“The Bionic Leaf”: Developing a Novel Bi-functional Nickel Oxide Catalyst to Use With the Bacterium Ralstonia eutropha for Artificial Photosynthetic Systems

Gurumukhi, Arya (School: Plano East Senior High School)

Annually, millions of lives are lost due to climate change-related factors, predominantly stemming from carbon dioxide emissions linked to fossil fuels. In this research, the development of a revolutionary "bionic leaf" capable of producing high-efficiency fuels by emulating photosynthesis is created. The engineering goal is to create a bionic leaf that would have a solar storage efficiency of 60% and create 10 mg/L of alcohol-based fuel after a sustained time of 100 hours while being environmentally sustainable and cost-effective. A key factor to achieve this engineering goal was the synthesis of a novel bi-functional catalyst material. Nickel oxide (NiO2) was synthesized with the sol-gel process to create 1D nano-rods. It was then doped with iron (Fe) to weaken the hydrogen bonds in the NiO2 to create oxygen vacancies. These oxygen vaccines and 1D nanorods improve conductivity and reaction speed. The resultant bi-functional catalyst material, combined with a binder solution and an amorphous photovoltaic cell, forms the basis of the final "bionic leaf." This leaf is then incorporated in the three-electrode cell set-up with the genetically modified bacterium Ralstonia eutropha which had its PHB gene deleted to redirect its carbon flux to release an alcohol-based fuel more efficiently. Remarkably, over 100 charge and discharge cycles demonstrated no signs of degradation. Surpassing the engineering goals, the fuel exhibited a power density and energy density comparable to modern diesel, all achieved sustainably at a cost of $5. Future endeavors aim to further enhance solar efficiency and fuel production levels, exploring advanced nano-synthesis techniques.