Public summary of PhD-thesis of Dario Cambié
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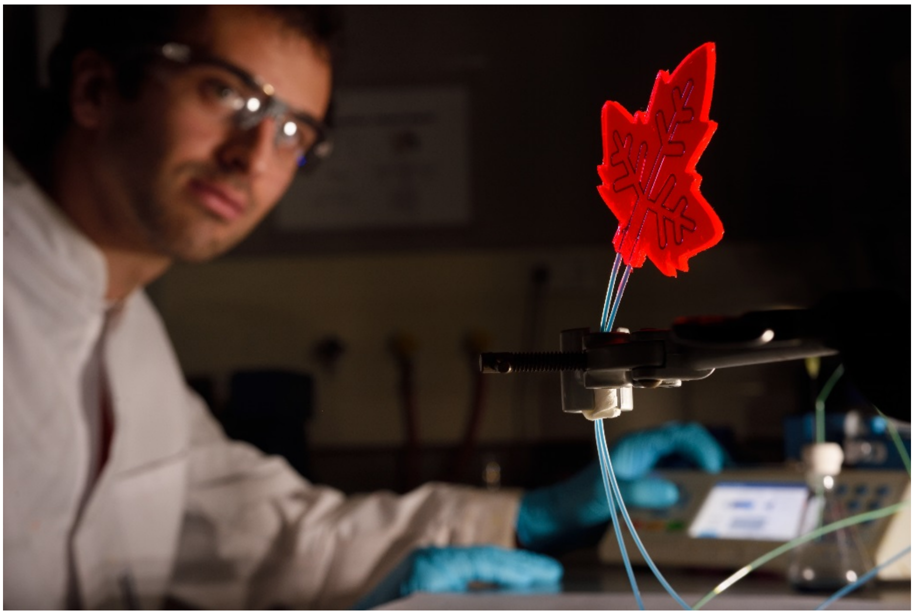
Microreactors that are efficiently powered by fluctuating sunlight

Solar light is the most sustainable energy source available. How can we efficiently use it in the production of valuable molecules? Researcher Dario Cambié from Eindhoven University of Technology has adapted a light concentration technology originally called Luminescent Solar Concentrators for use in photochemical reactors. The resulting device is capable of steadily produce chemicals with solar light, even under cloudy sky conditions, thanks to a microcontroller connected to the reactor.

An attractive solution to make photochemical processes environmentally friendly is to directly use sunlight, replacing artificial lamps. However, compared to the predictable and constant light output provided by lamps, solar light is more challenging. It is available intermittently (day and night) and sky conditions vary. Furthermore it has a broad wavelength distribution, whereas specific wavelengths are required to power reactions.

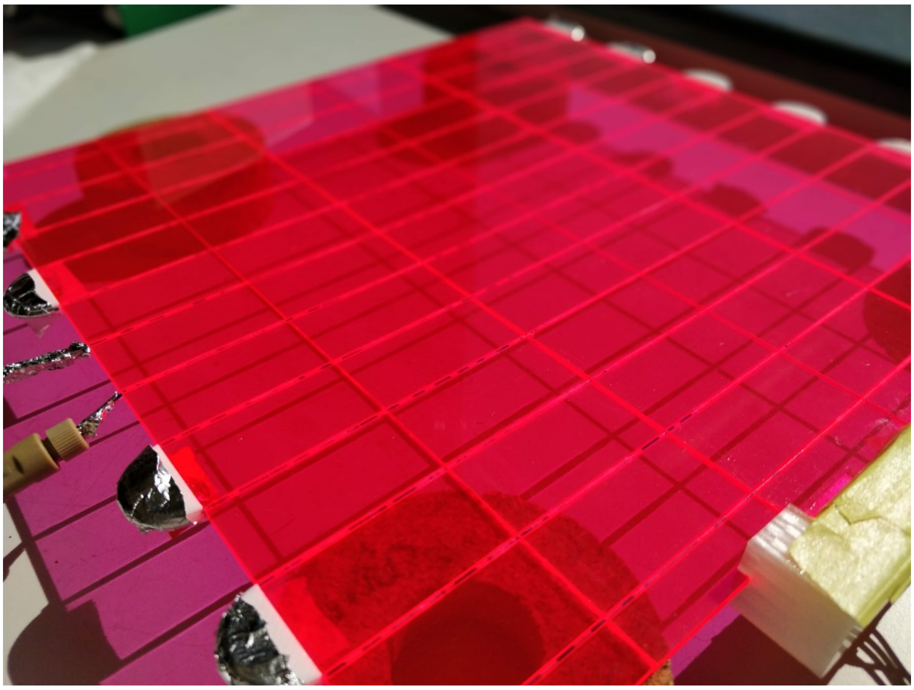


PhD candidate Dario Cambié near a leaf-shaped reactor for solar photochemistry (photo: Bart van Overbeeke)

In my PhD I have developed a novel reactor for solar photochemistry called Luminescent Solar Concentrator-Photomicroreactor (LSC-PM) that solves most of the problems associated with the use of sunlight as energy source for photochemical reactors. This reactor repurposes fluorescent slabs of plastic called Luminescent Solar Concentrators (LSC) to provide the reaction with a light characterized by a narrow bandwidth distribution (i.e. a specific “color” of light). The LSC is capable of collecting white light, converting it to a specific color and concentrating it. Small channels in this plastic slab are where the reaction takes place. Since the white light of sun is converted into a single color it becomes suitable to be used in photochemistry to selectively activate specific molecules, called photocatalysts. Notably, the light focused by the LSC in the reactor channels can be up to 4.5 times more intense than what the intensity of that color is in natural sunlight, meaning that the solar-powered reactions are often accelerated with the use of LSC-PM.

To understand which are the major parameters affecting the device performance, a detailed simulation of the photon paths in the device was carried out with a ray-tracing program. This program calculates the trajectories of the photons coming from the sun and reaching the reactor, and provides an overall balance of the fates of the different photons (e.g. how many photons are absorbed in the LSC and how many are lost by transmission through the plastic).

The results of this study gave us the idea of designing a simple mini-computer that could address the variability of solar light intensity by continuously changing the time that the reactants are exposed to solar light. In particular, a small light sensor was connected to the reactor. The light intensity measured by the sensor is then used to adjust the speed to which the reaction mixture is flowing in the channels, affording stable product quality even under fluctuating sunlight conditions.



A red LSC-PM reactor next to a window, while illuminated by sunlight. Inside the reactor channels, blue slugs containing the reaction are visible. On the right side, the light sensor.

Finally, I developed a new design for the reactor using small transparent tubes included in the Luminescent Solar Concentrator plates. In this way the photons can reach the reacting chemicals, while the chemicals do not come into contact with the LSC part of the reactor, resulting in a more robust and versatile reactor. Several reactions were performed in reactors made this way, featuring red, green and blue LSCs.

Further research ongoing in the lab of prof. Noël will focus on the development of a small, self-sustainable mini-pant based on the LSC-PM concept.

Title of PhD-thesis: The development of luminescent solar concentrator photomicroreactors to enable solar photochemistry. Supervisors: dr. Timothy Noël (TU/e) and dr. Michael Debije (TU/e).