Young Career Focus: Professor Timothy Noël (Eindhoven University of Technology, The Netherlands)

Background and Purpose. SYNFORM regularly meets young up-and-coming researchers who are performing exceptionally well in the arena of organic chemistry and related fields of research, in order to introduce them to the readership. This Young Career Focus presents Professor Timothy Noël (Eindhoven University of Technology, The Netherlands).

Biographical Sketch

Prof. T. Noël

Timothy Noël was born in 1982 in Aalst (Belgium) and received his M.Sc. degree (Industrial Chemical Engineering) in 2004 from the KaHo Sint-Lieven in Ghent (Belgium). He then moved to Ghent University to obtain a Ph.D. at the Laboratory for Organic and Bioorganic Synthesis under the supervision of Professor Johan Van der Eycken (2005–2009). The title of his Ph.D. thesis was 'Synthesis and application of chiral dienes and chiral imidates for asymmetric transition metal catalysis'. Next, he moved to Massachusetts Institute of Technology (MIT, USA) as a Fulbright Postdoctoral Fellow with Professor Stephen L. Buchwald. At MIT, he worked on the development of new continuous-flow methods for cross-coupling chemistry at the MIT-Novartis Center for Continuous Manufacturing. In 2011, he accepted a position as an Assistant Professor at Eindhoven University of Technology (The Netherlands). His research interests are flow chemistry, homogeneous and heterogeneous catalysis and organic synthesis.

In 2011, he received the Incentive Award for Young Researchers from the Comité de Gestion du Bulletin des Sociétés Chimiques Belges, in 2012 a VENI award from NWO and he was also a finalist of the European Young Chemist Award 2012. In 2013, he received a Marie Curie Career Integration Grant from the European Union. Since 2015, he has coordinated the Marie Skłodowska-Curie ETN program 'Photo4Future' on the development of photoredox catalysis in photomicroreactors (www.photo4future.com). In 2014, he obtained a prestigious VIDI award from NWO, and in 2016, he received the Thieme Chemistry Journals Award. He serves as an associate editor for the *Journal of Flow Chemistry*.

INTERVIEW

SYNFORM *What is the focus of your current research activity?*

Prof. T. Noël The Noël group is interested in the development of new enabling tools which assist chemists in their daily job and allow them to carry out hazardous manipulations without compromising personal and environmental safety. Key in our strategy is the use of continuous-flow technology. Continuous-flow reactors have been increasingly used in synthetic organic chemistry to facilitate chemistries which are otherwise difficult to carry out. This includes gas-liquid reactions, photochemical transformations, chemistry utilizing hazardous compounds, extreme reaction conditions and multistep reaction sequences. Underlying all these advances are chemical engineering principles that enable chemical processes to be carried out under perfectly controlled reaction conditions.

Taking advantage of these tools, our ambition is to develop new catalytic strategies for chemical synthesis that engage novel reactivity concepts which facilitate the rapid generation of biologically active molecules. By combining these tools and new reactivity concepts, we strive in the long run to develop an automated and chemo-catalytic equivalent to Nature's biosynthetic machinery that will build essentially any molecule on demand.

Our approach is unique in the sense that we position ourselves at the interface of organic synthetic chemistry and chemical engineering. I have an M.Sc. in chemical engineering and I obtained my Ph.D. in organic synthetic chemistry. My group consists of both synthetic chemists and chemical engineers. Consequently, we are able to rapidly recognize those synthetic problems which would benefit from microreactor technology and to tackle the problem from a different angle than was done traditionally.

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SYNFORM *When did you get interested in synthesis?*

Prof. T. Noël I got interested in organic synthesis in high school. In my final year, we got a basic introduction to organic chemistry and I immediately realized that this was a topic that seemed natural to me. After the examinations, the teacher came to me and said that I had talent for organic chemistry and that I should do something with it. I never forgot those encouraging remarks and every time I needed to make a decision about my career, I chose the more synthetic career path.

Next, I started my academic education and I enrolled in a chemical engineering program. The reason I chose chemical engineering is because of the large breadth of different topics it provides. It not only offers chemistry subjects but also courses on mathematics, mechanics, automation, electricity, etc. Also, we got some basic organic chemistry courses and again I was deeply interested in the subject. I decided in my final year that I should do something with it and, consequently, I performed my M.Sc. final thesis in the group of Johan Van der Eycken on the synthesis of a fluorescent label for labelling a peptidic inhibitor of HIV. I liked this synthetic experience so much that I decided to stay in that group and perform Ph.D. studies in organic synthesis. In 2009, I obtained my Ph.D. and, subsequently, I went to the USA to do a postdoc at MIT in the group of Stephen L. Buchwald. There, I started for the first time in my life to work with flow microreactors. Immediately, I realized that all the pieces fell into place and I deeply enjoyed the project. This was the ideal subject for me as knowledge about both organic synthesis and chemical engineering was required to come to a satisfactory result.

SYNFORM *What do you think about the modern role and prospects of organic synthesis?*

Prof. T. Noël Organic synthesis is an indispensable part of many related disciplines, for example chemical biology, materials science, medicinal chemistry, nanotechnology, molecular motors, etc. Without organic synthesis, these disciplines would simply not be possible. It is therefore crucial that we keep training future student generations in this important discipline.

I believe personally that more and more synthetic processes will be automated in the future. If you read the recent reports on this subject, then you will learn that a combination of smart programming and flow reactors allows computers to optimize chemical reactions. This type of work remains a time-consuming undertaking for the chemist but can now be done overnight with great success. Moreover, it also avoids exposure to hazardous chemicals and is therefore perfectly suitable for carrying out those optimizations which pose a high risk to the practitioner (e.g. working with oxygen gas under high pressure, working with HCN, or other toxic substances). This does not mean that chemists will be entirely replaced. Chemists will still be required to monitor the processes, to provide input and to make a final selection in what is worth pursuing and what is not. Nevertheless, there is still a lot of work on the plate to really make these automated optimization robots widely applicable and fail-proof.

Another important role for organic synthesis is the development of milder transformations which are driven by sustainable activation modes, for example photoredox catalysis, electrochemistry, and other room-temperature catalysis modes. Currently, thermochemical activation is one of the most-used ways to drive chemical reactions forward. Strikingly, industrial process heating operations account for 70% of the total energy use. The development of new synthetic methods and processes driven by renewable energy sources, for example solar and wind energy, would be a tremendous improvement. Here as well, continuous-flow chemistry can help to maximize the energy efficiency of these transformations, for example by overcoming the Bouguer–Lambert–Beer limitation of photochemistry.

SYNFORM *Your research group is active in the area of photoredox catalysis and C–H activation. Could you tell us more about your research and its aims?*

Prof. T. Noël Since the start of my independent academic career in 2012, my group has been intrigued by visible light photoredox catalysis. Photoredox catalysis provides neat solutions for previously elusive organic transformations (broad scope, high functional group tolerance, mild reaction conditions). We have developed a number of different photocatalytic transformations over the years, including the Stadler–Ziegler reaction, trifluoromethylation reactions, oxidation chemistry and disulfide formation. Typically, we select those transformations which have a gaseous reagent. Such gas–liquid reaction mixtures can be handled in flow very well and mass transfer limitations are minimized. However, one of the biggest hurdles of photoredox chemistry was its scalability and we have worked on continuous-flow microreactor solutions to overcome these challenges. We have also studied the engineering aspects concerned with photocatalytic gas–liquid reactions in flow. This includes the potential (i) to extract kinetics efficiently, (ii) to increase the energy efficiency of the photomicroreactor and (iii) to scale the chemistry up with a numbering-up strategy.

Figure 1 Luminescent solar concentrator based photomicroreactors which allow for increased harvesting of solar light for application in organic synthetic photochemistry

Similarly, we have selected C–H activation chemistry as a notable field where continuous-flow processing can make a difference. Again, we try to select reactions with a gaseous reagent, for example oxygen. These transformations are very hard to carry out in standard batch labware. Due to improved gas–liquid characteristics and excellent heat transfer, we were able to reduce the reaction times from hours to the minute range.

SYNFORM *What is your most important scientific achievement to date and why?*

Prof. T. Noël This is a hard question as I like each publication we have published. However, our recent discovery on Luminescent Solar Concentrator based photomicroreactors is definitely something special (D. Cambié, F. Zhao, V. Hessel, M. G. Debije, T. Noël 'A leaf-inspired luminescent solar concentrator for energy-efficient continuous-flow photochemistry' *Angew. Chem Int. Ed.* **2017**, *56*, 1050). Previously, solar photochemistry was done by placing the reaction flask outside in the sun. Reaction times were typically in the range of several hours to days depending on the amount of light. So, almost nobody uses solar energy to power their reactions due to the low solar intensity at higher latitudes. However, our novel leaf-inspired photomicroreactor (see Figure 1) allows efficient harvesting of solar energy by using a luminescent solar concentrator. The reactor is fabricated from PDMS polymer which contains fluorescent dyes that can capture solar light and, due to internal reflection, the re-emitted light is guided towards the reaction channels. Moreover, the emission profile of the embedded dye was matched with the absorption spectrum of the photocatalyst which flows in the reaction channels. Due to this spectral overlap, the reaction mixture flowing in the channels experiences an amplified photon flux that is wavelength-concentrated to an energy window where the reaction occurs optimally. Interestingly, our device works particularly well in those regions where sunlight is not abundant. The device can capture diffuse light and still direct this light efficiently to the reaction channels. The ability to concentrate energy aids in enhancing the chemical reactivity in the reaction channels and makes solar energy a viable activation mode in organic synthesis.

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