

Fueling the Future

Presidential Research Professor Tao Xu

Department of Chemistry and Biochemistry

Northern Illinois University

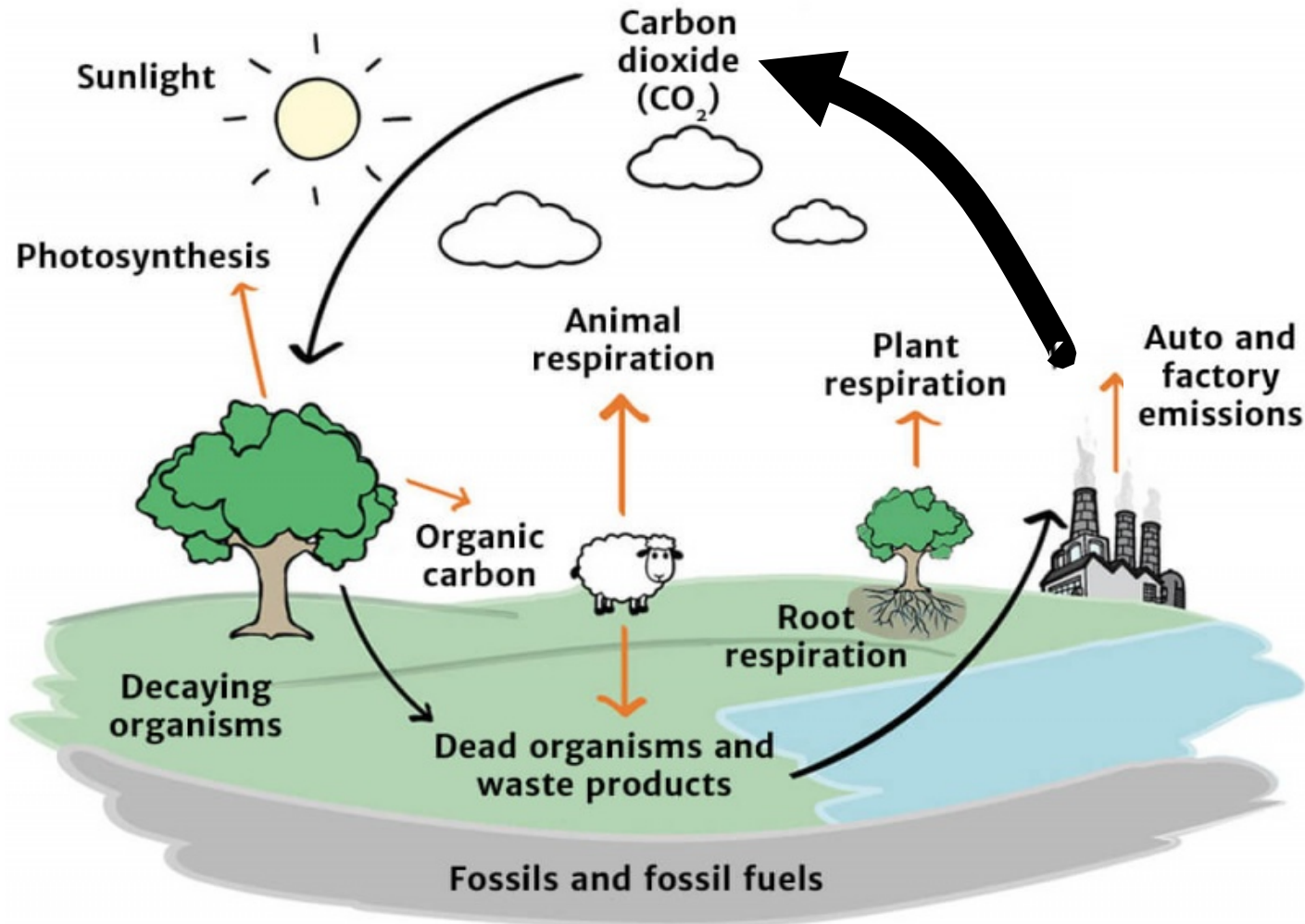


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Presented to NIU Board of Trustee on Nov. 18, 2021

Carbon Cycle



Two key research directions

1. Solar energy

Example: Advancing perovskite solar cells

2. Catalysts

Example: Electrocatalytic conversion of CO_2 to fuels

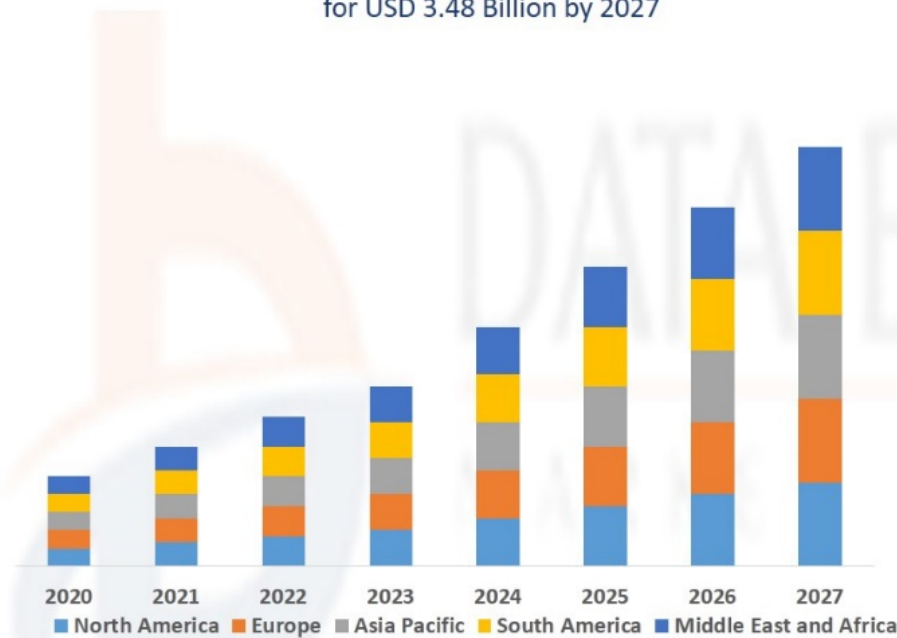
Potential Market for perovskite solar cells

Advantages of perovskite solar cells over silicon solar cells

- **Low cost**
- **High power conversion efficiency**
 - **Recyclability**
 - **Easy processing**

Efficiency of perovskite solar cells surpassed all other thin film solar cells

Global Perovskite Solar Cell Market is Expected to Account for USD 3.48 Billion by 2027



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Global Perovskite Solar Cell Market, By Regions, 2020 to 2027



DATA BRIDGE MARKET RESEARCH

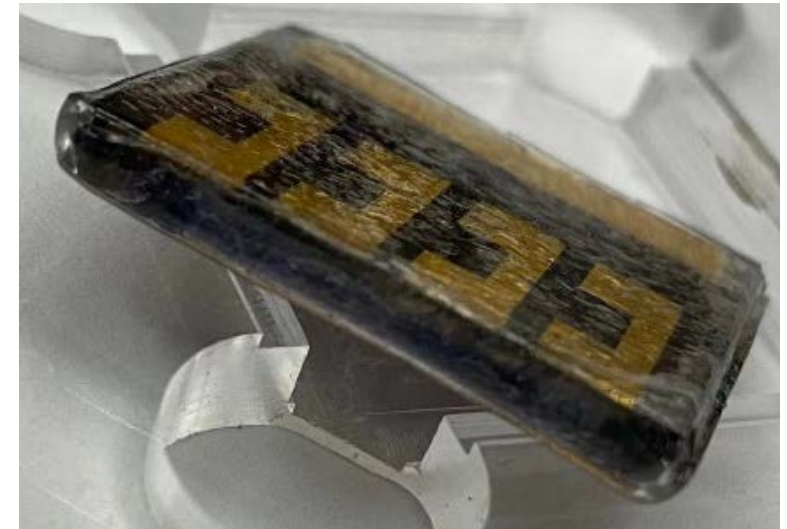
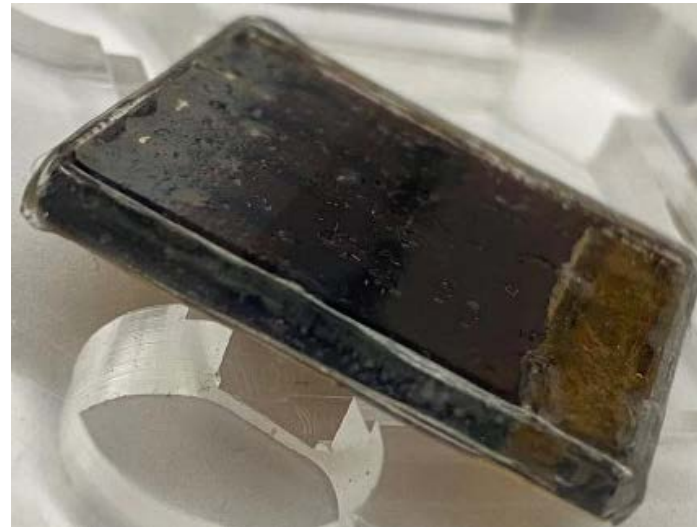
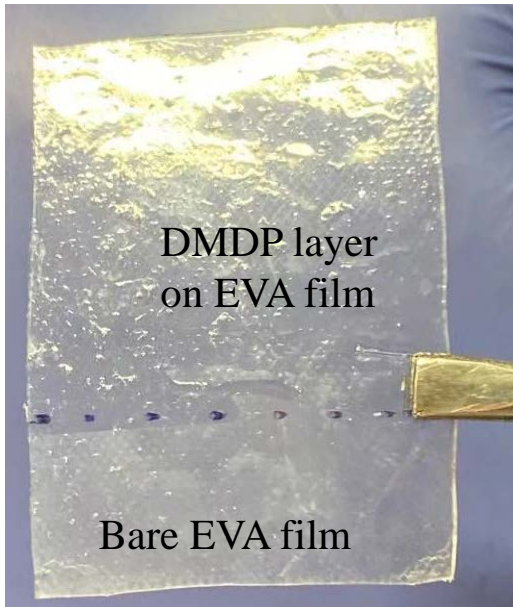


Lead-capturing tape ready for industry

Last-mile Challenge:
Lead toxicity

Our solution: Lead-absorbing
solar cell encapsulation EVA film

**Captures over 99.9% leaked
lead if device is damaged**



Nature, 2020, 578, 555–558,
Nature Sustainability, 2021, in press

Lead-capturing tape ready for industry

**Our patented lead-absorbing tape is a gateway technology.
Perovskite solar cells (PSCs) must be proven to be safe if damaged.**



Front shattered



Back scratched

We soaked damaged PSCs in water for seven days to mimic the worst-case scenario.

- The lead-absorbing tapes exhibited a lead-sequestration efficiency of over 99.9%.
- **A level safer than the standard for drinking water.**

We hope to team with EVA film manufacturers

Key EVA Film Market Manufacturers
3M, STR Holdings, Inc., Bridgestone,
Mitsui Chemicals Co., Sekisui Chem.

Highlighted by 170 outlets including [NSF](#), [Scientific American](#),
[ScienceDaily](#), [Yahoo Finance](#), [PV Magazine](#) and [NREL](#)

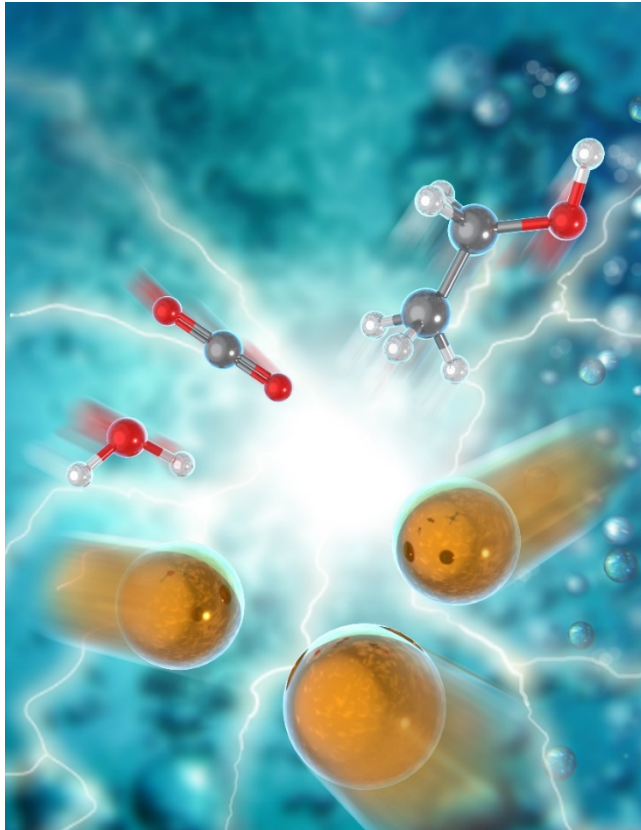
Developing prototype that converts carbon dioxide to ethanol or other organic fuels

- Intercept CO₂ emission from industry
- Electrochemically convert CO₂ to value-added chemicals
- Enhance sustainability of our economic infrastructure
 - Mitigate CO₂ accumulation in atmosphere

Advanced Photon Source at Argonne



In-situ characterization by synchrotron X-ray to garner insight during the electrochemical reaction, based on which a portfolio of catalysts are developed



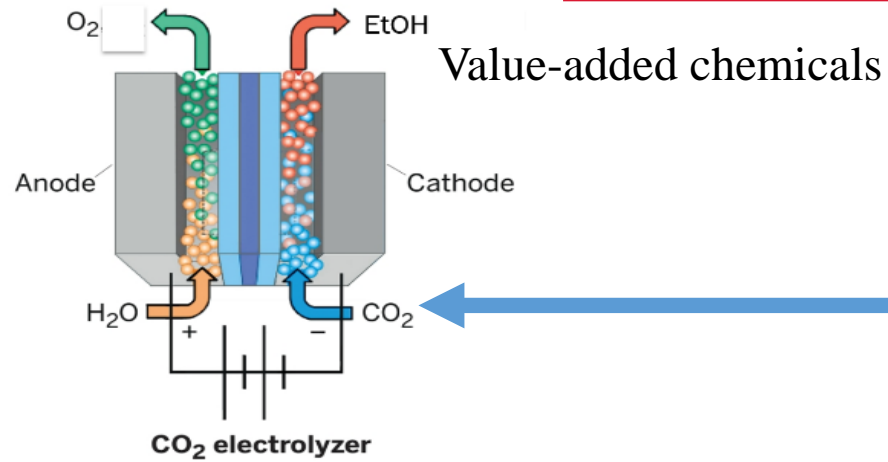
Highly selective electrocatalytic CO₂ reduction to ethanol by metallic clusters dynamically formed from atomically dispersed copper.

Building up a portfolio of highly efficient electrocatalysts for CO₂ conversion to value-added chemicals

	Product	Efficiency
Atomic Copper Catalysts	Ethanol	91%
Atomic Tin Catalysts	Formate	93%
Atomic Silver Catalysts	Acetone	91%
Atomic Rhodium Catalysts	Acetate	94%

Research highlighted by more than 100 outlets including [Argonne News](#), [Popular Mechanics](#), [Science Daily](#), [University of Chicago](#) and [Earth.com](#).

On-going R&D for entrepreneur



Our prototype CO₂ electrolyzer under R&D



EV equipped with our electrolyzer to convert CO₂ to value-added chemicals



Contributors

Students: 12 Ph.D. graduated (2006-2021); 5 current Ph.D. students, 10 undergraduates.

- Culturally diverse students
- Half of Ph.D. graduates are women
- 30+ students awards and honors
- Ph.D. students have gone on to STEM-related careers

Major publications: Research published in prestigious journals *Nature*, *Nature Sustainability*, *Nature Energy* and others.

Collaborators: From Argonne National Laboratory, National Renewable Energy Lab, Northwestern University, Yale University, Carnegie Institute of Washington, Valparaiso University, University of North Texas and industry.

Extramural grants: Total \$3.5M (2006-present) from National Science Foundation, Department of Energy, Argonne National Laboratory, American Chemical Society



Back up slides



Your Future. Our Focus.

Xu Group, Department of Chemistry and Biochemistry
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1. Xun Li is the recipient of NIU 2020-2021 Outstanding Graduate Student Award.
2. Xun Li received American Chemistry Society Poster Competition Third Place Award.
3. Xun Li received NIU Dissertation Completion Fellowship 2021-2022.
4. Erik Sarnello received traveling scholarship from the XVII International Small Angle Scattering Conference in 2018, U.S. Department of Energy Graduate Student Fellowship.
5. Jue Gong received John D. Graham Scholarship from Northern Illinois University in 2017.
6. Jue Gong received Great Journeys Assistantship from Northern Illinois University in 2017.
7. Jue Gong was selected by Oak Ridge National Laboratory to attend US School on Total Scattering Analysis in 2017.
8. Jue Gong was selected by Argonne National Laboratory and Oak Ridge National Laboratory to attend 18th National School on Neutron and X-ray Scattering in 2016.
9. Jue Gong was the recipient of 2019 NIU Outstanding Graduate Student Award.
10. Heather Barkholtz joined University of Wisconsin Madison as a tenure-track Assistant Professor.
11. Heather Barkholtz won the Dissertation Completion Award in 2015.
12. Heather Barkholtz received John D. Graham Scholarship in 2015.
13. Heather Barkholtz was selected by Argonne National Laboratory and Oak Ridge National Laboratory to attend 16th National School on Neutron and X-ray Scattering in 2014.
14. Lauren Grabstanowicz won AAAS Student Poster Competition Award in the Physical Sciences category in 2014.
15. Lauren Grabstanowicz received Joshua E. Neimark Memorial Travel Assistance Award by AAAS in 2014.
16. Lauren Grabstanowicz won First Place in the Student Poster Session at the 2013 MWSCC Technical Symposium.
17. Lauren Grabstanowicz won an InSET NIU-Argonne Distinguished Graduate Student Nanoscience Fellowship (2013-2014) in 2013.
18. Xiaoqiao Zeng received the NIU Outstanding Graduate Student Award in 2013.
19. Lauren Grabstanowicz won the Midwest Chapter Society of Cosmetic Chemists Scholarship in 2011.
20. Zhenzhen Yang won the NIU Most Outstanding Dissertation Award in 2011.
21. Zhenzhen Yang was selected by Argonne National Laboratory and Oak Ridge National Laboratory to attend 13th National School on Neutron and X-ray Scattering in 2011.
22. Zhenzhen Yang won the NIU Outstanding Graduate Student Award and Outstanding Women Student Award in 2011.
23. Xiaoqiao Zeng won the John D. Graham Scholarship in 2011.
24. Chi-Kai Lin was selected by Argonne National Laboratory and Oak Ridge National Laboratory to attend 12th National School on Neutron and X-ray Scattering in 2010.
25. Chi-Kai Lin won the John D. Graham Scholarship in 2010.
26. Zhenzhen Yang won an NIU-Argonne Distinguished Graduate Student Nanoscience Fellowship (2010-2011) in 2010.
27. Zhenzhen Yang was awarded a graduate student travel fund for 2009 MRS Fall Meeting.
28. Zhenzhen Yang won an NIU Nanoscience Fellowship in 2009.
29. Chi-Kai Lin won the Dissertation Facilitation Award from Northern Illinois University in 2009.
30. Chi-Kai Lin won an NIU-Argonne Distinguished Graduate Student Nanoscience Fellowship in 2009.
31. Chi-Kai Lin was awarded a graduate student travel fund for 2009 MRS Fall Meeting.

STEMCafé *Feed your mind!*

Fueling the Future

with Renewable Energy

March 17, 2021 6 p.m. | Online go.niu.edu/stemcafe

Graduate Students: Ihor Kulchytskyy (BioVantage Fuels); **Chi-Kai Lin**, (post-doc at ANL, now manager of I-Car project at Apple Inc.); Lauren Grastanowicz (now Alcoa); Zhenzhen Yang (post-doc at ANL, now Chemist at ANL in Apple I-Car project); Dean Walters (Engineer at ANL); Qinglong Jiang (now Assistant Professor at U of AR, Pine Bluff); **Heather M. Barkholtz** (post-doc at SNL, now Assistant Professor at University of Wisconsin Madison); Jue (Jason) Gong (Pos-doc at Brown); Vivian Zeng (post-doc at ANL); Dominic Rebollar (Ph.D graduated); Crystal Ferrel (now post-doc at ANL), Haiping Xu (now post-doc at ANL); Xun Li (PhD student), Owen Wostoupal (PhD student), Erik Sarnello (to be a postdoc at ANL)

Diversified backgrounds
but all converge to



Undergraduates: Zachary Liveris(graduate student at Loyola Univ.); Jordan Rucinski; Savannah E. Benjamin (REU student, graduate student at Notre Dame), Kate Powers (graduate school at Alberta Univ, now a STEM educator); Robert Rickard (Chemist, PQ Corp.); Nick Barone (Chemist, Deibel Laboratory)

Collaborators:

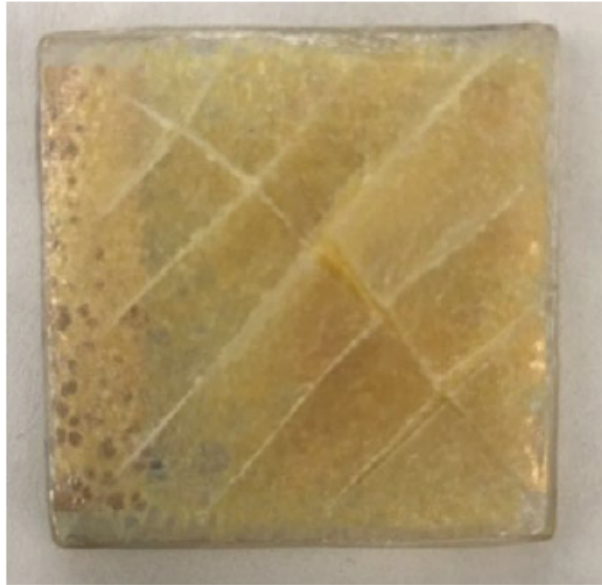
Drs. Di-Jia Liu, Cong Liu Jeffery T. Miller (now at Purdue) at Argonne-CSE;
Dr. Kai Zhu at National Renewable Energy Lab;
Drs. Richard Schaller, Peijun Guo (now at Yale), Yuzi Liu at Argonne-CNM;
Dr. Chao Wang Argonne-MSD (now at Johns Hopkins); Prof. Haiying He at Valparaiso University;
Drs. . Dale L. Brewes, , Chengjun Sun, Randy E. Winans, Tao Li at Argonne-APS.



Back up slides



Front shattered



Back scratched

