Bilayer Fabrication of Transient Devices using Poly(phthalaldehyde)

Alexa Espinoza

PI: Dr. Paul Kohl

Mentor: Jisu Jiang

Georgia Tech Institute for Electronics and Nanotechnology

National Nanotechnology Coordinated Infrastructure

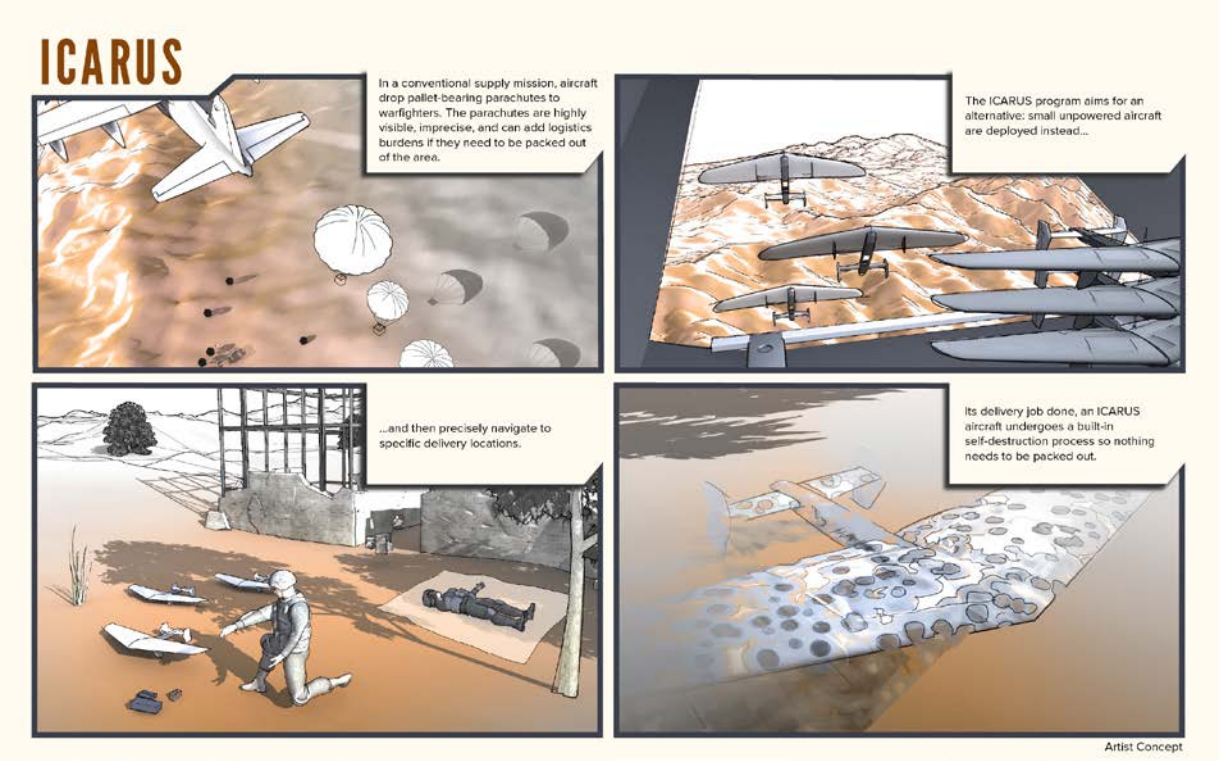
SENIC Southeastern Nanotechnology Infrastructure Corridor

NSF

Southeastern Undergraduate Internship in Nanotechnology, NSF EEC-1757579

Motivation

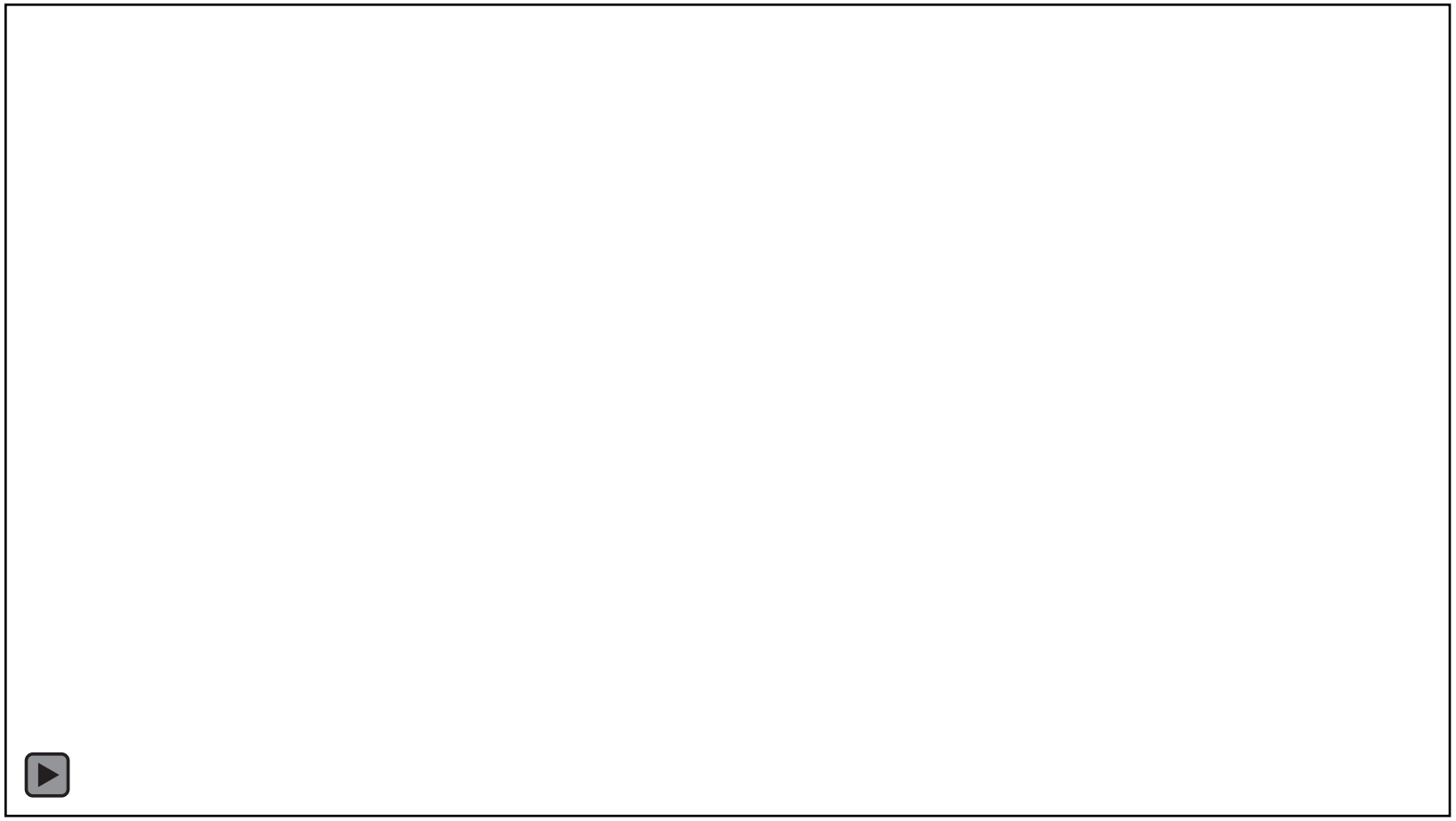
- The objective of DARPA ICARUS project is to create vanishing aircrafts.
- Small items would be supplied using these low cost, disposable aircrafts to military teams operating in difficult-to-access areas.



https://www.darpa.mil/news-events/icarus-proposers-day

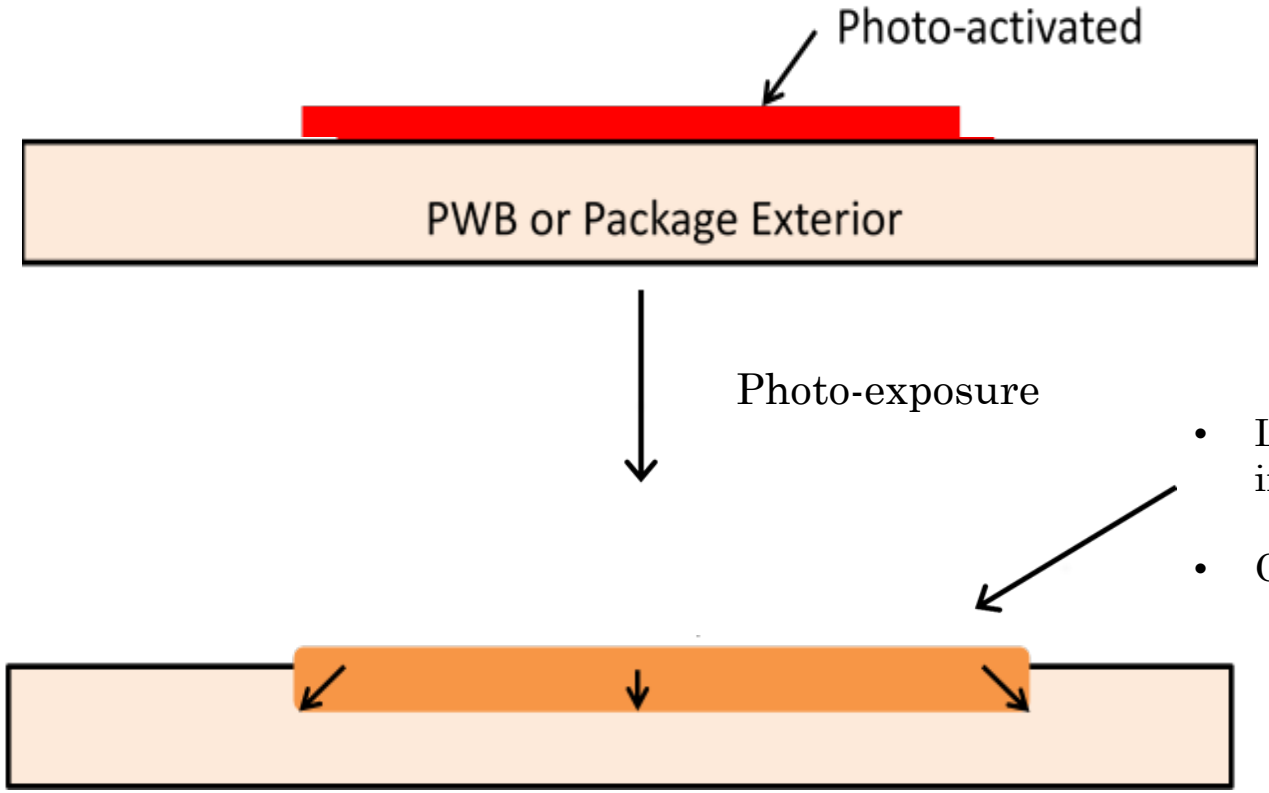
SENIC Southeastern Nanotechnology Infrastructure Corridor

Time Lapse Video Showcase (200X speed, actual case took 1 hr)



Film was approximately 2” x 1.5”

Design Structure for Two Layer Structures

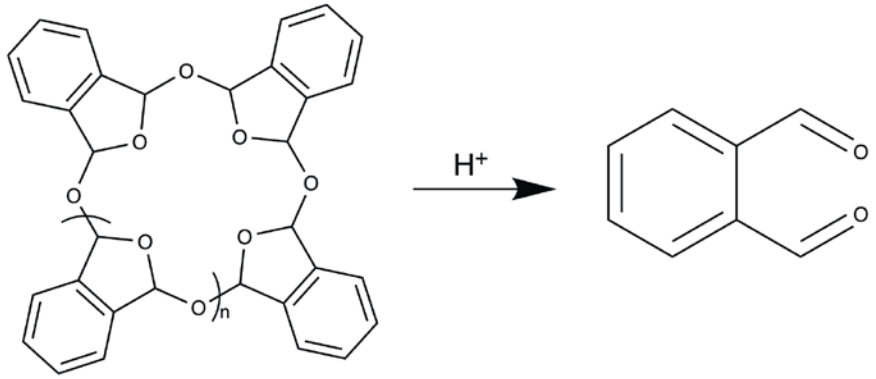


- Liquid layer with catalyst penetrates into substrate causing decomposition.
- Catalyst diffuses in liquid layer.

Method

- Spray coating
  - Inexpensive and easy to apply
- Methanol development
  - Solvent for monomer, non-solvent for polymer
  - Wash out monomer from decomposition

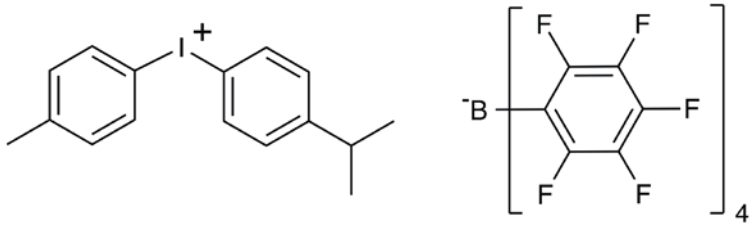
Poly(phthalaldehyde) polymer



- Synthesize with high molecular weight (up to 400 kDa)
- Highly sensitive to acids
- Self-immolative polymer
  - Rapid unzipping after acid trigger
  - Clean monomer → Environmental friendly

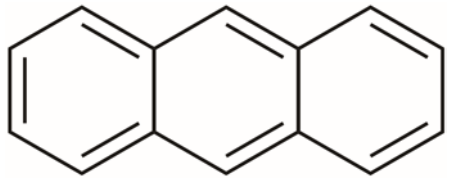
Visible Light Sensitization

- Photo Acid Generator (PAG)
  - Upon UV exposure, PAG produces a strong acid.
  - Photo-active spectrum is limited to UV light.

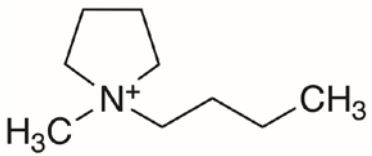


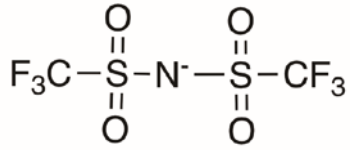
Rhodorsil FABA

- Anthracene
  - Anthracene → absorbs UV light at λmax = 370 nm (near UV)
  - Photo-electron transfer reaction between anthracene and PAG generates free acid.



- Butylmethylpyrrolidinium Bis(trifluoromethylsulfonyl)imide (BMP)
  - Added to keep low freezing point → keep products liquid.





SENIC Southeastern Nanotechnology Infrastructure Corridor

PPHA vs. No PPHA on Photosensitive Layer

Sample	% PPHA	% PAG	% BMP	BMP/PAG Ratio	Time to complete depolymerization (after exposure)	Stays liquid?
1	15.4	14.0	41.4	2.96	Crystallize	No.
2	19.2	31.0	41.4	1.34	Crystallize	No.
3	0	21.7	54.5	2.51	5 min.	Yes, 10 min.
4	0	9.9	49.2	4.97	10 min.	Yes, 12 min.
5	0	8.02	53.3	6.65	5 min	Yes, 16 min.
6	0	3.9	37.6	9.64	Immediately	Yes, 30 min.

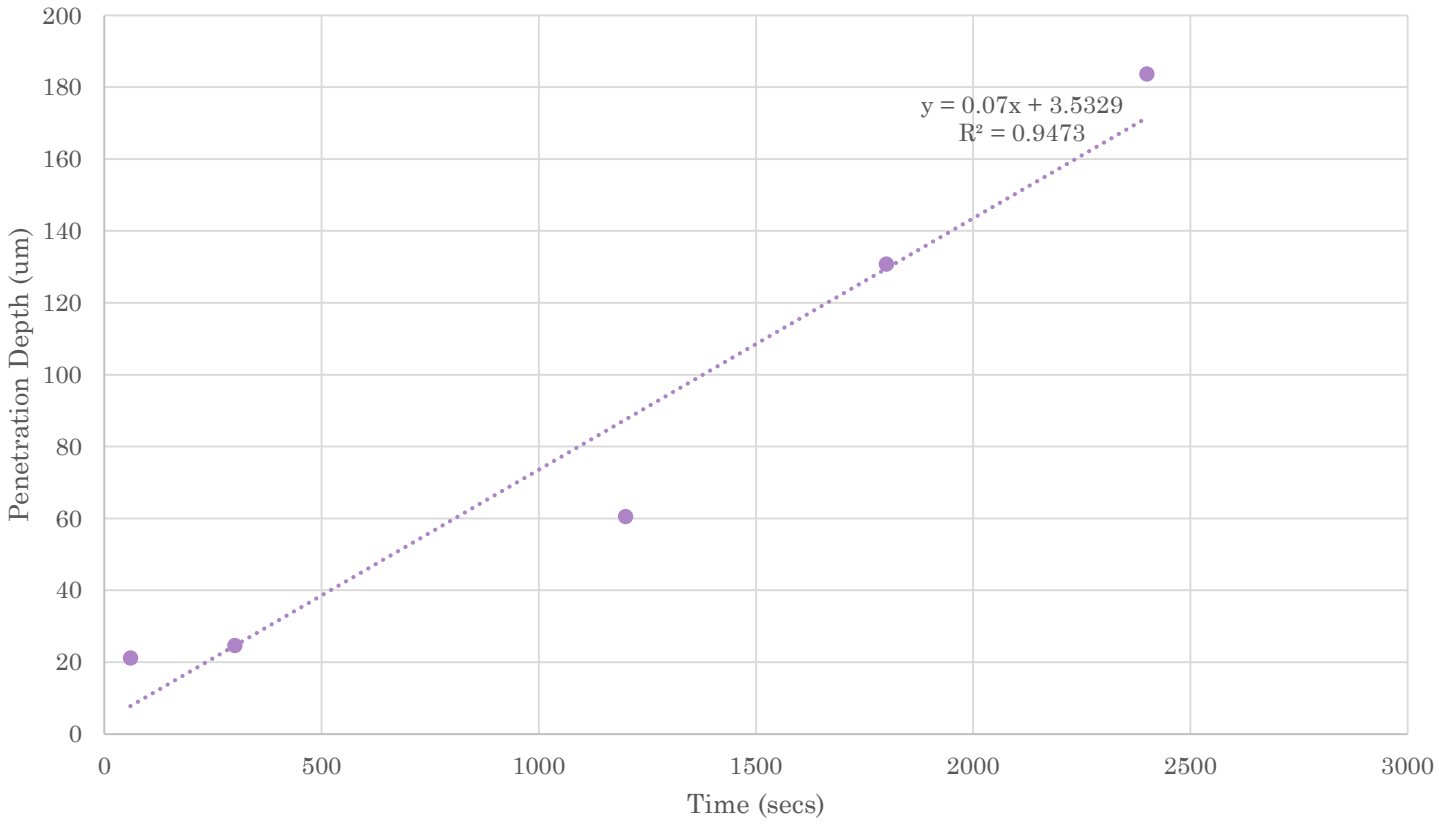
- Exposure dose: 1252.8 mJ/cm^2
- Base substrate formulation: 0.5g PPHA, 60% BMP, around 300 um thick.

- Adding PPHA into photopackaged layer
  - Induced crystallization
  - Prefer photopackaged top layer with no PPHA

- BMP/PAG ratio on top layer affect
  - Rate of depolymerization ⟶ better mobility of H+ into PPHA.

SENIC Southeastern Nanotechnology Infrastructure Corridor

Penetration Depth of Acid



- Exposure dose: 200 mJ/cm^2
- Average thickness recorded with a profilometer

Summary

- Photosensitive transient devices can be made.
- It is possible to fabricate a non-photosensitive device with photopackage added later.
- Photopackage does not contain the polymer – only photo compounds and plasticizer.
- Photo compound to plasticizer ratio is critical.

THANK YOU

SENIC Southeastern Nanotechnology Infrastructure Corridor