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From Chemicals to Chemistry

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New Directions in Industrial Chemical Research as Reflected in *Angewandte Chemie***

*Andreas Kreimeyer**

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Chemical research is now more than ever driven by the issue of how to secure the natural foundations of life for a growing world population. For the great chemists, from Justus Liebig through Carl Bosch and Fritz Haber to the leading researchers of our time, applying scientific knowledge for the benefit of society has always been the prime concern. With its growing complexity and the necessary cross-linking of its disciplines, the profile of chemical sciences has changed radically over the last few decades: whereas originally, individual molecules were the focus of research activity, emphasis has now shifted to intelligent chemistry in the form of holistic systems aimed at finding solutions to securing food, water, and energy supplies as well as maintaining quality of life. How we—academia and industry—find sustainable answers depends not least on the quality of the scientific dialogue, supremely well documented and repeatedly revitalized by the scientific journal *Angewandte Chemie* for 125 years. Like almost no other scientific journal in chemistry worldwide, it vouches for the quality and scientific relevance of the articles and, by functioning as an "early warning system", has accompanied the major social challenges and scientific developments, from the Haber Bosch process to the discovery of graphene and its potential applications. To mark its anniversary, we will take a look at the future topics of chemical science and solutions "from chemicals to chemistry".

The Future Belongs to Interdisciplinary Research

The focus of innovation in the chemical industry—and also in science as a whole—has shifted increasingly over the last few decades from molecules towards materials, effects, and systems. Today more than ever, the emphasis is on intelligent chemistry in the form of holistic systems designed to find solutions along the value chain for securing water and energy supply as well as maintaining quality of life. Whereas research in the 1970s was still centered on the development of single molecules, the focus of value creation has shifted increasingly toward functional materials—from raw materials, basic products, and intermediates towards system solutions. These types of more and more sustainability-driven innovations require an interdisciplinary approach and new ways of linking together different areas of expertise—both in industry and in academic research. Mentoring and driving this change forward is a major concern of *Angewandte Chemie*. Editor-in-Chief Peter Gölitz, for example, in his editorial to mark the journal's centenary in 1988, quoted Bunsen, saying "*A chemist who is not a physicist is nothing at all*" to describe openness towards neighboring disciplines as a characteristic feature of the articles printed in the Journal.[1]

This openness and the cooperation at international level, in a spirit of partnership, are indispensable if we are to develop "breakthrough technologies". While at the beginning of its history, chemistry was characterized by the discovery and development of substances, today we investigate and design complex systems as well as the functions of materials, constantly bearing in mind their use along the entire value chain. This development can be traced back in detail in *Angewandte Chemie*. Based on the shared history of *Angewandte Chemie* and BASF with respect to many different aspects of securing supply in the fields of energy, nutrition, and quality of life, a wide range of examples will be quoted from the achievements of industrial researchers whose scientific activity and cooperation has left a lasting legacy, as mirrored in this Journal:

- The color blue—from dye research to organic electronics
- New solutions through cross-sectional technologies—example: mobility of the future
- Miracle material graphene—the hope for a new breakthrough technology
- From the key molecule ammonia to raw material change—facing the challenges of the future

These examples will show the change in industrial chemical research which is becoming increasingly interdisciplinary.

[*] Dr. A. Kreimeyer
Research Executive Director, BASF SE
67056 Ludwigshafen (Germany)

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The Color Blue—From Dye Research to Organic Electronics

The color blue may be regarded as the starting point of BASF's history. Heinrich Caro, founder of the azo dye industry and first head of research at BASF, member of its Board of Executive directors and later of its Supervisory Board, managed in 1876 to create synthetically a pure blue coloring dye for cotton: methylene blue. Strasbourg chemist Adolf von Baeyer succeeded in synthesizing indigo, which was the most important natural dye in the laboratory back in 1880. Together with Farbwerke Hoechst, BASF acquired the rights to use the indigo patent, thereby entering the competition to establish an industrial-scale synthesis of the natural dye.

While one shade after the other on the color scale was unlocked in rapid succession, science and commerce in Germany experienced a new symbiosis—investment in science was specifically promoted and soon had the patent pipeline gushing.[2] During this time, hardly anyone was as skillful in combining scientific expertise with practical application as Heinrich Caro, who *"stayed up until late at night in his study (…) acquainting himself with the chemical journal literature and the latest developments in organic chemistry"* and sought an exchange of knowledge with scientists of the Royal College of Chemistry in London.[3] Caro's methylene blue was the first German dye patent following the introduction of patent legislation in 1877. The technical implementation of indigo production—the dye indigo was first produced on an industrial scale in 1897—brought to the fore Caro's all-round talents in technical and scientific expertise, combined with an unerring instinct for the needs of the markets.

OLED—Intelligent Chemistry Based on New Systems

Today, the color blue again marks the inception of a breakthrough technology in BASF's history, this time in the lighting market. Blue is the supreme discipline when it comes to imitating white light with organic light-emitting diodes. The previously developed materials, fluorescent emitters, are not efficient enough. The solution was found by BASF researchers in dye chemistry: several years ago they discovered highly efficient phosphorescent blue emitters capable of converting energy almost completely into light.

The blue component not only represents a major milestone in organic white-light-emitting diodes, but also a paradigm shift in research itself. In the 1950s and 1960s, chemistry had the task of producing molecules for polymers, dyes, and much more. Since then, chemists have witnessed an enormous broadening of their discipline: "*Chemistry is moving to both make the molecules but also to make them by design to have a function. What people are really interested in is the function. Making a molecule—that's terrific. But what you really want is a molecule that does something*", George Whitesides once said.[4]

Organic electronics is doubtless one such expansion and deepening of an existing research area. A possible approach was described by a research team made up of scientists from Dresden Technical University and industry in 2010. Along the same lines as the previously patented platinum(II) compounds, they gained access to a new class of complexes by using N-heterocyclic carbenes (NHCs; Figure 1). Investigations into transition-metal complexes suitable as emitters for phosphorescent light-emitting diodes (PhOLEDs) showed these new platinum(II) complexes with carbene ligands to have outstanding luminescence properties in the blue range of the visible spectrum.[5]

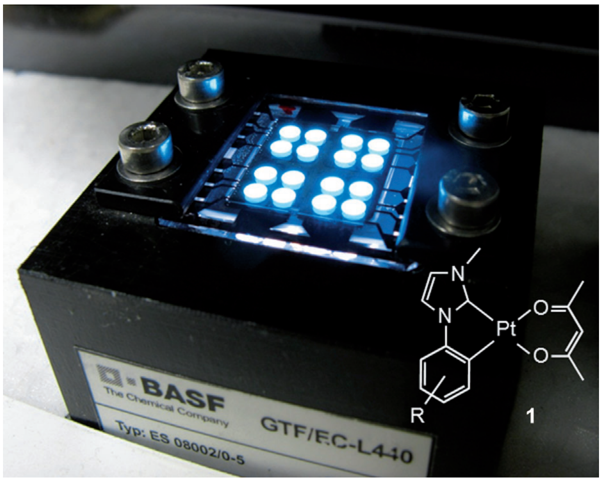

Figure 1. Test diodes based on a new class of emitters: cyclometalated Pt-NHC complexes.[5]

Dynamic Transfer from Research to Practical Applications

While it was nothing unusual in the past for it to take years or even decades for discovery to become implemented practically, today the innovation cycles are visibly accelerating, for example, in organic electronics. The development of large-format OLED display applications such as televisions, however, depends to a critical extent on increases in efficiency. Phosphorescent blue emitters display a high potential in this respect. Over the last few years, we at BASF have developed blue emitters with lifetimes in excess of 10000 h, thereby opening the way for a broad product portfolio and practical applications with our partners.

The driving forces behind this development are no less profound than in Caro's time: then as now, the main priorities are to increase efficiency in the innovation process. However, 125 years ago a molecule made all the difference, whereas today it is not enough merely to have the right "dye". In addition to the blue emitter, for example, the other materials also have to be robust and matched to the emitter. This is why BASF is currently working on the entire material system for the blue diodes (Figure 2).

New Forms of Cooperation

New forms of cooperation with partners from science and industry represent a key success factor for this step from the

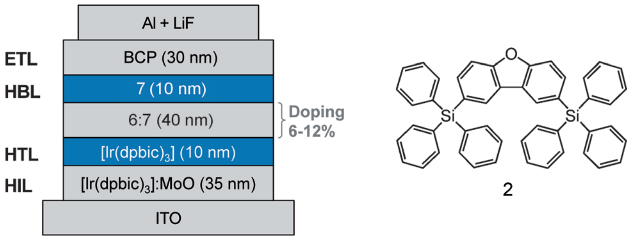

Figure 2. Structure of the diode test system (left) and structure of matrix material 2 (right). ETL = electron-transport layer, HBL: hole-blocking layer, HTL: hole-transport layer, HIL: hole-injecting layer, BCP: 2,9-dimethyl-4,7-diphenyl-1,10-phenanthrolin, [Ir(dpbic)$_3$]: iridium(III)-*fac*-tris[*N,N'*-diphenyl-benzimidazol-2-ylidene-C2,C2'], ITO: indium tin oxide. From Ref. [5].

molecule to system research. For example, since 2006, blue emitter classes and blue diodes have been developed in several subprojects of the OLED 2015 initiative as part of the high-tech strategy of Germany's Federal Ministry of Education and Research (BMBF).[*] The ongoing subproject, KOBALT (cost-effective OLED structural elements for applications in the lighting market), combines initiatives in the next stage for developing and commercializing energy-efficient lighting solutions.

Publicly sponsored projects also require the documentation and transparent analysis of results. When research progresses so rapidly, as it does in organic electronics, science magazines are indispensable for maintaining a dialogue between experts: Klaus Müllen and Ullrich Scherff mention that the development of polymer light-emitting diodes in the early 1990s advanced to become a new, tremendously dynamic research area in science and application.[6] To keep pace with this dynamic progress and provide guidance in an interdisciplinary environment, a scientific community must make use of professional media that record and evaluate breakthroughs and, even in areas where there is no clear overall picture, communicate the latest status of research and prioritize the importance of research results.

Organic electronics is now an important growth area for BASF. Whether material systems for OLEDs and display applications, organic materials for logic memories, or electronically active inks for e-paper: with such cross-sectional technologies, in the future it will be more important than ever to recognize synergies between synthesis, formulation, production, and system knowledge. However, this will only succeed if we adopt a holistic approach. In the case of organic electronics, this comprises not only OLEDs but also organic photovoltaics, and includes electricity generation as well as storage in an overall strategy.

[*] The subproject TOPAS 2012 (Thousand-Lumen Organic Phosphorescent Devices for Applications in Lighting Systems) ended in August 2011. Result: Development of suitable blue-emitter classes (low triplet lifetime); development of suitable host classes (high triplet energies); implementation in and optimization of complete blue diodes with lifetimes > 10 000 h/300 nits.

New Solutions through Cross-Sectional Technologies—Example: Mobility of the Future

The examples from organic electronics show that these innovations in electricity generation and use become possible only by employing cross-sectional technologies such as nanotechnology. This also applies to energy storage, for example, for the mobility of the future.

Nanotechnology opens up new perspectives and is key to numerous products. The position paper of the German Chemical Society (GDCh) "Perspectives in Chemistry"[7] refers in almost every chapter to the importance of nanostructures, nanocapsules, nanochemistry, or nanoelectronics: This cross-sectional technology is playing an increasingly important role in all areas of chemistry.

Why are we so convinced that this is one of the keys to solving our major issues of the future? Because it is this other dimension that makes invention possible—from nanoelectronics to new material classes and products. Particle sizes in the middle and lower nanometer range have, among other features, enhanced solubility, improved biological resorption, and modified optical, electrooptical, and other physical properties. "*Hence in addition to economic and ecological constraints there are also technical demands which appear to urgently require the development of new processes for the production of organic nanoparticles as alternatives to the established mechanical milling processes*", BASF researchers Dieter Horn and Jens Rieger wrote in 2001 in a frequently quoted article on modern aspects of particle formation.[8]

Chemists should focus their attention on molecules without losing sight of the problems where the molecules are only part of the solution. "*If chemists move beyond molecules to learn the entire problem—from design of surfactants, to synthesis of colloids, to MRI contrast agents, to the trajectories of cells in the embryo, to the applications of regenerative medicine—then the flow of ideas, problems, and solutions between chemistry and society will animate both*", explained George Whitesides.[9]

Example: Storage Envelopes—High-Performance Anode Materials for Lithium Storage Batteries

It is in the nature of cross-sectional disciplines to be integrated into numerous applications: for example, it was nanotechnology that first enabled new approaches in electrochemistry aimed at increasing the efficiency of batteries to be developed. The greatest challenges in the development of electromobility include the range of electric vehicles as well as the lifetime and cost of the battery. Although lithium-ion batteries already have the greatest energy density of all commonly used battery systems, the energy that can be stored in these units so far is not sufficient to achieve ranges for e-vehicles equivalent to those of conventional combustion engines. To solve this problem, the leading experts worldwide must cooperate. BASF has, for example, initiated the "Competence Network on Electrochemistry".[10] Together with leading world experts from academic research, the project will address fundamental questions related to materials, components, and systems for electromobility and electricity storage. One focus of these activities is on new materials and functional components for future battery types, such as lithium-sulfur and lithium-air batteries. Developing new and optimized materials for electrochemical energy storage systems is one of the most active fields of materials research. With the "Science Award Electrochemistry", BASF and Volkswagen launched an international initiative in 2012 to promote research into the development of high-performance energy stores. At the BELLA (Batteries and Electrochemistry Laboratory), operated jointly by Karlsruhe Institute of Technology (KIT) and BASF, both fundamental and application-oriented projects with objectives relating to future battery generations are in progress.

One approach would be to use new anode materials with a much higher discharge capacity. Although these are already known, their cycle stability is very limited. Work in the field of nanotechnology is opening up new perspectives and potential solutions for this storage technology. For example, a team from the Max Planck Institute for Polymer Research in Mainz, working together with BASF researchers, showed that flexible and ultrathin graphene layers around new anode nanoparticles significantly improved the properties of the anode.[11] The high conductivity of the enveloping graphene layers meant that the anode nanoparticles not only supplied much higher discharge currents but also greatly improved their cycle stability.

The publicly sponsored research project mastered the challenge of combining the high electrical conductivity of the thin partial layers of carbon with the high capacity of the anode nanoparticles. The authors concluded that a simple and cost-effective process has paved the way for the industrial-scale production of various functional electrode materials for energy storage.

The publication by the team headed by Klaus Müllen[11] was groundbreaking in several respects, since it took into account the overall relationship between research and its potential consequences, thereby making it easier for experts and interested parties to classify and assess these effects—in this case, the outstanding importance of graphene for the mobility of the future—and for numerous other applications which are presently left to our imagination.

BASF's holistic approach to the development of electromobility is based on four main elements: ecofriendly generation of the required electricity, economical and judicious utilization and transfer of electricity, as well as new battery materials and concepts (energy storage). Material-based—cost-effective—energy storage is essential in view of the increasing use of wind and solar energy, not only with regard to mobility. The scale of the task we are facing in this area is evident from the latest studies on chemical and physical storage methods for hydrogen. "*As in all energy technologies, the whole system has to be considered, and not one particular element of the technology chain exclusively*", to quote from Ferdi Schüth's study.[12]

Miracle Material Graphene—The Hope for a New Breakthrough Technology

Wallpapers with scrolling news headlines such as those we see on monitor screens, clothes that act as signal amplifiers to improve mobile telephone reception—is all this just science fiction or soon everyday reality?[13] In 2010, the Nobel Prize for Physics was awarded for investigating and isolating a two-dimensional carbon crystal: graphene, with its unique electronic properties, is now seen as a "miracle material". Reportedly, it provides decisive breakthroughs for applications involving electronic components up to and including electrochemical energy storage systems—perhaps including a news-ticker wallpaper with its flexible display.

In his Nobel Prize address, published in *Angewandte Chemie* in its Nobel Prize winner series, one of the discoverers, Novoselov, takes a notional "walk on the wild side" through the entertainment media and quotes the American sitcom "The Big Bang Theory", which was already mentioning graphene in 2010.[14] "*Graphene has captured the imagination of physicists with its potential applications*", blogged its scientific advisor Professor David Saltzberg. The fact that popular scientific media were already reporting on graphene at such an early stage shows what creative impulses were being provided by the numerous publications.

The combination of conductivity, transparency, mechanical strength, and elasticity could replace a large number of materials in existing applications in the future, as stated in the roadmap recently published in *Nature*, whose writers include the BASF researcher Matthias Schwab.[15] In light of the first successes in the run-up to the mass production of graphene, the authors see graphene as having the potential to become a disruptive technology—one which will not only permanently alter existing industrial processes, but could itself have an impact on our way of living and working.[16,17]

The one-atom-thin carbon material, with its mechanical strength, high electrical conductivity, and gas tightness can be obtained by, for example, exfoliation of graphite, or applied in the form of films onto practically any surface (Figure 3).

Polycrystalline graphene films are already being applied by chemical vapor deposition and demonstrate promising properties when used as transparent, electrically conductive layers in displays or touchscreens, thereby creating new applications. If graphene could be produced on an industrial scale, this would be a contribution to sustainable innovations securing our standard of living while simultaneously conserving the environment—our raw materials.[15]

Two things immediately claim one's attention: first, the rapid rate at which a completely new research area was developed and came to be seen as meriting the Nobel Prize—just under six years elapsed between the first studies by Geim and Novoselov and the award from Stockholm.[18,19] Secondly, the all-embracing nature of the discovery involving scientists from greatly differing research areas, and which at the very least is likely to change the orientation of chemical research towards sustainable innovations. Within a short time, a large number of scientific institutions were established to evaluate the potential applications.

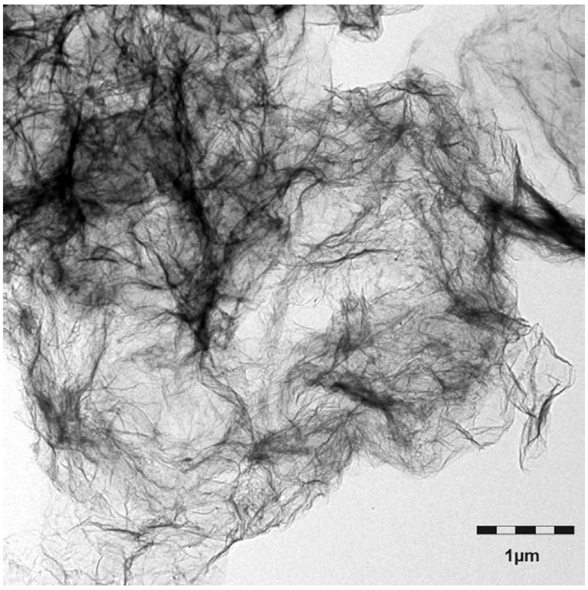

Figure 3. One atom thin carbon film: electron-microscopy image of a graphene flake exfoliated from graphite. Source: BASF.

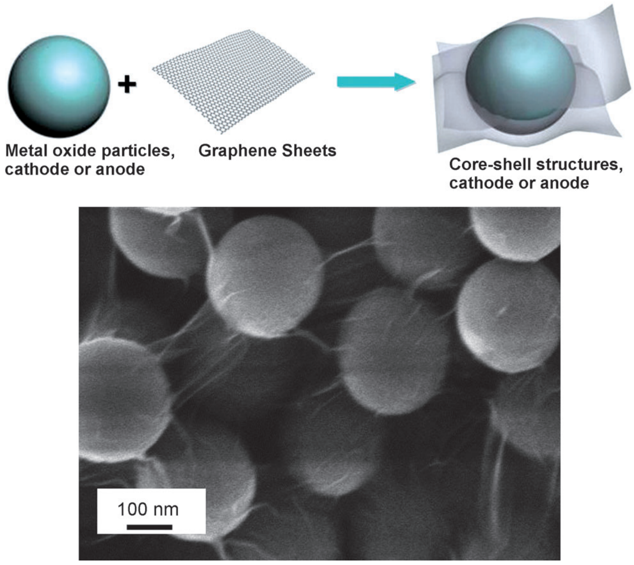

Figure 4. Novel core–shell structures for battery materials. Source: Yang et al. 2010.[11]

For BASF and Müllen's team at the Max Planck Institute of Polymer Research, the green light was given in 2012 for the foundation of a joint laboratory in Ludwigshafen, the Carbon Materials Innovation Center (CMIC).

The scientific media have helped foster this development: a series of articles published in *Angewandte Chemie* over the past eight years demonstrate how the discovery of the micromechanical cleavage of graphite layers (in short: adhesive-tape method) has also influenced chemistry: as early as 2008, for example, Klaus Müllen studied the suitability of graphene layers with their remarkable electronic properties for OLEDs and solar cells.[20] Novel core–shell structures for battery materials illustrate the potential applicability of graphene for future energy storage systems (Figure 4). Just recently, this was followed by a review of successful synthetic strategies, as well as the dimensions and areas in which graphene has already been successfully synthesized. Chemically synthesized graphene nanostructures deserve special consideration.[21]

This Journal, therefore, consistently emphasizes the special responsibility of chemical science to solve the challenges of the future. More than 20 years ago, George Whitesides described this situation in *Angewandte Chemie* as a competition between "societal pull" and "research push".[22] The chemistry of the future would simultaneously participate in solving major social problems and generate new ideas through fundamental research. As top-priority social issues, he identified health, environment, safety, energy, and globalization. Today, we are more than ever aware that these challenges cannot be mastered without innovations from chemistry. One need only think of the change in energy policy, the success of which will depend not least on breakthrough innovations in engineering materials. Science's answer to these challenges include materials chemistry, ranging from surfaces through functional and sustainable materials to computer chemistry, as well as fundamental research which—under the watchword "exploring the limits"—is prepared to push itself to its utmost boundaries. The latter doubtless also includes graphene research, which is showing what energies can be released by setting ambitious goals in research and development to deliver the urgently required solutions. It also demonstrates the complexity of modern research. In the case of graphene, both the search for the "miracle material" and the climate of tension between scientific discovery and social expectations of progress have produced an outstanding symbiosis between fundamental research at a Max Planck Institute (MPI) and BASF's process and application knowledge.

From the Key Molecule Ammonia to Raw Material Change—Facing the Challenges of the Future

Chemistry plays a decisive role in deciding how we will address the challenges facing us in the decades ahead.

The need to tackle the greatest scourge of humanity—hunger—prompted one of the most outstanding achievements in the history of chemistry: the Haber–Bosch process. Dunikowska and Turko remind readers of the fear that went around in Europe during the age of industrialization. As had already been predicted by Malthus, the political economist and demographer of the early 19th century, population growth, climate change, and intensive farming were also jeopardizing further development at the turn of the century.[2] In his legendary speech before the British Association for the Advancement of Science, British chemist William Crookes prophesied a famine in the western world: in 20 years the demand for nitrogen would exceed the supply, and the world population could then no longer be fed. Only chemistry could save the day.

All this was the driving force behind science and research, and led to the successful interaction between academic science and the burgeoning industry. The symbiosis between the scientist Haber, who synthesized ammonia at Karlsruhe Technical Institute, and Carl Bosch, who developed the industrial scale process at BASF, resulted in the world's first plant for the synthesis of ammonia in 1913—the anniversary of which we will be celebrating in 2013. This was also done in the knowledge that the military establishment's hunger for the raw material ammonium nitrate, in particular, was paving the way for the further development of the process to its industrial-scale use. The technically highly advanced process now supplies raw materials for applications ranging from fertilizers to pharmaceuticals, dyes, and explosives. The application of fertilizers to arable soil enabled billions of people to be fed and changed the world, as Jörg Albrecht wrote in the German newspaper FAZ in 2008.[23] Half of humanity could not survive without the Haber–Bosch process, was the conclusive comment in *Nature Geoscience*, marking the 100th birthday of the filing of the patent.[24]

In an interview several years ago, Swiss chemist Albert Eschenmoser described science as a "deeply human activity" which ultimately follows human modes of thinking and preferences.[25] Above all, however, he saw it as a continuation of the Enlightenment. The Haber–Bosch process is one outstanding example of this: "*As well as being of high industrial relevance, the catalytic synthesis of ammonia is also a key reaction for creating new life and a prototypical model reaction that helps in gaining a fundamental understanding of catalysis in general and (is) therefore of considerable scientific and cultural importance*", wrote Robert Schlögl in this Journal.[26] Nobel prize winner Gerhard Ertl is to be thanked for precisely this fundamental understanding of the discovery and mechanism of ammonia synthesis: Ertl, through his studies of surface physics and his definition of catalytic reactions as open systems, became the proponent of this technically and scientifically important discipline which—as he himself wrote—"*has long been characterized by its empiricism*".[27] He received the Nobel Prize in 2007 for his complete theoretical elucidation of the reaction and other achievements.

In the future as well, one of the major tasks of chemical research lies in raw material change, which is expected to yield innovative and sustainable contributions to securing supply. We are looking for ways to utilize raw materials more intelligently—with a lower energy input—and for alternatives to existing raw materials. One example is provided by recent research into the material utilization of CO_2, whose potential is currently being evaluated.[28] This is where the catalyst experts come in: because the economical use of CO_2 as a raw material can only be managed through catalysis, the stable, barely reactive molecule has to be made accessible for utilization by using reactive partners and suitable catalysts. In this selective and frugal balancing act lie the classical tasks of catalysis—and at the same time, the great future tasks of chemistry.

Efficient and, therefore, sustainable solutions demand a thorough evaluation of the complete value chain and the overall process. The use of CO_2 will certainly become eco-efficient only with renewable energy. Nevertheless, prematurely disclosed partial results relating to the use of CO_2 are increasingly entering public debate as solutions to the climate problem.

It is often overlooked that the current use of CO_2 as an industrial gas and chemical raw material makes up only one-thousandth of anthropogenic carbon dioxide emissions and can, therefore, only reduce the carbon footprint to a limited extent. Nevertheless, carbon dioxide as a resource is already being used as a raw material in a number of important chemical processes.

One promising approach is a process developed by BASF for the production of formic acid by way of CO_2 hydrogenation; it shows that CO_2, as a cost-effective C_1 building block, can be highly advantageous and demonstrates once more that chemistry is far from running out of ideas.

Among the industrial chemicals, formic acid comes closest to carbon dioxide in energetical terms.[28] Homogeneously catalyzed hydrogenation, however, has so far not found an industrial application because of the absence of efficient recycling concepts for the noble-metal catalysts and its lack of cost effectiveness. It wasn't until BASF researchers developed a multiphase liquid–liquid process concept that it was possible to combine catalyst recycling with the isolation of formic acid in three steps: hydrogenation, catalyst extraction, and product separation. BASF researchers Thomas Schaub and Rocco Paciello published a new method of formic acid synthesis by the hydrogenation of CO_2 in 2011 (Figure 5).[29] In this process, solvents, the amine, and the catalyst have been

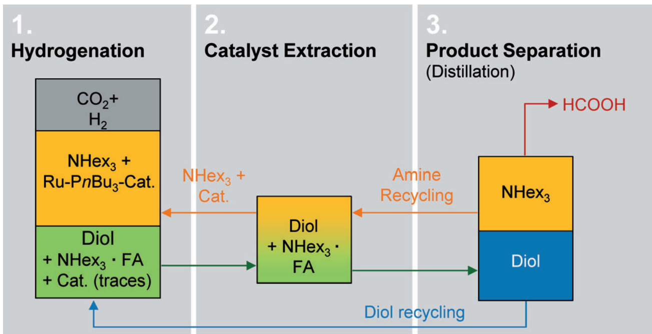

Figure 5. Process concept for the synthesis of formic acid by hydrogenation of CO_2.[29] FA = formic acid.

optimally matched to each other in terms of their material properties and phase behavior. Detailed investigations of the mechanism and thermodynamics were performed and published. While the process is currently being trialed in pilot plants, the publication has already resulted in further scientific contacts being established. The search for more-efficient catalysts is also continuing. Work is also in progress on applying the reaction principle to structurally related molecules.

In the field of raw material change, BASF is also intensively pursuing academic research in this area: together with the excellence cluster "Unifying Concepts in Catalysis" (UniCat), a joint laboratory for new catalytic processes for raw material change was inaugurated in 2011 to drive forward the search for alternatives to crude oil, especially the use of natural gas. The long-term goal is to achieve supply security with raw materials for the manufacture of chemical products. An international team of scientists has already been busy in the Catalysis Research Laboratory (CaRLa) since 2006, moving forward the "Industry on Campus" initiative, which was launched by Heidelberg University and BASF to find new homogeneous catalysts. In 2012, CaRLA reported the first catalytic synthesis of acrylate from CO_2 and ethylene, an important signal and possible contribution to added value for the production of acrylic acid or acrylate based on novel raw materials.[30]

Promoting Interdisciplinary Thinking and Action—A Core Interest of Angewandte Chemie

Historical and recent examples ranging from the Haber–Bosch process to our latest joint project, the Carbon Materials Innovation Center (CMIC), show that only research-driven industrial companies are successful in the long term. This first requires an outstanding partner in science, which also and especially includes the science publishing houses, as well as the willingness to commit to being a full member of the scientific community, not least by producing publications.

High-quality scientific articles, with their interdisciplinary impact, have been and continue to be important agents of change at all times: they set innovation processes in motion by balancing scientific knowledge against the needs of society—provided that, considering the proliferation of scientific literature since the mid-19th century, we have mastered the techniques of information processing. "*Science does not advance by piling up information—it organizes information and compresses it*", wrote social scientist Herbert Simon as long ago as 1947.[31] For innovation researchers, the processing and application of information and knowledge are, therefore, among the basic instruments of all research.[1] Yet, not only the strategic handling of knowledge, but also the capability for differentiation and selection have always been outstanding characteristics of *Angewandte Chemie*. Formulating answers to these needs by drawing on the resources of chemical science is a guiding principle of this Journal.

This is why the history of BASF is also reflected in *Angewandte Chemie*: among the numerous authors who have published articles on industrially relevant research topics in 125 years are names such as Walter Reppe—the father of acetylene chemistry—and Rudolf Knietsch (chlorine liquefaction). It is not only the scientific articles that should be mentioned; equally worth reading are the reprints of records of association meetings—scrupulously recording, for example, the disputes between Carl Duisberg and Heinrich Caro about the properties of dyes.[32] It is a journal's task to give "*expression to the close association between science and technology and providing experts working in daily practice with a digest of the multifaceted activities in all fields*", wrote the then-President of the Society of German Chemists, Karl Winnacker, in 1963 to mark the 75th anniversary. This task is more than fulfilled by this Journal.[33]

As a company increasingly conducting research on a global scale, we are also aware of the challenge represented by publishing a bilingual edition of *Angewandte Chemie*—and the high level of effort required for such a scientific language biotope. In 2005, François Diederich emphasized the important contribution being made to maintaining and further developing the German language in chemical research and teaching, particularly with a view to fostering the rising generation of scientists in secondary schools: "*This influence of the German Edition, and in particular of the reviews, is not only of importance for the academic and industrial world, but also helps make it possible to teach modern chemistry in German at high schools and other educational establishments.*"[34] We thus grant access to scientific literature and, in the long term, to our research topics.

It has only been possible to briefly quote a few examples of our shared history in this Essay. They testify to the fundamental paradigm shift from molecular to systems research which our sector is currently experiencing: in materials research on graphenes to battery materials, and also in catalysis. While chemistry is contributing on a broad basis to the fundamentals of technology, *Angewandte Chemie* itself is contributing to the foundations of chemistry—it is "the bridge between the islands of knowledge".[35]

In this sense, change has tradition. "Will journal publishers perish?" asked the Economist anxiously at the beginning of this century in the face of the triumphal march of online publishing and the Open Source Initiative.[36] The economic journal then answered its own question: "*No, because science could not function without the vetting and endorsement of results they provide*". It is a special art to maintain and further develop these key tasks while simultaneously taking media innovations on board with an open mind. *Angewandte Chemie* has long been tweeting in the social media world and has recently also become a convenient read on the iPad. Thus equipped, *Angewandte Chemie* will continue to reliably mentor its authors and readers. I wish you a continued supply of creative ideas combined with an unerring instinct for the future concerns of a unique science.

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