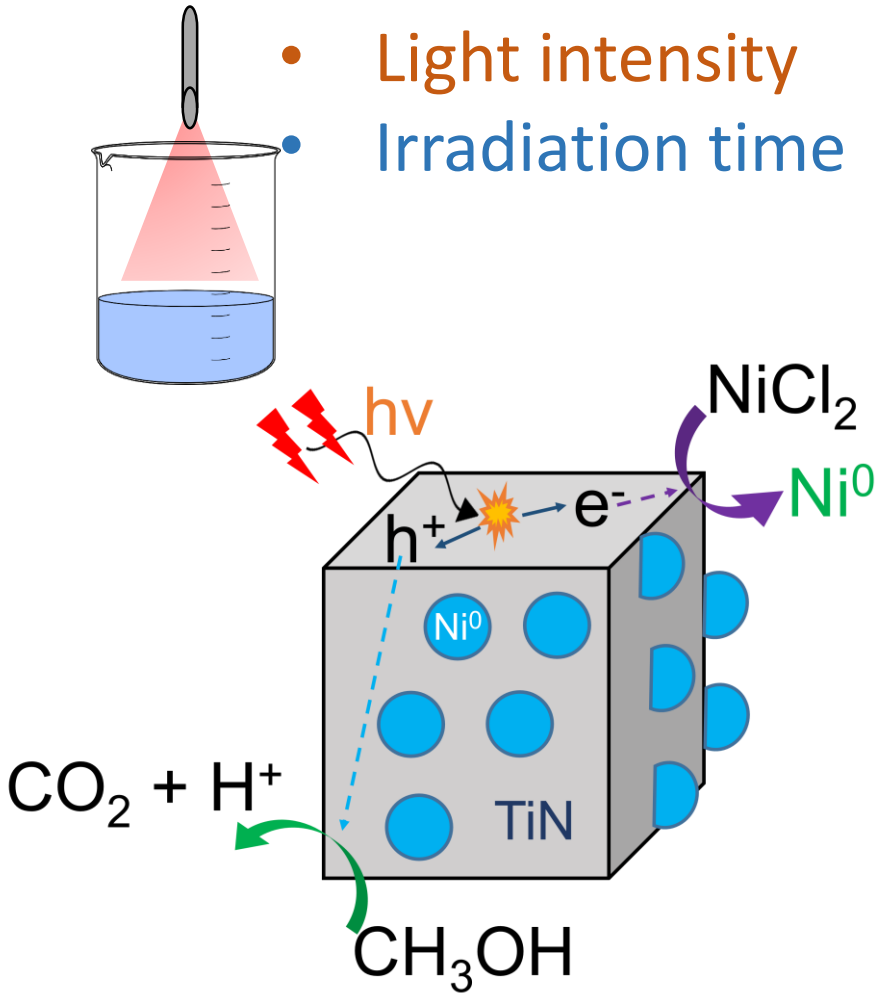
Adv. Mater. **2018**, *30*, 1801649

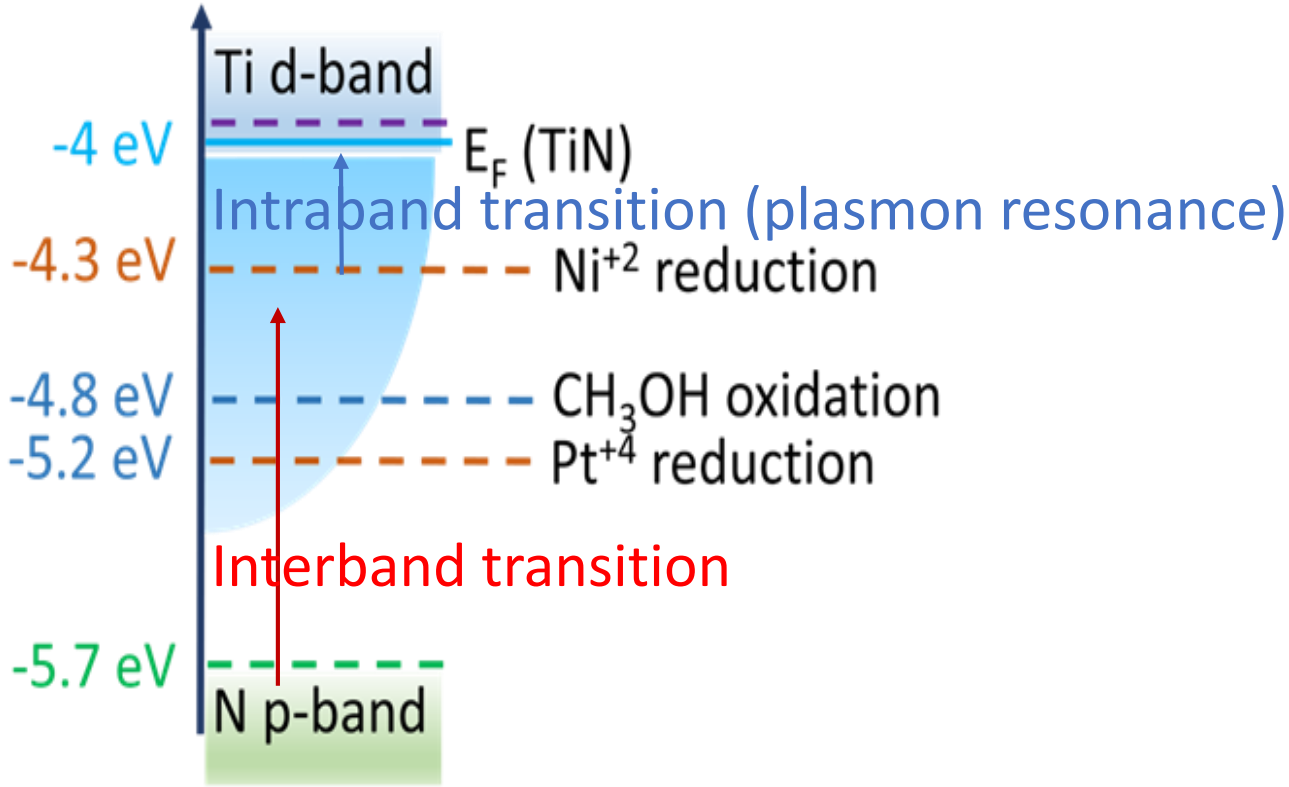


- High energy requirement
- Special conditions
- Complex synthetic steps
- Special instruments

Plasmon Enhanced Photodeposition Method

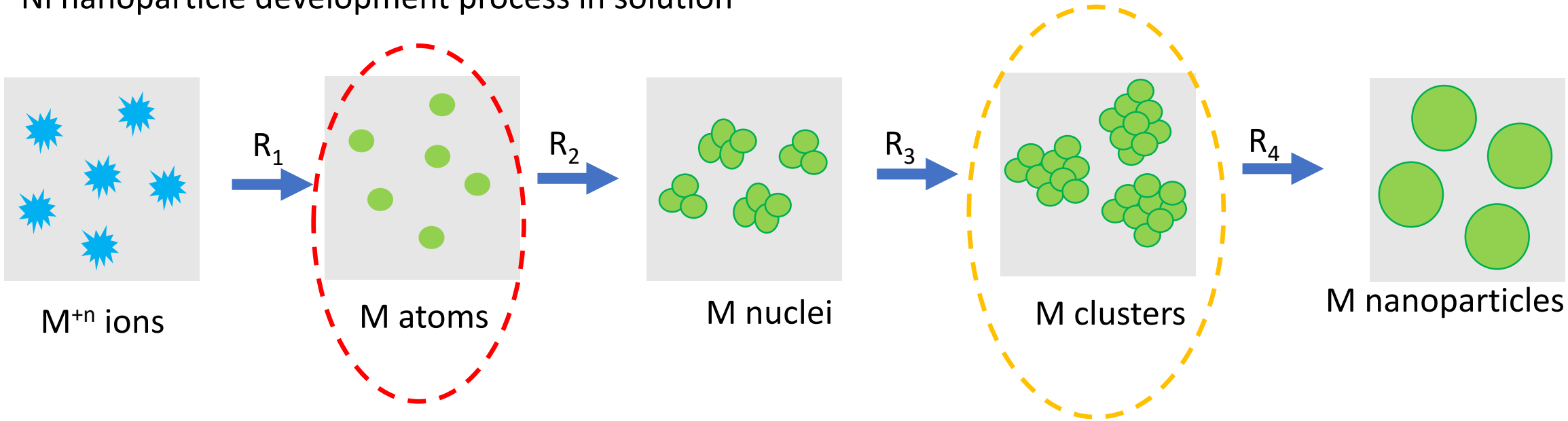
- Light intensity
- Irradiation time





- Visible light-sensitive plasmonic nanocomposite catalyst

Ni nanoparticle development process in solution



If R_1 is slow → M particle deposition

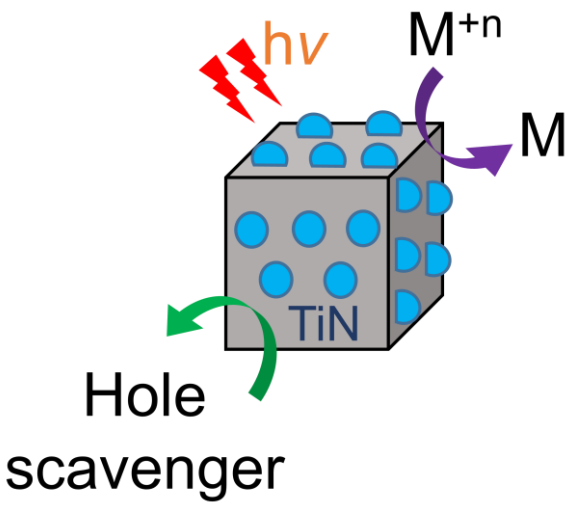
If $R_1 > R_2$ → More single atoms will remain → Ni Single-atom deposition

How to increase R_1

Using plasmonic properties → Intensity α Hot electron generation

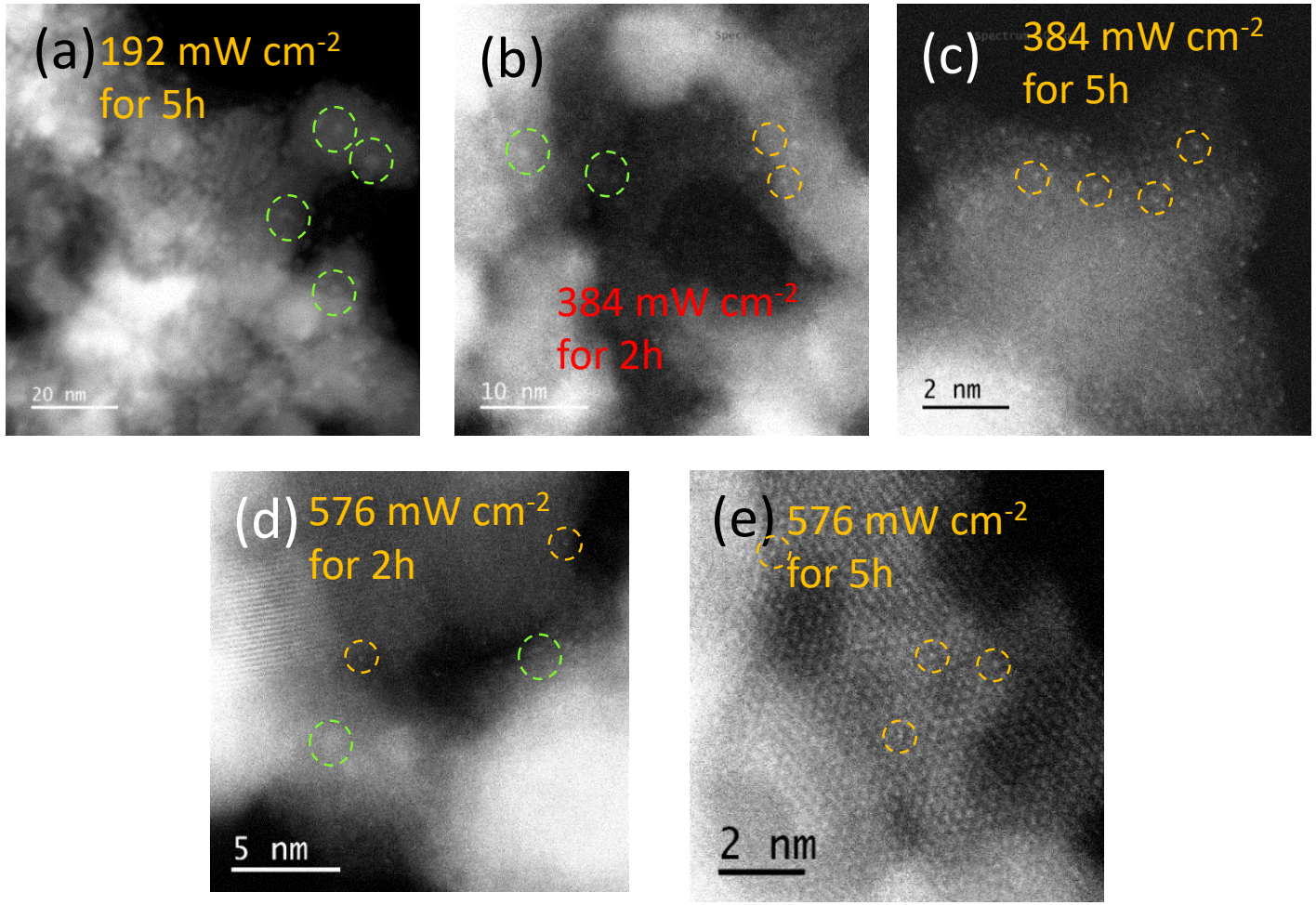
M^{+n} concentration

Hole scavenger concentration



Chen, D. H.; Wu, S. H. Synthesis of Nickel Nanoparticles in Water-in-Oil Microemulsions. *Chemistry of Materials* **2000**, *12* (5), 1354–1360. https://doi.org/10.1021/cm991167y.

Deposition of Ni SACs on TiN



Light intensity, Wavelengths & Irradiation time ⟶ Single-atoms

Deposition of Pt SACs on TiN

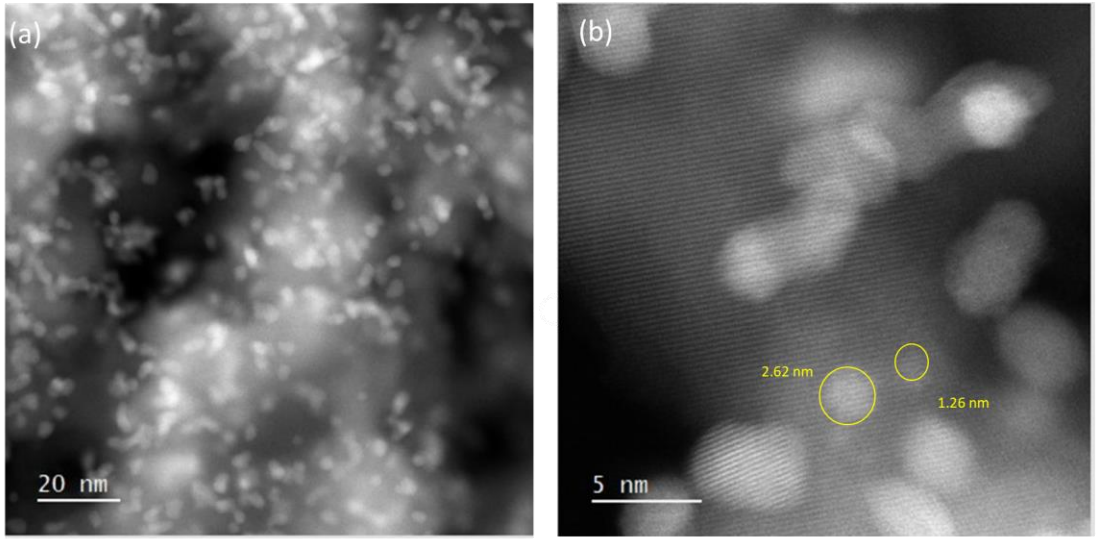


Fig. 2: (a) (b) STEM of TiN_Pt nanocomposites with Pt depositions

Avg. NPs – 2 -3 nm

- H-Lamp: 192 mW cm^{-2}
- 3 hours

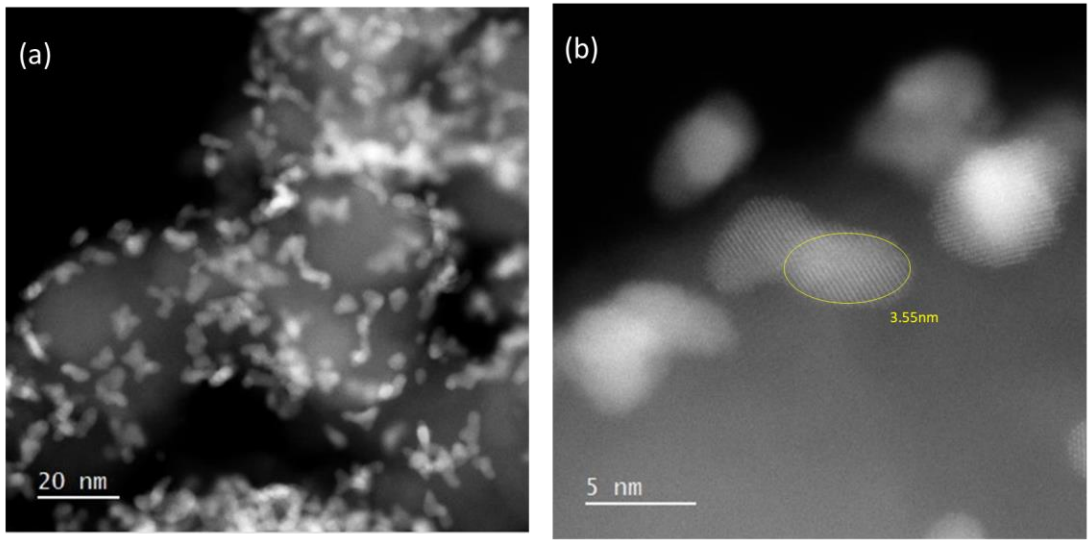
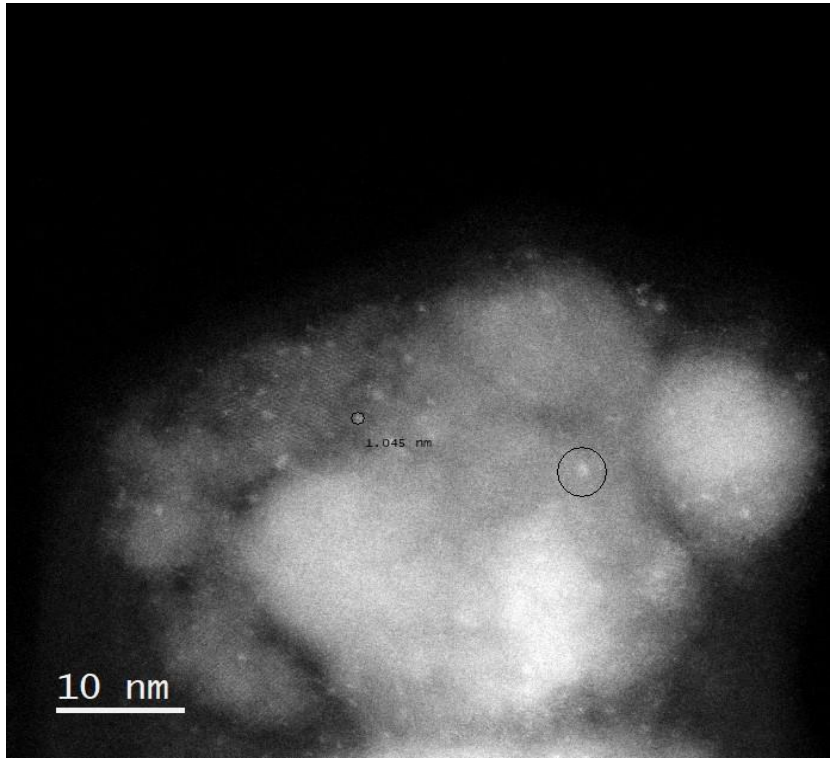


Fig. 3: (a) (b) STEM of TiN_Pt nanocomposites with Pt depositions



Where Can We Contribute:

- Solar Energy Enhanced Processes
- Recyclable Polymer
- Polymerization using Heat
- Light Mediated Additive Manufacturing of Polymer
- Removable Adhesive
- Catalysis
- Any Heat Mediated Processes Where Light can be Used to Generate the Required Heat!

Acknowledgements

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Past Members

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ACS PRF

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http://cint.sandia.gov

Los Alamos NATIONAL LABORATORY
Los Alamos, New Mexico
http://cint.lanl.gov

Center for Integrated Nanotechnologies
A U.S. DOE Nanoscale Science Research Center