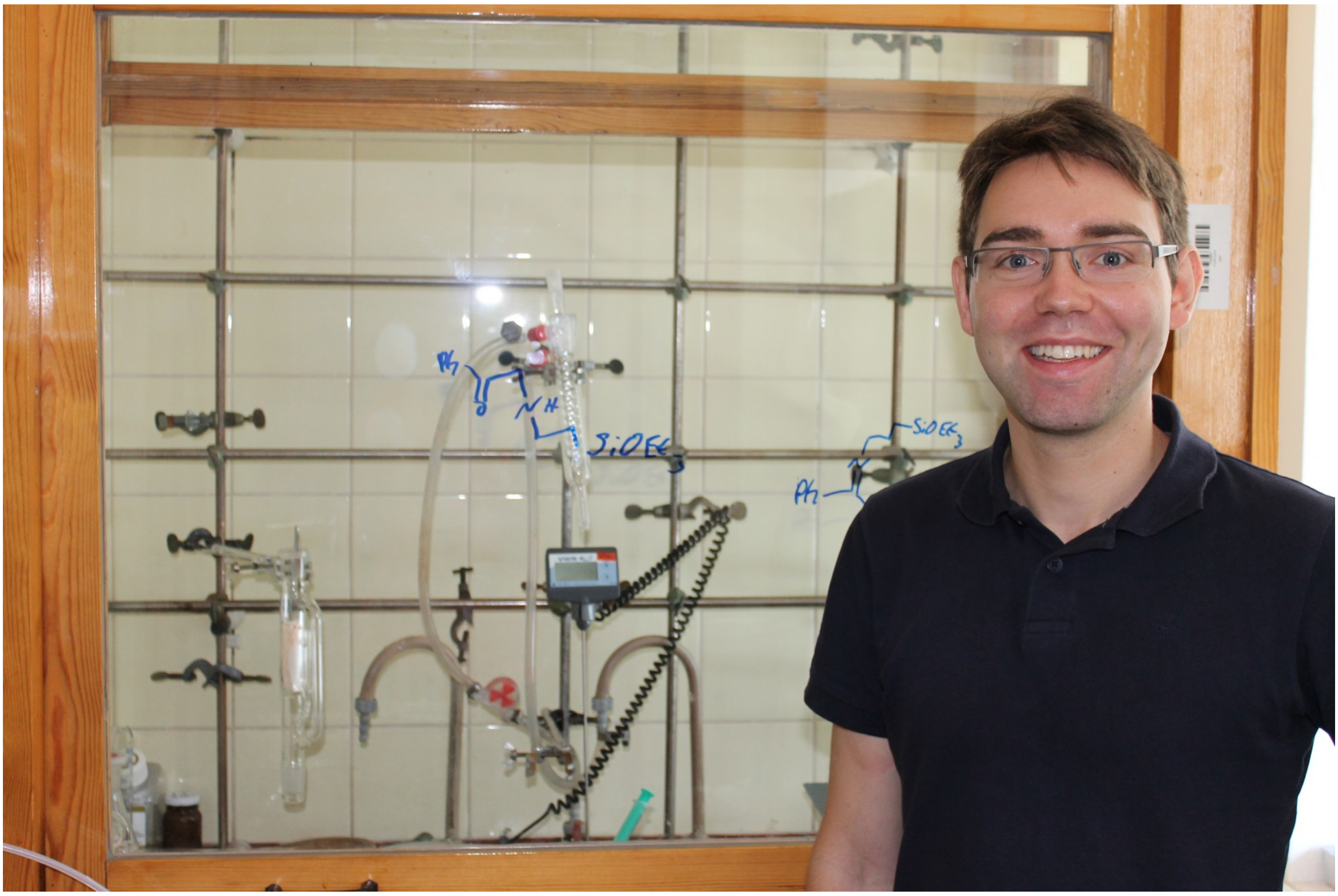
Bioeconomy BW

Thomas Paulöhrl: spatially and temporally controlled light-induced reactions

Thomas Paulöhrl, polymer chemist from the Karlsruhe Institute of Technology (KIT), was awarded the 2012 Lanxess Talent Award for his achievements in further developing light-induced click strategies that can now be used for generating various surface structures and three-dimensional frameworks. His Ph.D. thesis not only provides the basis for new ways to efficiently modify material, it also opens up new research opportunities in medical drug discovery.



Doctoral student Thomas Paulöhrl at his workplace at KIT.
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Thomas Paulöhrl achieved a breakthrough in a field of science that many researchers around the world had been trying for many years to achieve. Moreover, he gave the field of polymer chemistry a new impetus using nothing more than an everyday tool - a lamp, to be precise. His achievement relates to his ability to bring the two dimensions of space and time under control.

Thomas Paulöhrl grew up in Ulm. After he had finished school and civilian service, Thomas Paulöhrl decided to study chemistry. “I wanted to study something where I could bring in my own ideas. That’s why I chose chemistry,” Thomas Paulöhrl said explaining his decision. Around the time that he was preparing for his intermediate chemistry examination, Thomas Paulöhrl decided to establish a web hosting company to finance his studies. “I did not like the idea of doing badly paid manual work,” explained the doctoral student who also felt that the university courses he was doing barely touched on financial issues, which he would have liked to have learnt more about alongside his science classes. “Setting up my web-hosting company meant I could teach myself something about financial and other entrepreneurial issues as well as earning some money,” said Paulöhrl who still successfully runs his one-man company.

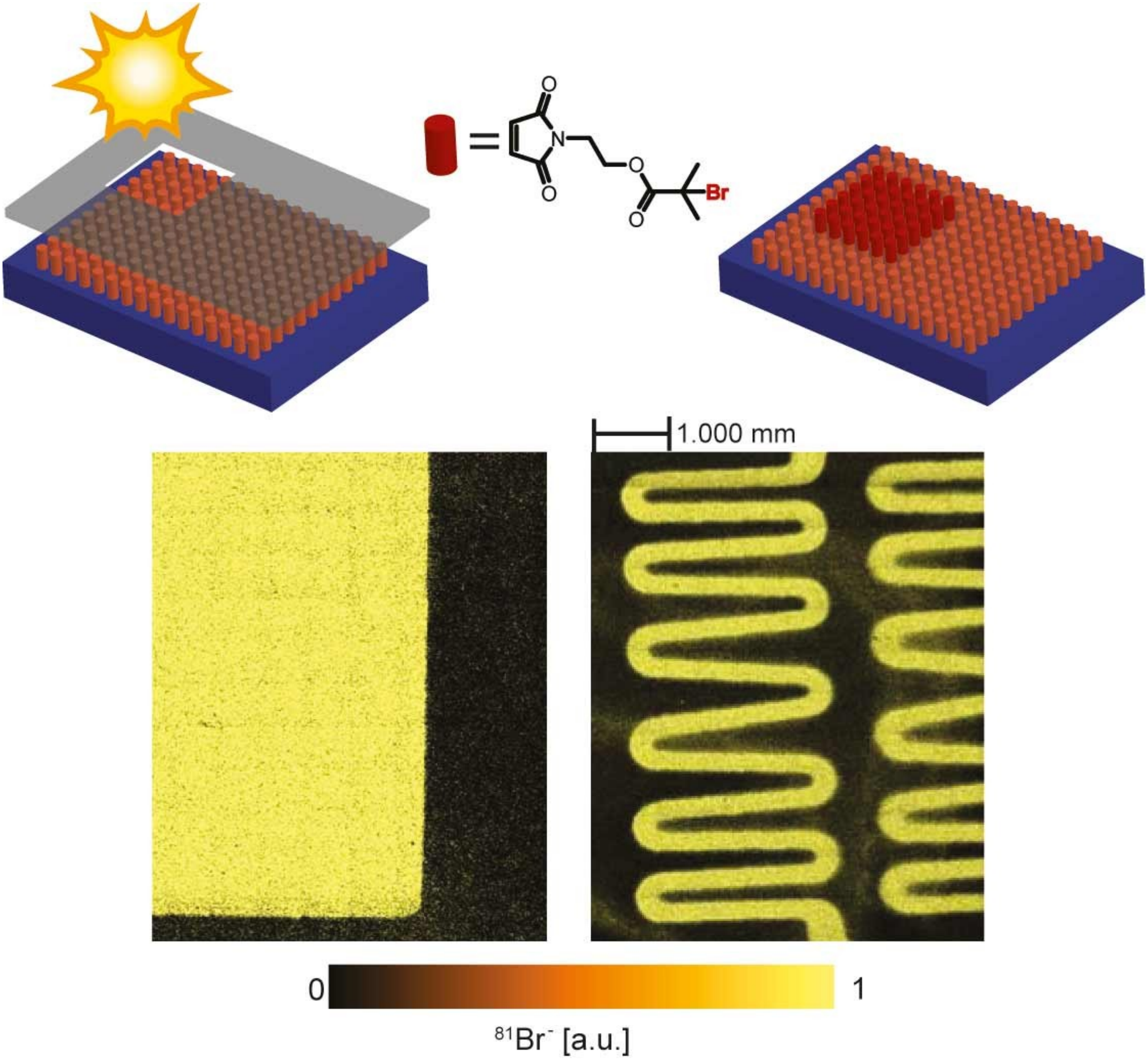
When he began working in the research group at the Institute of Technical Chemistry and Polymer Chemistry at KIT that he is still part of today, there were only eight people in the group. However, this was soon to change. Paulöhrl was sure that the group could get things moving. The group now has 40 members working on a wide range of topics, including the synthesis of complex macromolecular architectures and the light-induced modification of materials.

Click reactions with photoactive groups

Click reactions are key elements of polymer chemistry as well as Paulöhrl’s research activities. Complex molecular structures are first produced as partial rather than complete structures. During the subsequent reaction, these structures “click” together rapidly, similar to a peg game. However, clicking is usually spatially and temporally uncontrolled and therefore not sufficient for generating surface structures and three-dimensional frameworks. “If you add different “click” units into a glass of water, you know that something is happening, but you do not know where,” said Paulöhrl explaining the problem that can arise when researchers want to modify specific surface areas rather than the entire surface. However, simple methods can be used to apply light to a specific area, which gave Paulöhrl the idea of inducing a click reaction using light from a normal lamp and photoactive molecules. The time, site and duration of light irradiation can be controlled so that the “click” reactions take place in a temporally and spatially predetermined manner. This means that if only a specific spot of a plate containing photoactive molecules is irradiated, it is only at this spot that the molecules “click” together.

Thomas Paulöhrl is specifically focused on such challenges. “It usually takes quite a long time for students to obtain a comprehensive knowledge base in the field of chemistry. Students usually study for around five years before getting their degree. However, once they have their degree, students are ready to focus on a state-of-the-art research project during their doctorate, which takes around three years to complete,” said Thomas explaining general study times and procedures.

After he had managed to successfully induce a click reaction of simple molecules with light, Thomas Paulöhrl went on to use bigger building blocks. “I then used slightly bigger building blocks and investigated whether different conditions and reactions occurred,” said Thomas, going on to explain that he used peptides and mass spectrometry methods for his subsequent investigations and analyses. He also found that in this case also, molecules with photoactive groups attached were activated upon selective light irradiation, which enabled the peptides to “click” together. Once it became clear that the reaction also took place in the presence of a broad range of different functional groups, Paulöhrl went on to use other functional groups. “I found that the light-induced click reaction also worked with oximes as functional groups,” Paulöhrl said.



Reactions can only occur in the light-irradiated areas.
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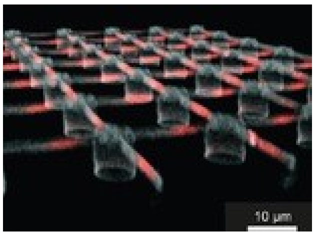
Observing cells using spatially and temporally controlled click reactions



Reconstruction of a 3D fluorescence microscopy image in which specific areas (red) were functionalised.
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Paulöhrl then went on to work with a group of biologists and physicists in order to develop the project further for medical applications. A team led by Professor Martin Wegener from the DFG-funded Centre for Functional Nanostructure (CFN) had already explored the potential of 3D laser lithography for creating a 3D framework and was working on fixing molecules at predetermined sites in the 3D framework. Using Paulöhrl's light-induction method, they succeeded in clicking fluorescence markers to specific sites in the 3D polymer framework, where the spatially resolved attachment process is triggered via light. The next step will be to use living cells and attach them to the 3D polymer framework in order to look at their behaviour under three-dimensional conditions, which are close to the natural situation in the human body. Three-dimensional cell cultures of this kind are specifically important in the fields of cancer research and drug development as such conditions help the researchers to assess the behaviour of cell cultures under conditions that are as realistic as possible. The temporal aspect, which Paulöhrl is able to control with his method, is an important part of the researchers' work. This enables cells in different stages of development to be clicked to the 3D framework at different points in time and thus mimic the natural proliferation of a cell group under investigation.

Light-induced click reactions therefore have great potential for use in medical research, including for studying stem cell differentiation. "We started off using molecules in solution, then went on to investigate the behaviour of certain molecules that are fixed to surfaces, and now have a method to hand that is suitable for stem cells," said Paulöhrl, with a slightly sheepish smile. However, this is where Paulöhrl's work ends, at least for him as a chemist. "The chemical approaches that we have developed will now be applied in biological and physical areas with the aim of further developing the approaches."

The properties of materials can be specifically modified

Controlled click reactions are also of interest for other areas in the field of polymer chemistry as they enable researchers to modify the properties of materials, such as hydrophilic and hydrophobic properties. Some of Paulöhrl's colleagues are working with industrial partners on this area with the aim of patenting their findings.

Thomas Paulöhrl will finish his doctorate in about a year's time, but does not yet know whether he will chose a career in industrial research or an academic career, although each has its attractions, he said. In June 2012, Thomas Paulöhrl was awarded the 2012 Lanxess Talent Award, which is given to young scientists for excellent work in the early phase of their academic career. This award is not the only one that he has received so far, but is certainly an important one. Paulöhrl explains why: "In the field of basic research, results cannot be planned. But I am trying to develop something that has the potential to be used in application. This is important because otherwise industry will lose interest in what we are doing," said Paulöhrl alluding to the fact that this was the case with his controlled three-dimensional click reaction. "Inducing a reaction with light in water is a relatively simple principle, but it works."

About:

Thomas Paulöhrl was born in Ulm in 1985 where he also did his university entrance examination. After having spent nine months doing civilian service, he started studying chemistry at the University of Karlsruhe. He was awarded the Procter & Gamble Prize for his degree thesis in 2010. In the same year, he started his doctorate under the supervision of Prof. Christopher Barner-Kowollik and funded with a grant from the Chemical Industry Fund.

The 2012 **Lanxess Talent Award** with a prize of €4000 in the categories "Advances in Polymer

Materials" and "Innovations in Process Engineering" was awarded for the first time in 2012. Candidates were proposed by their university teachers and had to present their research work at the first Summer School of the Research Institute for Interactive Materials at Aachen University (RWTH). The laureates were selected by an expert jury of RWTH and Lanxass Deutschland GmbH staff.

Literature:

Pauloehrl, T.; Delaittre, G.; Winkler V.; Welle, A.; Bruns, M.; Börner, H. G.; Greiner, A. M.; Bastmeyer, M.; Barner-Kowollik C.; Adding Spatial Control to Click Chemistry: Light-Triggered Diels–Alder Surface (Bio)functionalization at Ambient Temperature, Angew. Chem. Int. Ed. 2012, 51, 1071–1074.

Article

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Ines Vondracek
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