Electrochemical Reduction of Carbon Dioxide on Molybdenum Disulfide Edges

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Abstract:

During the last few decades, the amount of carbon dioxide (CO_2) has reached the highest level (396.80 ppm) of the last 20 million years[1], causing radical and largely unpredictable changes in the environment[2,3,4]. Recent efforts have revealed that CO_2 can be converted by electrochemical reduction processes using renewable energy sources into energy-rich modules, offering an efficient path for both CO_2 remediation and an alternative energy source[5,6,7,8,9]. In this study, we found that MoS_2 catalyst with molybdenum (Mo) terminated edges exhibits higher CO_2 reduction performance compared to the noble metals (e.g. gold and silver) with a significantly high current density and low overpotential (54 mV). The catalysts' overall performance by multiplying current density and faradaic efficiency as the two major electrochemical parameters at different overpotentials shows that MoS_2 exhibits the highest performance at each overpotential. The exceptionally high catalytic activity of MoS_2 is attributed to the Mo terminated edges, where the Mo atoms possess approximately one order of magnitude higher electronic (d orbital) density than noble metals. Moreover, the lower work function (3.9 eV) also promotes the advanced performance of the MoS_2 catalyst. The performance of the MoS_2 catalyst is further improved by designing an atomic edge terminated surface via synthesizing vertically aligned MoS_2. This finding exhibits a non-precious and earth abundant MoS_2 catalysts can successfully replace expensive noble metal electrodes, with the promise of higher CO_2 conversion rates and selectivity.

Keywords: Carbon dioxide reduction, Molybdenum Disulfide, electrochemical reduction.

References:

1. Ed Dlugokencky and Pieter Tans, *NOAA/ESRL (www.esrl.noaa.gov/gmd/ccgg/trends/).*
2. Davis, S. J., Caldeira, K. & Matthews, H. D. Future CO_2 Emissions and Climate Change from Existing Energy Infrastructure. *Science* **329**, 1330-1333 (2010).
3. Brook, E. J. Leads and Lags at the End of the Last Ice Age. *Science* **339**, 1042–1043 (2013).
4. Parrenin, F. *et al.* Synchronous Change of Atmospheric CO_2 and Antarctic Temperature During the Last Deglacial Warming. *Science* **339**, 1060–1063 (2013).
5. Whipple, D. T. & Kenis, P. J. A. Prospects of CO_2 Utilization via Direct Heterogeneous Electrochemical Reduction. *J. Phys. Chem. Lett.* **1**, 3451–3458 (2010).
6. Kumar, B. *et al.* Renewable and metal-free carbon nanofibre catalysts for carbon dioxide reduction. *Nat. Commun.* **4,** (2013).
7. Rosen, B. A. *et al.* Ionic Liquid-Mediated Selective Conversion of CO_2 to CO at Low Overpotentials. *Science* **334**, 643–644 (2011).
8. Rosen, B. A. *et al.* In Situ Spectroscopic Examination of a Low Overpotential Pathway for Carbon Dioxide Conversion to Carbon Monoxide. *J. Phys. Chem. C* **116**, 15307–15312 (2012).
9. Salehi-Khojin, A. *et al.* Nanoparticle Silver Catalysts That Show Enhanced Activity for Carbon Dioxide Electrolysis. *J. Phys. Chem. C* **117**, 1627–1632 (2013).