Photocatalytic Conversion of CO$_2$ on Mars
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Introduction
Light on Mars shows potential for providing the energy means necessary for enhanced In-Situ Resource Utilization (ISRU). Through photocatalysis, the energy barrier required to convert CO$_2$ is lowered and CH$_4$ production is favorable.

General Reaction Mechanism
(1) CO$_2$ + 2H$^+$ + 2e$^-$ → HCOOH
(2) HCOOH + 2H$^+$ + 2e$^-$ → HCHO + H$_2$O
(3) HCOOH + 2H$^+$ + 2e$^-$ → CH$_3$OH
(4) CH$_3$OH + 2H$^+$ + 2e$^-$ → CH$_4$ + H$_2$O

Photocatalyst Requirements
• High CH$_4$ selectivity
• Utilize H$_2$O as a reducing agent
• Convert CO$_2$ at low temperatures
• Activate under ultraviolet and visible light (UV-Vis)

Material Characterization
Scanning Electron Microscopy (SEM)
• Detailed imaging of nanoparticles
  MoS$_2$ Nanoflowers

Transmission Electron Microscopy (TEM)
• Detailed imaging of crystalline structures
  Hexagonal MoS$_2$ within flake (by GRC)

X-Ray Diffraction (XRD)
• Lattice parameter calculation

Synthesis via Chemical Vapor Deposition (CVD)
• Reactants are vaporized by incoming gas and high temperatures to react while suspended
  $2\text{MoCl}_5 + 4\text{S} \rightarrow 2\text{MoS}_2 + 5\text{Cl}_2$
• Resulting TMD deposits on downstream substrate

Catalysts of Interest
Transition Metal Dichalcogenides (TMDs)
• MoS$_2$  MoSe$_2$  WS$_2$  WSe$_2$
• Solid powders and thin layer films used for catalysis exhibit ideal band gap for CO$_2$ reduction

Future Work
• Application of TMD powders supported on quartz wool in new reactor system with LEDs and solar simulator
• Improve CH4 selectivity of TMD-based photocatalysts

Reactor System Design
Packed bed photoreactor
• TMD powders are supported on quartz wool and stored within the outer tube
• CO$_2$ is humidified with H$_2$O and sent through reactor bed as a continuous flow
• Photocatalyst is radially exposed to UV light using a light stream in the inner tube and LED straps on the exterior shell
• Product gas will be analyzed with Gas Chromatography (GC) and Fourier Transform Infrared Spectroscopy (FTIR)