# Encapsulation with Ultralow Permeability (PV-6)

A joint India-U.S. research consortium funded under the *Joint Clean Energy Research & Development Center (JCERDC)*

## Scientific Achievement:

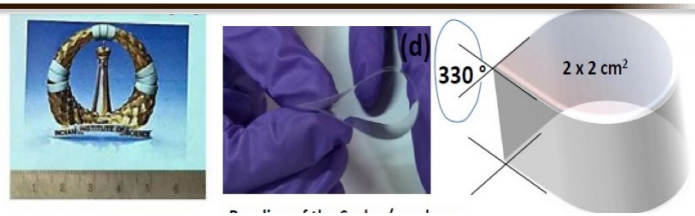
**A single graphene layer embedded in a flexible polymer reduces its water vapor transmission rate (WVTR) by up to a million-fold. Large-area, transparent, graphene-embedded polymers (GEPs) with a WVTR as low as $10^{-6}$ g $m^{-2}$ $day^{-1}$ are demonstrated.**

## Significance and Impact:

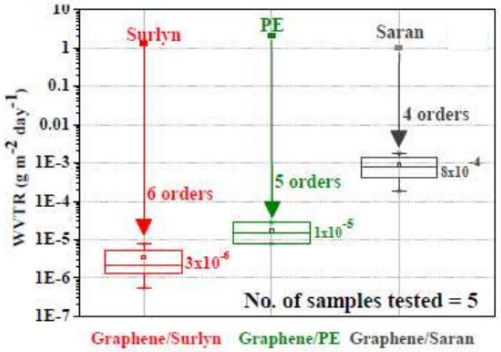
**Water is a bad actor for the lifetime of photovoltaic modules. Therefore, development of encapsulation materials with ultralow WVTR is required. Accelerated aging studies of on organic photovoltaic (OPV) devices encapsulated in the developed GEP material show a 50% lifetime of > 15,000 hours.**

## Research Details:

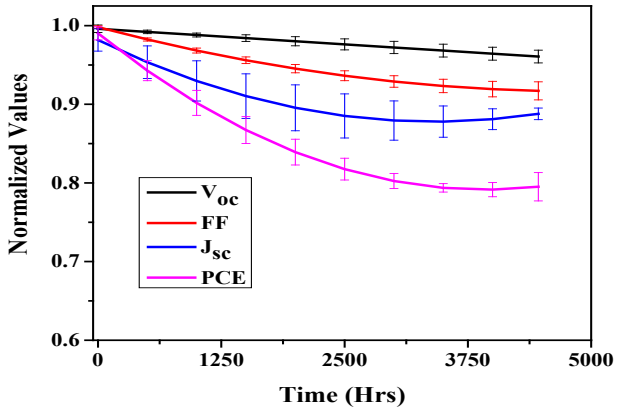
- Monolayered graphene, synthesized by chemical vapor deposition, has been transferred onto the polymer substrate directly by a very simple and scalable melt-casting process to fabricate the GEPs.
- These GEPs-encapsulated OPV devices exhibit improved stability.
- Bending the GEP-encapsulated devices a 1,000 times does not decrease the performance of the device.
- Defect-free graphene transfer onto the polymer is observed to be the critical parameter when preparing the encapsulation.




Million-fold decrease of GEPs water permeability




**GEP encapsulated device aging**




**Publication:** S. Sindhu, K. Shishir, K. Bharadwaj, G. Madras, S. Raghavan, P.C. Ramamurthy "Million-fold decrease in polymer moisture permeability by a graphene monolayer," *ACS Nano* **10**(7), 6501–6509, 2016.

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