Catalytic Farming: Reaction Rotation Extends Catalyst Performance

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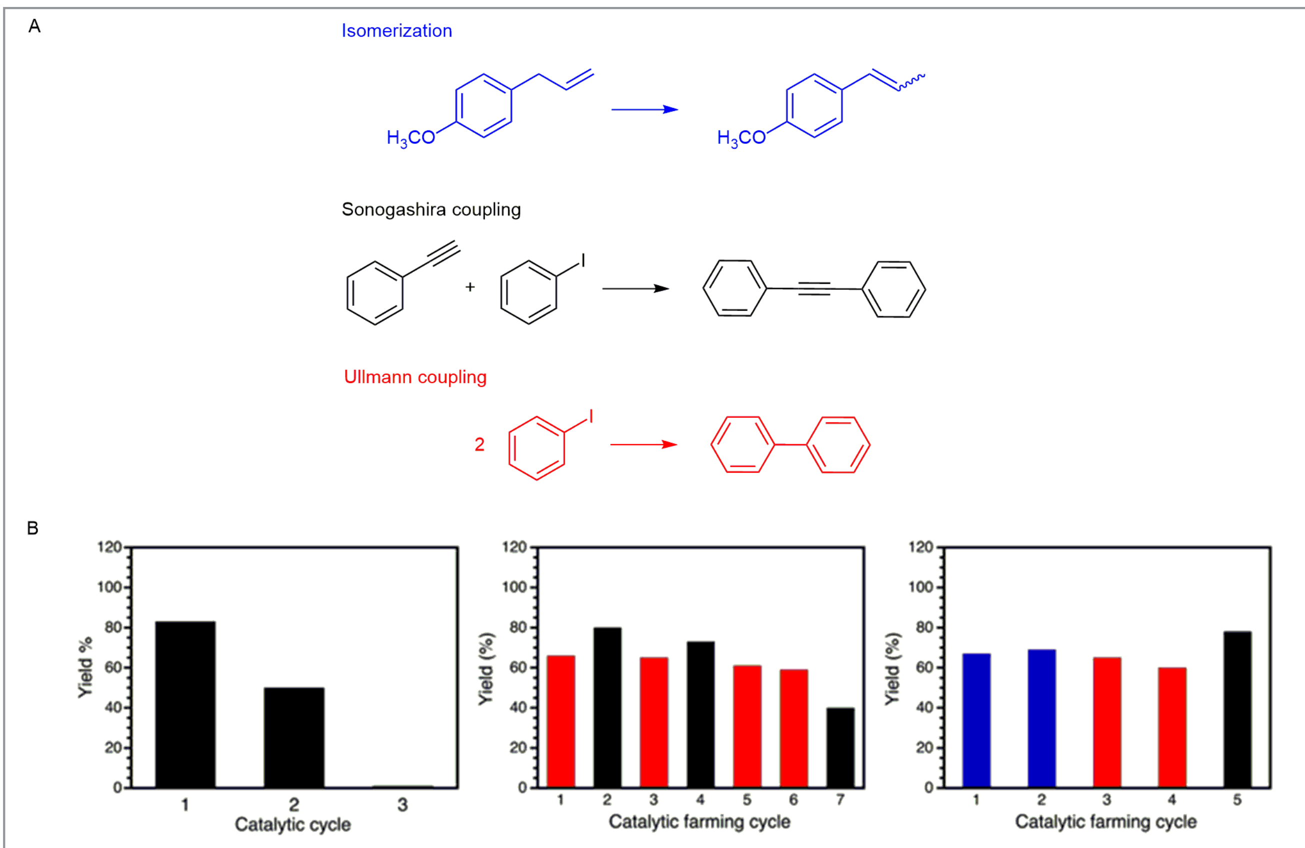
The use of heterogeneous catalysis has improved the separation and reusability of catalyst materials considerably compared to their homogeneous counterparts. Nevertheless, the turnover of these catalysts can still suffer from different deactivation pathways. "Current techniques to overcome this issue involve the use of heat and/or high oxygen or hydrogen pressures, a process that is usually expensive and wasteful," said Professor Juan Scaiano from the University of Ottawa (Canada), whose group has been researching this area for several years. "As green chemistry practices have inspired many changes in the industrial synthesis of traditional chemicals, alternative strategies based on the reduction of waste production while regenerating the catalysts activity are welcomed."

Dr. Anabel Lanterna, one of the co-authors, added: "Since we started our venture towards the use of heterogeneous catalysis, we have been looking for processes that can reactivate the catalytic activity in a more environmentally friendly manner. Inspired by practices in agriculture, we decided to explore a new strategy named 'catalytic farming' due to its resemblance to the crop rotation approach that farmers have been using for centuries." Dr. Lanterna continued: "As farmers know, a crop can deplete the soil of nutrients that other crops can restore in the following growing season, therefore rotation of the crops can improve the yields and extend the durability of the field productivity. Likewise, we can use reactions that can 'reactivate' the catalyst for another type of reaction in the



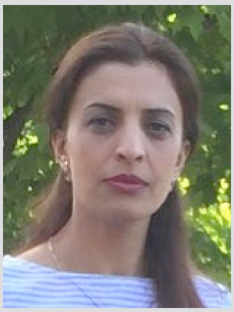
Scheme 1 (A) Three different reactions photocatalyzed by Pd-decorated TiO_2. (B) Yields of the reactions after different catalytic cycles, demonstrating that reaction rotation extends the catalytic activity of the material; the colors represent the different reactions shown in part A.

subsequent catalytic cycle (Scheme 1). At this point it is important to highlight that none of the strategies tested could be done without properly knowing the catalytic mechanism and the changes the catalyst might undergo during catalysis."

This strategy is not limited to the systems the group has studied; indeed, it can be extended to different catalytic systems as long as the catalysts can be employed for more than one catalytic reaction. "This implies thorough knowledge of the catalytic mechanisms taking place in each case, or at least knowledge regarding the changes in the catalyst chemical structure. The strategy also shows potential for flow chemistry, as we envision that different consecutive reactions can be catalyzed simply by changing reagents at the flow system input," said Professor Scaiano.

"It is important to highlight that farmers have taken years to develop the best crop rotation practices, and yet there is no preferred choice among them," remarked Professor Scaiano. He continued: "Thus, the perfect rotation sequence also considers other external parameters such as usefulness of the crop, economic competence and environmental liability. Likewise, in chemistry, there is no perfect reaction rotation order and the strategy can vary from one chemist to the other." In this particular case, the group faced cases where, despite appearing suitable for reaction rotation, the system evolved in a different way on the bench. Professor Scaiano concluded: "Noticeably, the work summarized in this contribution is the result of many trials, both fruitful and ineffective ones, and great perseverance as we always believed this strategy would find its way to a successful story."

About the authors



A. A. Elhage

Ayda Ali Elhage, originally from Lebanon, is currently a PhD candidate in chemistry at the University of Ottawa (Canada). She earned her undergraduate degree in chemistry from the Lebanese University in Beirut (Lebanon). She completed a high school teaching certificate at the Faculty of Education, Beirut, Lebanon then started to share her passion for molecules to high school students in public and private schools for many years. After moving to Ottawa, Canada in 2011, she worked at Lycée Claudel, a private French school, for three years. In September 2014, Ayda quit her job to pursue graduate studies under the supervision of Prof. Juan Scaiano at the University of Ottawa. Her research is focused on the development of supported metal nanomaterials (plasmonic and/or non-plasmonic metals) for heterogeneous photocatalytic systems. She is also working on developing a new type of heterogeneous catalyst for potential uses in continuous-flow photochemistry, by functionalizing glass fiber surfaces prior to metal nanoparticle decoration for organic transformation applications.

Dr. A. E. Lanterna

Anabel E. Lanterna obtained her PhD in chemistry from the National University of Córdoba (Argentina) in 2013. During her PhD studies, she spent some time at the University of Johannesburg (South Africa) and at the University of Valencia (Spain) working on plasmonic metal nanoparticles. After she graduated, she joined the Scaiano group at the University of Ottawa (Canada), where she began her work in heterogeneous photoredox catalysis. Since then she has published more than 20 contributions in peer-reviewed journals, with more than 10 of these in the field of heterogeneous photocatalysis. She is the recipient of the 2018 Canadian Society for Chemistry (CSC) Award for Young Materials Chemists and the 2018 Inter-American Photochemical Society (IAPS) Gerhard Closs Postdoctoral Award. Currently, she is interested in the design and study of new nanomaterials for use in catalysis and health applications.

Prof. J. C. Scaiano

Juan C. (Tito) Scaiano holds the Canada Research Chair in Applied Photochemistry at the University of Ottawa (Canada). Professor Scaiano's scientific career includes the publication of over 700 scientific papers, two books and several book chapters. He is recognized for his work in photochemistry and nanotechnology and his h-index is 77. His research interests include organic photochemistry, nanomaterials, catalysis, sunscreens, and single-molecule spectroscopy. He is the founder of Luzchem Research, an Ottawa-based instrument manufacturer. His research group of about 15 co-workers currently concentrates on the study of nanomaterials and catalysis.