# Solar fuels
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*Sustainable energy storage*

**Large scale implementation of renewable energy sources in our current energy infrastructure involves balancing the differences in time and place of energy generation and consumption. In particular for wind and solar energy, efficient storage and distribution are essential to overcome these supply-demand mismatches. Solar fuels offer an attractive solution by creating a fuel without carbon foorprint via energy storage in chemical bonds.**

The DIFFER solar fuels research and development program is driven by the need for cost-effective production of solar fuels and the use of abundantly available materials. The central theme is to achieve power efficient dissociation of $CO_2$ or $H_2O$ (or both). Subsequently, established chemical conversion methods (Fisher-Tropsch, Sabatier, etc.) may be applied to convert the resulting CO and $H_2$ into the fuel of choice. The concrete research areas are materials synthesis for photocatalysis, materials for photo-electrochemical water splitting, membranes for fuel conversion applications, and plasma for efficient $CO_2$ conversion.

## Two new research lines

Most of the worldwide research efforts in solar fuels are directed at the splitting of water into hydrogen and oxygen. However, no efficient catalytic or traditional chemical alternative catalyst is yet available. DIFFER has installed two new groups to initiate research in this area.

One group is led by Anja Bieberle and studies the electrode-electrolyte interfaces of photo-electrochemical systems. By combining experiments on different materials chemistries, micro- and nanostructures, and 3D structures with state-space modeling and simulations of the photo-electrochemical interface, she wants to uncover the limiting features in today's photoelectrodes.

The other group is led by Mihalis Tsampas and studies photo-electrochemical promotion of solar fuel conversion in solid electrolytes. Co-catalysts are developed for utilizing light induced species to drive electrocatalytic reactions. Emphasis is given on the catalytic formation of fuels from streams of $CO_2$ and $H_2$, produced by water splitting in a previous step.

## Program leaders

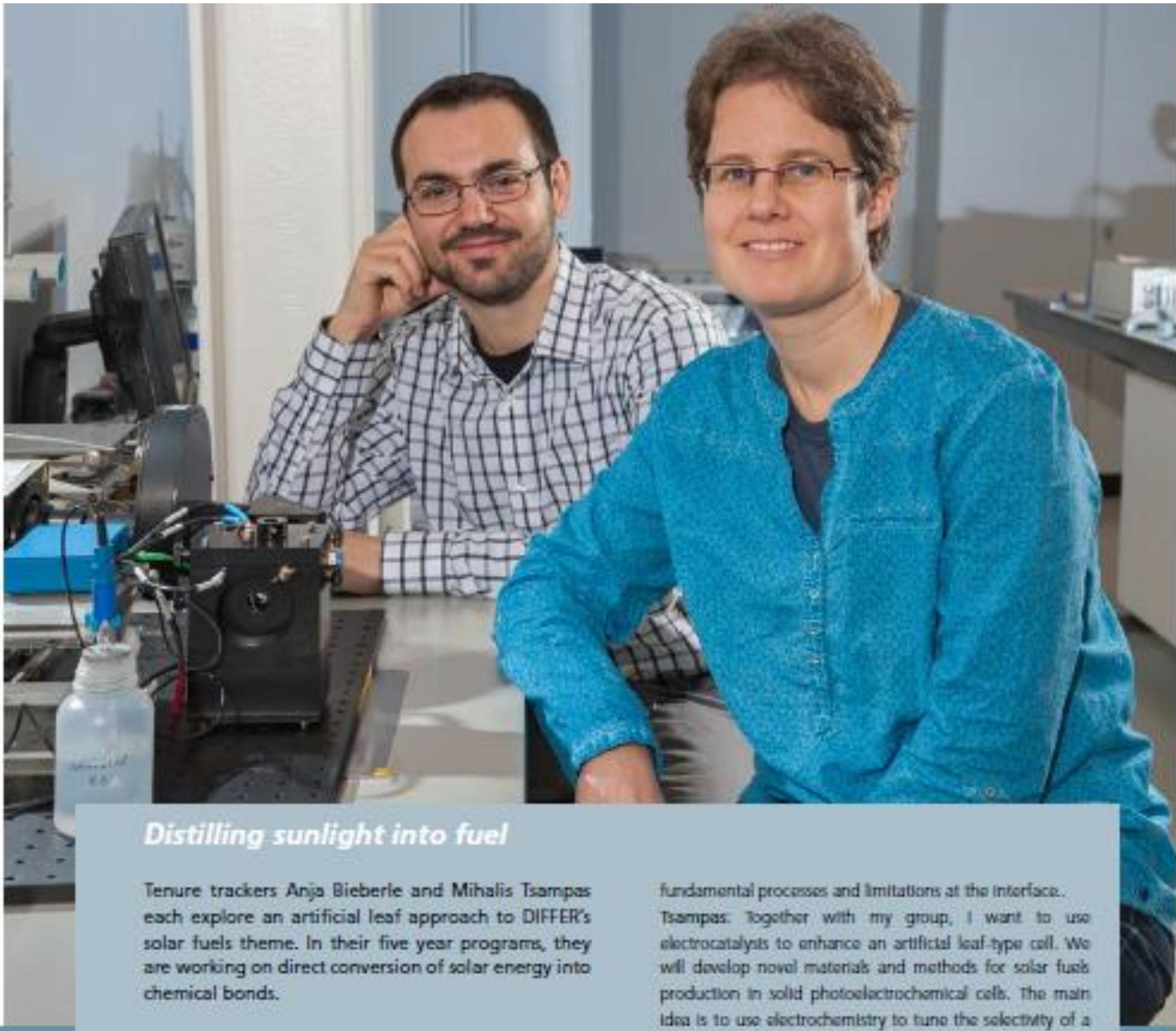
Anja Bieberle, René Janssen, Mihalis Tsampas, Hindrik de Vries, Gerard van Rooij, Michael Gleeson, Waldo Bongers

## Funding

NWO program $CO_2$-neutral fuels; NWO program New Chemical Innovations; STW-Alliander plasma conversion of $CO_2$, TKI Gas; Topsector Chemistry NCI; STW-Alliander plasma conversion of $CO_2$, Topsector Energy.

## Collaborations

Fujifilm Research, Tilburg, NL; IPP Stuttgart, Germany; Radboud University Nijmegen, NL; TU/e, Eindhoven, NL; University of Antwerp, Belgium; University of Leiden, NL; University of Twente, Enschede, NL; Sichuan University, Chengdu, China; Alliander, NL.



## *Distilling sunlight into fuel*

**Tenure trackers Anja Bieberle and Mihalis Tsampas each explore an artificial leaf approach to DIFFER's solar fuels theme. In their five year programs, they are working on direct conversion of solar energy into chemical bonds.**

**Bieberle**: Take a walk outside: sunshine, wind - all that energy is available, and we are not using it. Yet! When you get electricity from a solar cell, you either need to use it immediately or you have to store it in a battery. Direct conversion of sunlight into a storable fuel would be much better, right?

**Tsampas**: The goal with solar fuels is to offer an alternative to fossil fuels. Fundamental research is essential to develop these sustainable technologies. Both our approaches are electrochemical in nature: we directly use sunlight in a device to convert water and $CO_2$ into hydrogen or hydrocarbons.

**Bieberle**: In my group, we want to design better photoelectrodes for photoconversion. To reach that goal we investigate the interface where solid electrode meets liquid electrolyte in solar fuel devices. By combining experiments with modeling and simulations, we can investigate the fundamental processes and limitations at the interface..

**Tsampas**: Together with my group, I want to use electrocatalysis to enhance an artificial leaf-type cell. We will develop novel materials and methods for solar fuels production in solid photoelectrochemical cells. The main idea is to use electrochemistry to tune the selectivity of a reaction towards a desired product, i.e. specific fuel.

**Bieberle**: This is one of the things that I like at DIFFER: working together with people from diverse disciplines. I am collaborating with different researchers from the fusion group on nanostructuring surfaces with plasma and on modelling and simulation of interfaces. Although our fields are different, the shared focus on energy makes it easy to connect.

**Tsampas**: In our groups and in energy research in general, we draw on many different disciplines to realize a breakthrough: chemistry, materials science, engineering, physics... I think that over the next years, when we're all in the same building, the current research groups will find more and more synergy and inspire each other to even more innovative approaches.