Dynamical cooling plus freeze-drying separate the solvent removal and molecular alignment during the fabrication of optimal BHJ organic solar cells. *In situ* Raman spectroscopy monitors the progression of molecular stacking of pristine P3HT and P3HT: PCBM in *o*-dichlorobenzene during the fabrication process. The results show that the P3HT polymer undergoes drastic ordered aggregation when the solubility limit of P3HT is reached, as evidenced by the emergence of pronounced redshifted narrow Raman peaks due to intermolecular coupling.

S-SNOM and *in situ* Raman spectroscopy were employed to study the nanomorphology and molecular stacking of P3HT blended with PCBM. These innovative optical techniques yield critical structural information of the active layer in organic photovoltaics, greatly facilitating the development of new organic semiconductors and their processing methods.

Dr. Juen-Kai Wang is currently leading a photovoltaic project that integrates the forces of photovoltaic studies at National Taiwan University, Academia Sinica, and other universities—specifically in materials development and in-depth analysis—to form an upstream research team with close collaboration. Complementary facilitation among new-generation photovoltaic technologies (organic, organic-inorganic hybrid perovskite, and inorganic metal chalcogenide) would engender the optimal photovoltaic performance in large-area devices via the best combination of their respective advantages. Additionally, the participation of a mid-stream research team from the Institute of Nuclear Energy Research in this project enhances the integration between fundamental research and mid-stream developments. In summary, the focus of executing this program is guided integration with a noble mission.

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2D materials: "holy grail" for photocatalytic CO_2 reduction into solar fuels

Artificial photosynthesis: a "killing two birds with one stone" approach for tackling energy and environmental challenges

A research group led by Li-Chyong Chen and Kuei-Hsien Chen at the Center for Condensed Matter Sciences, National Taiwan University, has created a way to trigger a chemical reaction in a synthetic two-dimensional (2D), specifically, graphene oxides (GOs) and hybrid GOs that convert CO_2 into solar fuels. This process is so-called artificial photosynthesis, mimicking the way plants convert CO_2 and sunlight into glucose. Here, solar fuels and solar chemicals are produced utilizing solar energy in the gas phase.

Inspired by what Mother Nature has been doing for billions of years, fuels produced from sunlight through artificial photosynthesis can serve as future energy sources that are an environmental friendly alternative to fossil fuels. As per current global energy and clean environmental policies, the production of alternative green-energy sources while reducing CO_2 emissions without affecting our energy demand is highly challenging. Taiwan's geography and climate provide an abundance of solar light and water as free natural resources. Professors Li-Chyong Chen and Kuei-Hsien Chen believe that the conversion of CO_2 and water into solar fuels via solar light is an approach capable of tackling both energy and environmental issues and addressing future prospects

via efficient, cost-effective solar fuel production. Several semiconductor materials have been explored for photocatalytic CO_2 reduction. However, all the previously explored photocatalysts are not suitable for commercial requirements due to their low quantum efficiencies and lack of product selectivity. As a main goal for the Academic Pioneering Research Project recently awarded to Li-Chyong Chen, the team has introduced several efficient novel materials and a breakthrough idea to this artificial photosynthesis research.

Graphene oxide (GO) is an atomically thin two-dimensional (2D) carbon nanostructured oxide of graphite. The isolated oxygenated functional groups on the basal plane, with a typical C/O ratio of ~3, make GO a wide band gap semiconductor material. This sufficiently large band gap and suitable band alignment to straddle the reduction and oxidation levels of CO_2 and H_2O make GO a potential candidate for photocatalytic CO_2 reduction. To further improve the photocatalytic activity, several methods to modify GO have been developed. Among them, Cu-nanoparticle (NP)-modified GO was successfully synthesized by a simple microwave process, and CuNP/GO possessed an order-of-magnitude enhancement in solar fuel production. More recently, the team developed an *in situ* carbon-doped 2D tin disulfide material (C-SnS_2), wherein strain was inherently induced. Under visible light, C-SnS_2 exhibited a highly effective photocatalytic activity for CO_2 reduction with a photochemical quantum efficiency exceeding 0.7 %, a world-record value reported for an inorganic catalyst. The US patent application for this technology was filed earlier this year.

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