

# Artificial Photosynthesis

## A Future Source of Clean Energy

RC Parida & PK Ghosh

**A**BOUT 400 million years ago, as a historic event, evolution created plants with green leaves that carried on a groundbreaking process called photosynthesis. It used sunlight as the source of energy to convert carbon dioxide from the air and water, provided by the roots from the soil, to generate oxygen and sugar (carbohydrates) to shape the earth's environment for the complex organisms to evolve and survive. Of course, prior to it, some algae and bacteria were carrying on the process, but it turned revolutionary after the appearance of the green leaves. It still continues to be the most essential life-sustaining process, serving as the primary provider of clean, oxygen-rich air to breathe, food to eat, and pure water to drink, without which life on the surface of the earth could have been doomed.

At present, one of the most serious problems that mankind is encountering, which is increasing with time, is the growing energy needs. On the other hand, the sources of fossil fuels are fast depleting, and the extensive use of those has also become a root cause of environmental pollution, the most devastating consequence of which is global warming. Therefore, all our efforts are now underway to develop dependable and clean renewable sources of energy. While at present, harnessing the ones like solar power and wind power have gone a long way in this direction, several others are under development to meet the future challenge. Among those, an effective one is copying the process of photosynthesis by developing different devices known as artificial leaves, which are capable of carrying on artificial photosynthesis, opening ways for the generation of clean energy.

It is a process that mimics natural photosynthesis to convert solar energy into chemical energy. The key approaches of it include photosynthetic water splitting, carbon dioxide reduction, and the creation of photo-electrochemical cells. The devices designed for the purpose are meant to produce fuels and other valuable chemicals from readily available resources like water, carbon dioxide, etc.

### Splitting of water

The first artificial photosynthesis device, also called "artificial leaf", was designed by a team of scientists led by Daniel Nocera at the Massachusetts Institute of Technology (MIT). It was a silicon-based device having the ability to split water molecules into hydrogen and oxygen using sunlight as the source of energy. Since then, many other types of such devices have been designed and tested successfully.

Primarily, an artificial leaf is a sheet of semiconducting material, silicon, used in solar cells, which makes the electrons move when sunlight falls on it to generate an electric current. It splits water to release oxygen and hydrogen, which can be

stored for the generation of electricity. The semiconductor, on one of its sides, is covered with a cobalt-based catalyst that helps increase the speed of the reaction, while the other side is coated with a nickel-molybdenum-zinc alloy. No external wires or control circuits are needed to operate the device. It is simply placed in a container containing water and has a barrier in the middle. When exposed to sunlight, it begins to produce bubbles of oxygen from one side and hydrogen from the other. The gases are collected separately and stored to be used in devices like fuel cells to produce electricity and water.

In a paper published in the journal *Science* (September 2011), Daniel George Nocera and his coauthor Steven Reece have explained that their future objective is to make devices more portable, efficient, and cheap by using particles of the materials that they have been using, making those similar to photosynthetic algae. The advantage of it can be that for a given mass, small particles have more surface area, which can allow them to harness the sun's energy with greater efficiency. Ultimately, these devices can be developed to be used commercially to produce oxygen and hydrogen, to store those separately, and to feed the solar cells, where electricity is needed, particularly in inaccessible areas.

The artificial photosynthesis devices, or artificial leaves, in their present wireless form have a mere 2-5 per cent efficiency in direct sunlight to produce hydrogen and oxygen, but by using wires to connect the catalysts to the solar cells, it can be raised to 4.7 per cent. Besides, those can also be made cheaper by using materials like iron oxide as an alternative to silicon.

### Reduction of Carbon Dioxide

In the meantime, another type of artificial leaf has been developed by the researchers from the University of California, Berkeley, led by Dr Virgil Andei, belonging to the Yusuf Hamied Department of Chemistry. It uses sunlight to convert carbon dioxide to hydrocarbons, the constituents of oil and natural gas. The light-absorbing device integrates a perovskite-based solar cell with copper 'nano-flowers' that act as a catalyst to generate ethane and ethylene from carbon dioxide, water, and glycerol, which can not only be used as a clean fuel but also for manufacturing other chemicals and plastics (*Nature Catalysis*, February 2025). In order to improve its efficiency further to overcome the energy limits of splitting water, they have added silicon nanowire electrodes that can oxidise glycerol. This new platform produces hydrocarbons about 200 times more efficiently than the earlier systems. The reaction not only boosts carbon dioxide reduction performance but also can produce high-value chemicals like glycerate, lactate, and formate, having