Photocatalytic Conversion of CO_2 on Mars

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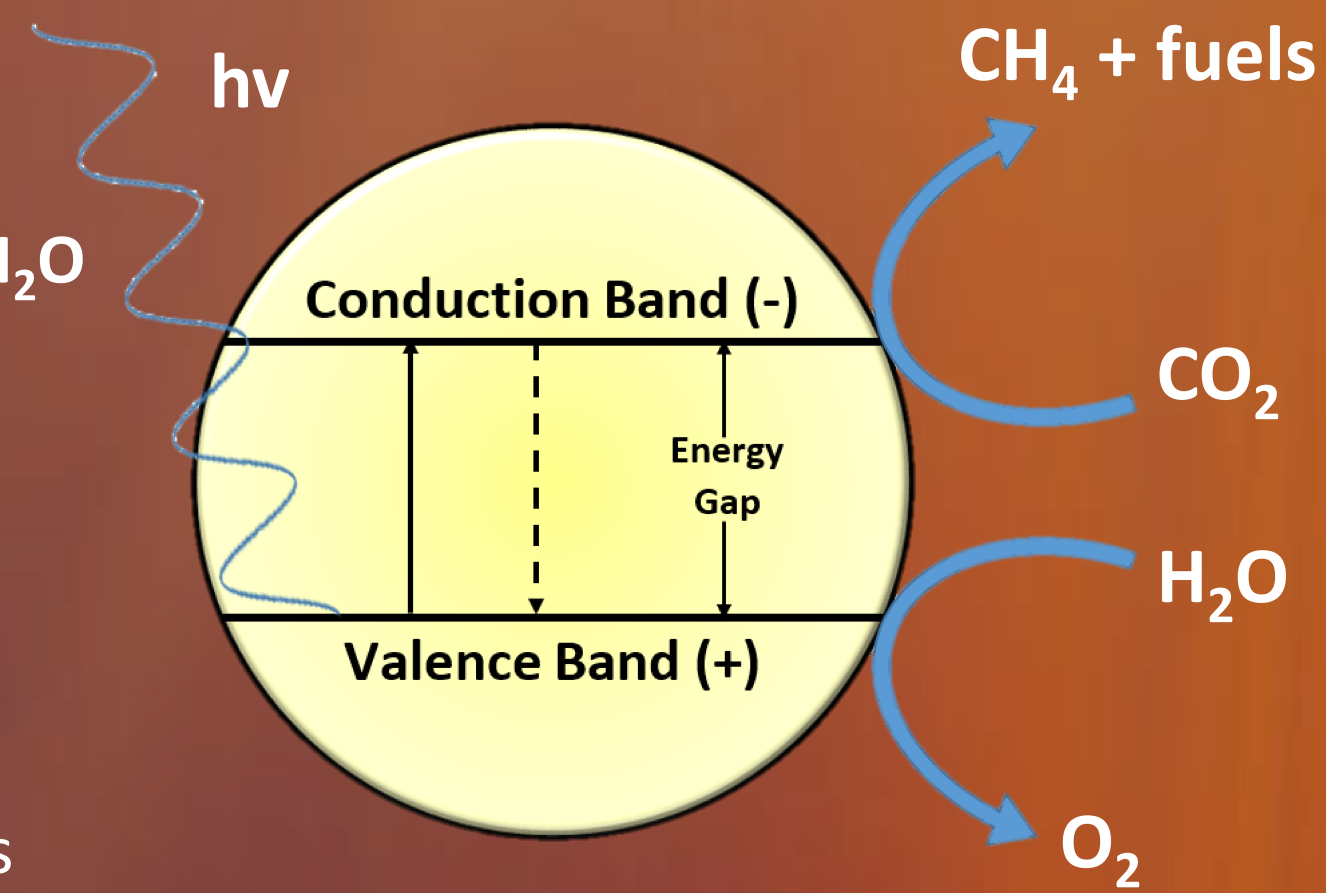
Introduction

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) $CO_2 + 2H^+ + 2e^- \rightarrow HCOOH$
(2) $HCOOH + 2H^+ + 2e^- \rightarrow HCHO + H_2O$
(3) $HCOH + 2H^+ + 2e^- \rightarrow CH_3OH$
(4) $CH_3OH + 2H^+ + 2e^- \rightarrow CH_4 + H_2O$



Photocatalyst Requirements

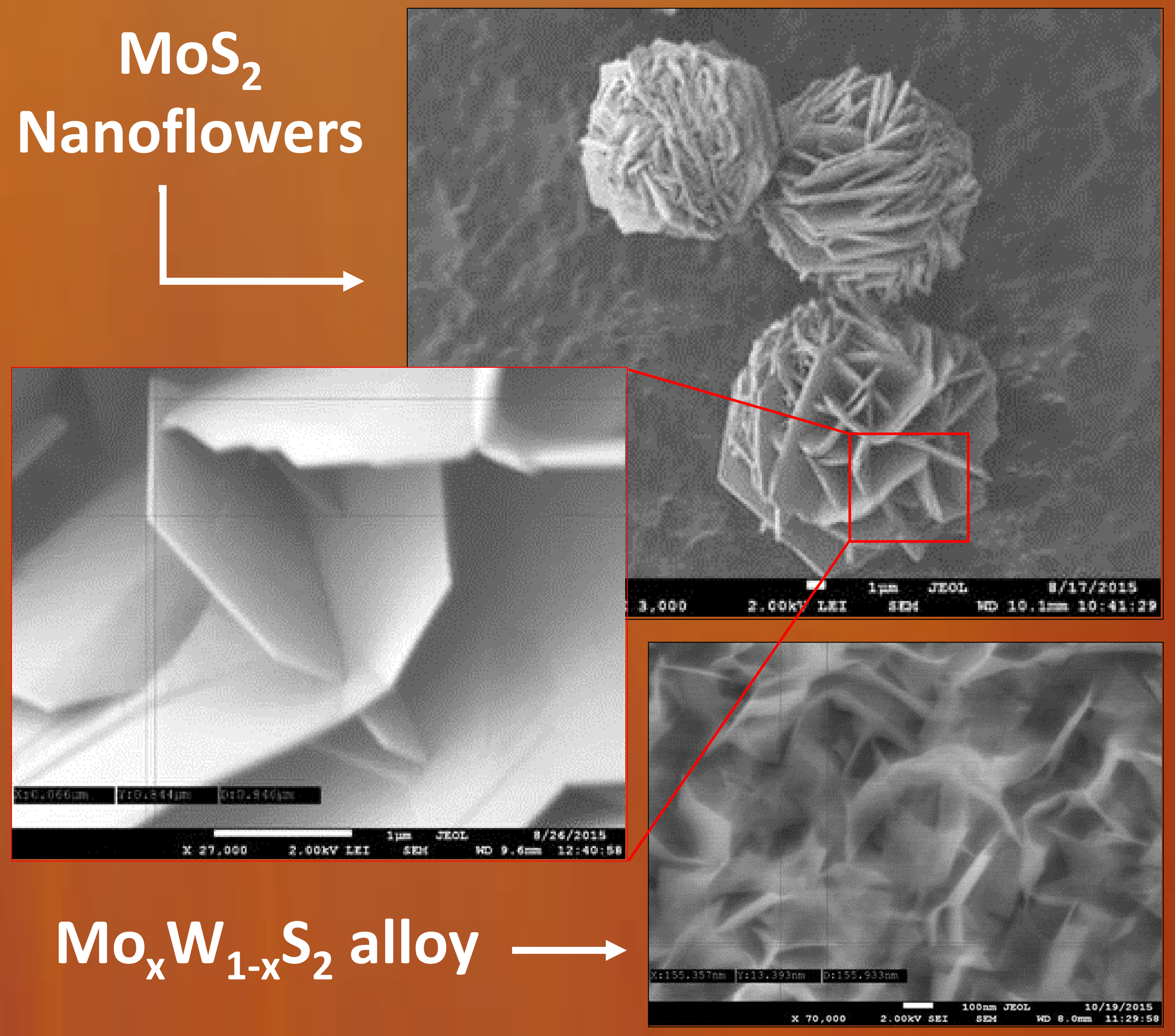
- High CH_4 selectivity
- Utilize H_2O as a reducing agent
- Convert CO_2 at low temperatures
- Activate under ultraviolet and visible light (UV-Vis)

Material Characterization

Scanning Electron Microscopy (SEM)

- Detailed imaging of nanoparticles

MoS_2 Nanoflowers



$Mo_xW_{1-x}S_2$ alloy

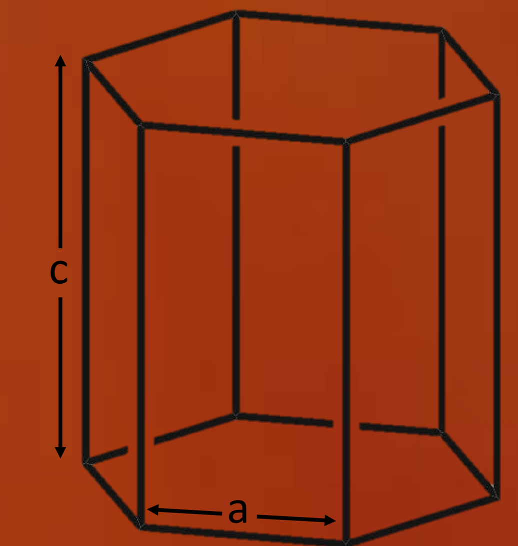
Transmission Electron Microscopy (TEM)

- Detailed imaging of crystalline structures

Hexagonal MoS_2 within flake (by GRC)

X-Ray Diffraction (XRD)

- Lattice parameter calculation



MoS_2 Cell Parameter	Value
a	3.15 Å
c	18.32 Å
Cell Volume	158.5 Å^3

Catalysts of Interest

Transition Metal Dichalcogenides (TMDs)

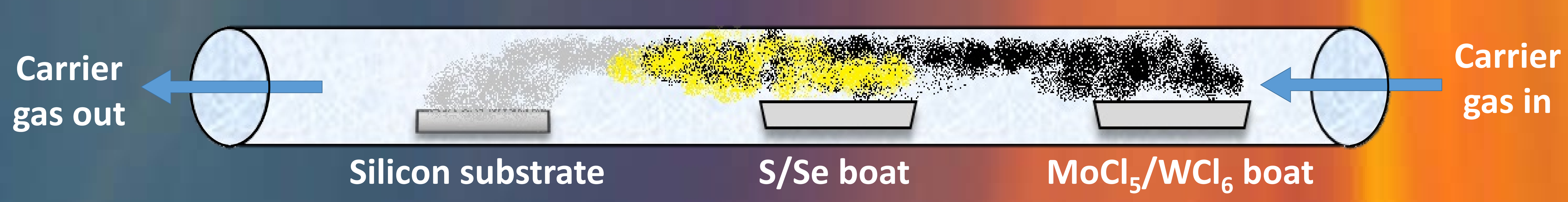
- **MoS_2**
- **$MoSe_2$**
- **WS_2**
- **WSe_2**
- Solid powders and thin layer films used for catalysis exhibit ideal band gap for CO_2 reduction

Synthesis via Chemical Vapor Deposition (CVD)

- Reactants are vaporized by incoming gas and high temperatures to react while suspended

$$2MoCl_5 + 4S \rightarrow 2MoS_2 + 5Cl_2$$

- Resulting TMD deposits on downstream substrate

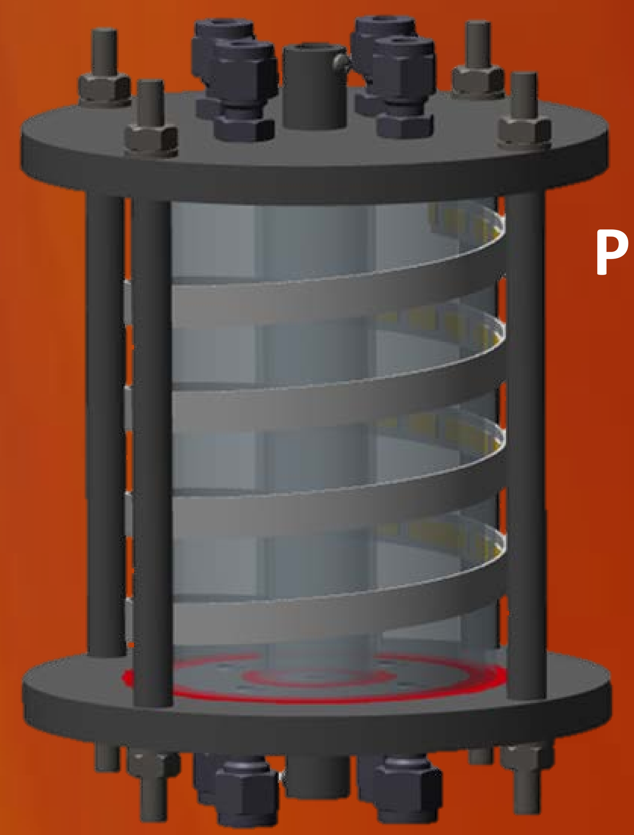


Reactor System Design

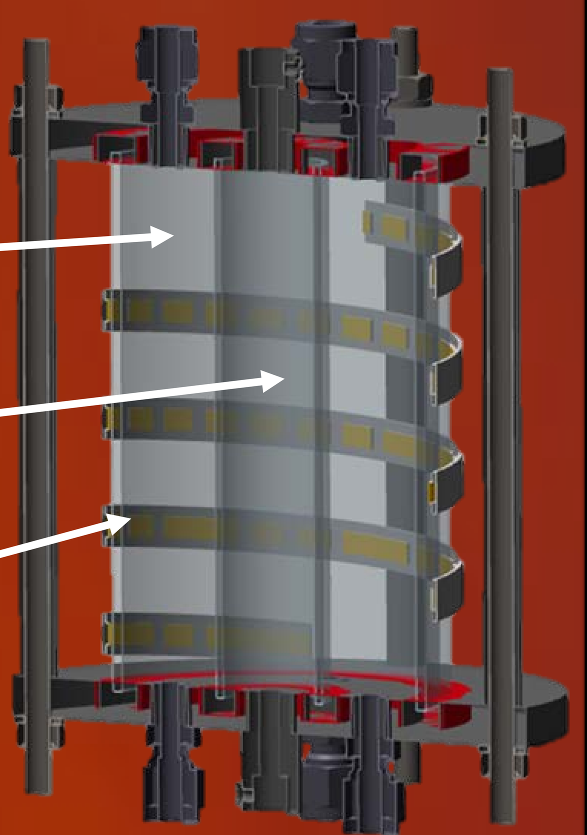
Packed bed photoreactor

- **TMD powders are supported on quartz wool** and stored within the outer tube
- **CO_2 is humidified with H_2O** 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)**

Exterior view



Cross-Sectional View



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