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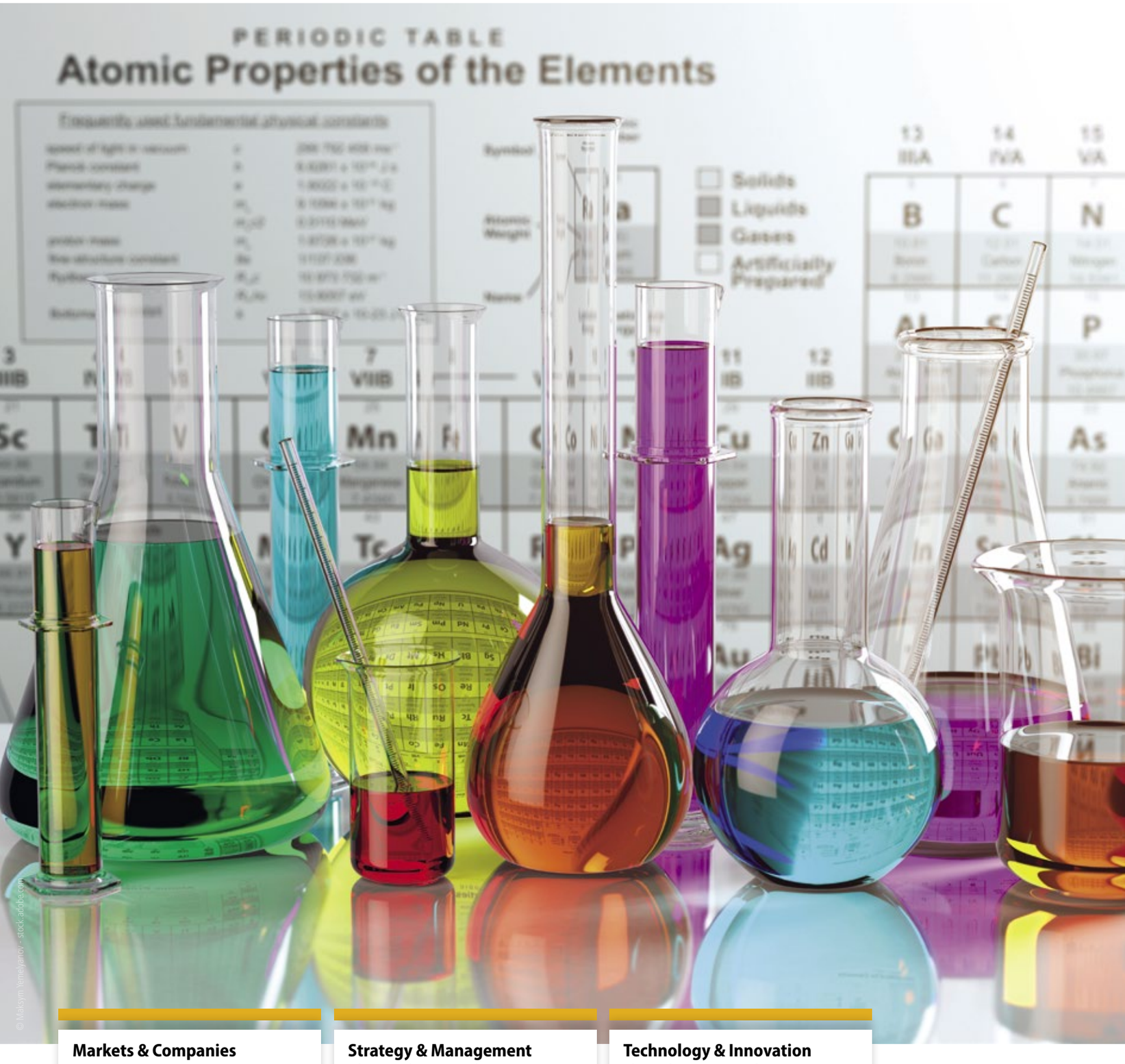

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M&A: Asian Investment in European Chemical Companies, Global Biologics CDMO Market, Company News

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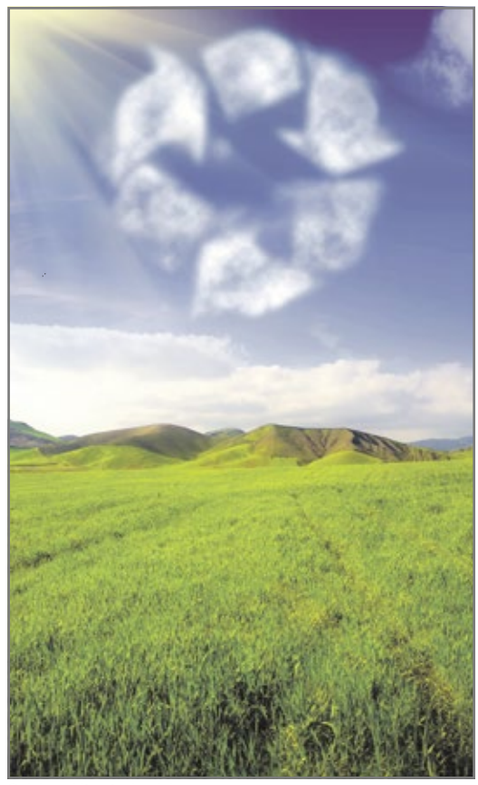

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Technology & Innovation

Cover Page

Periodic Table of Chemical Elements turns 150

The Periodic Table of Elements is one of the most significant achievements in science. 150 years ago, Russian chemist and inventor Dmitri Ivanovich Mendeleev created his farsighted version of the periodic table. He used it to correct the properties of some already discovered elements and to predict the properties of eight elements yet to be discovered.

The year 2019 marks the celebration of the 150th anniversary of the periodic table. On the occasion of this anniversary, 2019 has been designated by UNESCO as the International Year of the Periodic Table (IYPT 2019).

The discovery of the "periodic law" by Mendeleev and the creation of the tabular display of the chemical elements in order of increasing atomic number has since been of inestimable value in the development of chemistry. Naming them all would go beyond the scope of this note.

Qi-Feng Zhou, IUPAC president, calls the periodic table "a map of our knowledge, particularly in chemistry, and a symbolic representation of the process of scientific research."

ChemPubSoc Europe, a partnership of 16 continental European chemical societies, and ChemistryViews.org are highlighting the 150th anniversary of the 150th anniversary of the periodic table to raise global awareness of chemistry and show creative ideas on this topic. The cover page of this edition of CHEManager International shows the periodic table to recognize its importance for generations of chemical researchers. Without Mendeleev's invention 150 years ago, science would have taken a different route or at least a detour and many discoveries that have led to innovation and progress would probably have never been made. (mr)

Asian Interest in European Chemical Firms

Chemical M&A Buoyant after a Record Year in Asia

The chemical industry is one of the most international sectors with activity dominated by cross border transactions. Chinese and other Asian firms have been particularly busy expanding their global footprint and taking advantage of the quality assets for sale.

Worldwide, geopolitical tensions and slowing global economic growth took its toll in terms of the number of deals, according to Mergermarket data for fiscal year (FY) 2018. However, deal volumes jumped 11.5% to $3.53 trillion in 2018 compared to the prior year while more specifically the Asia-Pacific (excl. Japan) M&A region recorded 4,036 deals totaling $717.4 billion, a 2.6% hike over 2017.

Overall, the industrials and chemicals sector was the most attractive sector in 2018 by both value and volume. The final tally was 318 deals priced at $68 billion, compared to $82 billion across 321 deals in 2017.

China continued to be an active participant although the ongoing trade wars with the US caused a dramatic shift in deal flow. Europe became the preferred destination with Chinese acquisitions in the region surging 81.7% to $60.4 billion from $33.2 billion in 2017. Dealmaking slowed down in the fourth quarter, but the first nine months saw 23 transactions of which, for example, ten in the consumer or a respective seven in the business services and energy, mining and utilities sectors. By contrast, transactions in the US plummeted 94.6% to $3 billion last year from a record $55.3 billion in 2016, according to Mergermarket figures.

> *"Chinese and other Asian firms have been particularly busy expanding their global footprint and taking advantage of the quality assets for sale."*

The motives behind European transactions are the same as those driving other global purchases — to close the gap through acquiring technological prowess as well as expertise, proprietary formulations and products. One example is the roughly €200 million sale of European engineering plastics specialist Elix Polymers by Sun European Partners to Beijing-based Sinochem. The deal supports the ABS Compound producer's strategy to expand its activities in Asia, a region in which it is currently underrepresented. At the same time, it will boost Sinochem's presence in the plastics industry beyond chemicals trading and fertilizer production.

Bernd Schneider, Alantra

Growing Investment Interest in Sustainable Industries

It has been well documented that the Chinese economy is slowing to 6% growth from an originally forecasted 6.5%, but growth is still relatively robust compared to the low single growth figures of many developed countries. Chinese companies will continue to look for opportunities

in traditional chemical segments, but they are also interested in buying organizations involved in pollution, water and waste treatment solutions as well as green and sustainable chemicals and plastics.

This is being driven by the government's new environmentally-friendly laws under the 12th Five-Year Plan which aims to clamp down on unsustainable industries and incentivize clean and green energy businesses.

Chinese Government Influence

While the flow of deals has mainly been from China to the West, the tide has not been just one way: Global conglomerates are divesting Chinese operations as well. As always, high quality assets are constantly in demand, such as the Hovione/Imax deal. But tighter government regulations have increased costs for companies and spurred divestment discussions.

The Chinese government has clearly stated it intends to standardize chemical parks along the lines of global industry best practice. Currently, only about half of the chemical production plants in China are in dedicated chemical parks, but this proportion is expected to increase drastically by 2020, with some provinces having set targets of 90% or more. Western companies, especially those who do not obtain a permit to increase capacity, are increasingly exploring all options for their assets instead of moving to one of the new parks.

The domestic industry is also set for a further bout of consolidations. Last year already saw Chinese **chemical** product manufacturers Yantai Wanhua and Wanhua Chemical joining forces in a $12.7 billion tie-up, but anticipation is running high for the merger between Sinochem and its rival Chemchina, which completed China's largest outbound deal a year ago with the $44 billion takeover of Swiss agribusiness Syngenta, a deal in which Alantra was involved. The transaction, which would produce an oil-to-chemicals giant with more than $100 billion in assets, has been in the works for at least two years and would eclipse Germany's BASF, the world's largest maker of industrial chemicals, by sales.

If completed as anticipated, the deal is expected to significantly change the landscape of China's chemicals industry. It is likely to trigger a wave of restructuring resulting in new strategic plans and the hiving off of subsidiaries. Specialists and niche companies would be particularly attractive not only due to their sharper competitive edge and technological expertise but also lower valuations on the back of a weaker stock market. Medium-sized companies in the US and Europe such as the German Mittelstand would be especially interested in them because many missed out on getting a foothold in the Chinese market due to increasing prices during the first wave of M&A activity.

Bernd Schneider, managing director and global head of Chemicals, Alantra, Frankfurt am Main, Germany

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The Missing Piece

Chemicals in Circular Economy

The concept of circular economy has long been a staple in the vocabulary of anyone who wants to come across as at least somewhat progressive. Today, circular economy is more than just a buzzword. One crucial, but often overlooked part of a circular economy is the role of chemicals. While considerable efforts are being made to reduce pollution and depletion of the earth's resources by simply increasing recycling, little attention is paid to the contents of the old products that we turn into new ones.

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The truth is that today's chemicals legislations are not adapted for a sustainable circular economy, as many hazardous chemicals are unregulated and in widespread use. These chemicals fulfill thousands of different functions in all kinds of everyday household items. And as these items are the very same we recycle and turn into new products in a circular world, it also means we are recycling their toxic contents.

Luckily, a growing number of brands and retailers are realizing that, at the moment, legal compliance is neither a good benchmark for corporate chemicals management nor for a circular economy. In order to account for weak legislation and stay away from toxic chemicals in products and supply chains, many companies have internal chemical requirements that go beyond legal compliance.

Circular Economy as Business Opportunity

In our society, the prices of raw materials and trash collection are increasing because of physical limitations. The resources available in the earth's crust are simply shrinking. The "take, make, waste" paradigm within the linear economy has led us to a critical point that also affects business, through higher commodity prices and higher volatility. This will lower margins and profitability for companies and increase consumer prices in the long run.

The idea of a circular economy is to manufacture components, articles and products that can be perpetually disassembled and re-used, thus creating a no-waste society and minimizing the strain on natural resources. To simply use and discard is no longer a viable option. To achieve this change, however, both businesses and society need to re-think the way we make profits and design products.

In business, sustainability is sometimes seen as a necessary but nevertheless burdensome cost — not something that actually strengthens the business idea and profitability. In a sound circular economy, companies prosper due to environmental success, not despite it. There is a need for a change in the business mindset, so that company interests, societal needs and environmental challenges are merged into one business idea.

"In a sound circular economy, companies prosper due to environmental success, not despite it."

Anne-Sofie Bäckar, ChemSec

Since hazardous chemicals are common ingredients in all kinds of materials they obviously end up in recycled materials as well. This fact makes it virtually impossible to grow the market for recycled materials — the material transparency is simply too low for chemically progressive brands to want to reuse these materials in new products.

The way forward is increased transparency on the chemical contents of all materials. This information should follow materials all the way to the waste phase. Used properly it will raise the price of recycled materials. The end goal is to eliminate hazardous chemicals from waste streams through design and innovation, not dilution and costly risk analyses.

The use of recycled material can only be profitable in the long run for a company if it fulfills the same criteria as virgin material.

Product Planning and Design

A smart design is the most critical stage in a product's life cycle. The most cost-effective approach is to select the appropriate materials and chemicals right at the drawing board, before the product even exists. By doing this, toxic waste can simply be "designed out" and instead replaced by resources and products that can be utilized by somebody else.

The greatest obstacles to successful recycling are actually the original design and lack of information about what chemicals were added to the materials from the very beginning. By

demonstrating knowledge and transparency you add value to the product. Products and materials that are designed to be recoverable, reconditioned and upgraded have around twice the value of products and materials that are not, as they can be sold several times.

By decreasing the hazardous content of a product, you increase the possibilities for recycling and success in the aftermarket. You also reduce the need for virgin raw materials and the energy costs to produce them.

The novel idea that the circular economy presents is that good design is not only environmentally and morally good; it's also more profitable.

As a consequence, chemicals management should have a higher priority on the corporate agenda. Depending on company goals, chemical issues can be prioritized at different levels. At the lowest, so-called reactive level you simply follow regulations and adapt on the fly. By contrast, at the highest and most ambitious level you actively seek out green chemistry and sustainable materials that position the organization for the circular economy.

Supply Chain Management, Transparency and Traceability

Since a product consists of components that are produced and assembled by many different suppliers in the supply chain, it is impossible to communicate the chemical content down the supply chain without proper information from the previous suppliers.

The need for systematic chemical control up and down the supply chain is already a priority for many companies. Unsurprisingly this need will only grow in the future as recycled materials are being circulated back into the production loop.

There are mainly two activities that are needed in order to approach the circular economy from a chemical point of view:

- increase knowledge of the composition of products, and
- phase out chemicals that do not fit within a circular economy.

Some industries have already created effective systems for transferring information between suppliers and users in the supply chain. The IMDS and BOM-check databases are already used in the automotive industry and the electronic industry respectively, and relevant parts may be accessed by everyone in the entire supply chain.

Systems like this can be used to include extensive chemical information. The barcode system is another such example. It is technically very easy to include chemical information in a system like this; all you need is the information. The challenge lies in implementation and standardization.

This change is happening already, as many brands with big purchasing power are pushing for more and more chemical transparency in the supply chain. By putting pressure on suppliers to increase chemical transparency and use safer alternatives, these companies serve as role models and pave the way for other, smaller companies to follow suit.

Legal Compliance Is Not Enough

Just as hazardous man-made chemicals are complex and wide reaching, so is the legislation set up to regulate them.

The EU has enforced REACh (Registration, Evaluation, Authorization and Restriction of Chemicals), a comprehensive legal framework that addresses all chemicals in use and requires companies that market chemicals to present a set of test data. The US equivalent, TSCA (Toxic Substances Control Act), set some basic requirements but is much more limited in scope. In many other parts of the world there are other regulations in place to address chemicals, some aiming to be similar to REACh or TSCA. There are also many product-specific regulations in the EU and in other regions for controlling hazardous substances in products such as electronics.

But legal compliance does not guarantee automatic success in the circular market. In fact, this is far from the truth. Even in the EU, which in many ways has the most ambitious chemical regulation in place, substances with hazardous properties are still in widespread use. This is because regulation moves slowly, and it will take many years before REACh includes all the substances it intends to regulate. In addition, REACh does not fully cover the chemical content in articles that are imported into the EU.

The regulatory system for chemical control is therefore not a reliable guide for sustainable business or for identifying which substances are compatible with a circular economy. This is why chemically progressive companies are setting the bar higher than legislation and enforcing their own chemical requirements for products and supply chains. The number of such companies with their own chemical standards is increasing, and today represents sizeable chunks of their respective industries.

Reuse and Recycling

Many waste streams contain hazardous substances and should not be recycled without a prior decontamination step.

In current business models, recycled materials struggle to be competitive with primary raw materials markets. This is often due to the fact that recyclers cannot deliver the level of material transparency that many brands are asking for. Recycling markets can only be sustainable if they can assure that recycled materials do not contain toxic substances. Willingness to support the development of non-toxic material cycles will thus not only protect health and the environment but will also enhance the quality of secondary raw materials and boost recycling markets.

Legally, in order to incentivize high-quality recycling, there is a need to avoid creating a two-tier system between virgin and raw materials, or between products and articles imported from the EU and those imported from elsewhere.

Recycling should never be viewed as a low-cost solution. It might sound contradictory, but setting identical, strict rules for recycled materials will help them compete with virgin materials.

It is a fact that regulation drives innovation, and recycling is no exception. Putting the appropriate legislation in place is not a burden, it will provide clarity and is essential to establish a circular economy.

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A Better Way to Use Resources

At Nouryon, Circular Projects Are Linked to Improving the Existing Value Chain

Availability and supply of essential resources for chemical production are getting increasingly challenging. At the same time, mankind has developed a throwaway mentality that is producing billions of tons of waste — waste that contains valuable resources in the form of, for instance, biomass, plastics or scarce metals. All this calls for a circular economy. As many other chemical companies, Nouryon is looking for ways to create a more sustainable future through chemistry. Interviewed by Michael Reubold of CHEManager, Marco Waas, Director RD&I and Technology at Nouryon, discusses the concept of circular economy and describes projects that contribute to a more efficient use of resources and a better use of secondary raw materials from waste.

CHEManager: Mr. Waas, Nouryon has embraced the circular economy in its sustainability agenda. How do you implement this concept into the corporate strategy?

Marco Waas: Sustainability has to be an embedded strategy, not a separate program. For example, our chlor-alkali and chlorate businesses are very energy intensive and our efforts in energy efficiency and renewable energy are therefore key to securing a reliable energy supply in the long term. Our circular projects are all linked to improving our existing value chain by looking at a better way to use resources. Ultimately, sustainability is business and business is sustainability.

What are the most interesting projects currently under way to improve your resource & energy efficiency?

M. Waas: One project I like a lot is Waste-to-Chemicals. This is based on a technology from Enerkem to make methanol from household waste that we cannot otherwise recycle. This is the type of technology that can really change the entire supply chain in the coming years. After 20 years, the technology is mature enough to scale up to factory size. With several partners we are planning a plant in Rotterdam that will be able to convert 360,000 tons of waste per year into 209,000 tons of methanol for the chemical industry.

In a another, much-respected project, Nouryon is partnering with Tata Steel and the Port of Amsterdam to study the feasibility of a "green" hydrogen cluster in the Amsterdam region. What potential do you consider green hydrogen to have for building and contributing to a circular economy?

M. Waas: Green hydrogen is really the game changer for circular chemistry. Our industry still gets a lot of its raw materials from hydrocarbons such as gas or oil. You can also get the carbon from other sources, such as waste or CO and CO_2 emissions from steel factories, but for optimal use you need to add hydrogen. So, this is where we come in. For example, Tata Steel can use our green hydrogen, produced from water and renewable electricity, to turn their waste gases into useful chemicals. With green hydrogen, waste carbon becomes a valuable raw material instead of a wasteful emission to the atmosphere.

Marco Waas, Nouryon

You are building a demonstration plant to produce chemical building blocks from carbon dioxide and sunlight at Delfzijl, the Netherlands, with partner firm Photanol. Do you

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expect such processes to eventually solve the climate problem caused by CO_2 emissions?

M. Waas: This technology will contribute, by using CO_2 as a raw material — effectively turning chemical production into a carbon sink instead of a carbon emitter. But one technology will not solve climate change. We need to work together on all fronts and really go for a joint transformation of our petrochemical and heavy industries.

You are actively participating in the trend of collaborative and open innovation by partnering with other companies as well as academia and research organizations. How does, for instance, Nouryon's Imagine Chemistry initiative contribute to developing more sustainable chemical platforms for your customers?

M. Waas: Imagine Chemistry helps us become a more reliable and valuable partner to our customers by bringing in outside innovations. For example, we are working with a start-up, Semiotic Labs, to use predictive algorithms at our factories so we know when to replace or repair critical equipment. By bringing in this knowledge from outside the chemical industry, we can reduce downtime and improve the reliability of our plants, which is a huge asset to our customers.

Another example is our partnership with Holiferm, one of the winners of the Imagine Chemistry challenge in 2017. They have a new process to improve fermentation processes to make surfactants from bio-based sources. We have helped them on the road from a lab setting to a real start-up. Our Collaborative investment fund, ICOS III, has recently announced an investment in Holiferm. We do this with the aim of ultimately making better and cheaper bio-surfactants available to our customers.

> „Sustainability has to be an embedded strategy, not a separate program."

Collaboration across CO_2-intensive industries is also a major trend in the aim to battle climate change. Nouryon, together with partners from research and industry, is participating in the publicly funded Carbon2Chem project coordinated by German steel producer Thyssenkrupp. What is Nouryon's contribution and intention here?

M. Waas: This is another example of using CO and CO_2 with green hydrogen to make methanol and other chemicals. Nouryon is contributing technical and operational expertise in water electrolysis and the conversion of syngas to methanol.

Which guidelines do you apply to allocate R&D budget to a circular economy project and evaluate the progress?

M. Waas: We start by looking at the strategic fit with our business and assessing the return on investment, both short and long-term. On bigger projects with a longer horizon we often work with partners to increase the chances of project success and decrease risk. When you look at the entire value chain of the project, from raw material to end product, there are often a lot of hidden opportunities, which is another reason to pursue these projects in partnerships.

After the split from AkzoNobel, Nouryon is private-equity-owned and under scrutiny of the investors. How — and when — will the circular economy projects pay of in terms of financial success?

M. Waas: There are a number of technologies coming to maturity that can contribute in the coming years. The Waste-to-Chemicals plant in Rotterdam can be operational in three years' time for example. Production of green hydrogen is another example. This is based on electrolysis technology and we already operate several large-scale electrolysis facilities to produce chlor-alkali. I therefore see no large technical obstacles for the deployment of water electrolysis for hydrogen production. I cannot predict market prices, but in the current socio-economic climate I think the transition of the industry can also be a major opportunity for long-term growth.

> "The chemical industry is now entering an entirely new growth cycle based on circular chemistry."

The term "do more with less" implements that we will need less materials to produce the same — or better — products in the future. How will the current volume-based business model of the chemical industry have to change in order to "earn more with less"?

M. Waas: I think the chemical industry is now entering an entirely new growth cycle based on circular chemistry. In the 1960's, we were focused on investing in new materials, such as plastics. Then it was all about mass production and making product affordable for a growing world population. The next wave of innovation will be focused on circular chemistry, to make affordable products for the world population in a sustainable way.

Several projects lead to savings in energy costs, but others are adding extra costs to products. At the end of the day, you will have to ask your customers to remunerate you for your investments in more sustainable and efficient products. How do you rate their readiness to do so?

M. Waas: Our customers are looking for a reliable partner to supply them with essential chemicals, and our innovations are supporting this. When it comes to pricing, European society is increasingly seeing carbon emissions as a cost, which is reflected in energy and carbon prices. Energy efficiency projects are making us more cost effective, not less. The same will apply to circular chemistry in the long run. Many technologies are only now scaling up — imagine what it would mean when we make our products from wind, water and waste.

www.nouryon.com

Imagine Chemistry 2019 Generates 162 Ideas

Imagine Chemistry, the collaborative innovation challenge of Nouryon (formerly AkzoNobel Specialty Chemicals) now in its third year, was launched to tackle chemistry-related challenges and uncover new ways to create value for customers. For this year's edition, more than 160 innovative ideas from 30 countries were submitted by start-ups, scale-ups, university spin-outs, and other potential partners.

Nouryon will select up to 20 finalists to attend an intensive three-day event in May at its RD&I center at Deventer, the Netherlands, where they will work with company experts and business leaders to further develop their ideas into a joint value case.

The 2019 edition of Imagine Chemistry set challenges in the areas: sustainable bio-based surfactants (in partnership with Unilever), performance-boosting nanoparticles, sensing in demanding chemical environments, label-free chemistries, and pushing the frontiers of chemical innovation.

The challenge is a key part of Nouryon's even greater focus on innovation the company's Chief Technology Officer, Peter Nieuwenhuizen, said. "We believe in the power of innovation and collaboration to drive growth and create sustainable solutions for our customers. Our Imagine Chemistry program helps bring innovative solutions to the next level and helps us better meet our customers' needs."

This year's edition of Imagine Chemistry is supported by Unilever, China Petroleum and Chemical Industry Federation (CPCIF), seed investor High-Tech Gründerfonds, venture capital firm Icos Capital, research and advisory firm Lux Research, multi-stakeholder collaboration Green Chemistry & Commerce Council, UK innovation agency Knowledge Transfer Network, Brazilian content portal Startupi, Dutch accelerator StartupDelta, the European Commission's Enterprise Europe Network, and S/park, the chemical technology-focused open innovation center located at Nouryon's RD&I site in Deventer. (mr)

Solving Challenges at Interfaces

Surfactants are used in a Variety of Applications from Detergents to Crop Protection to Oil & Gas

Surfactants are used in a wide spectrum of applications. This broad range of use, among other things, will be at the center of interest of the 11th World Surfactants Congress to be held in Munich in early June 2019. Staffan Asplund, president of CESIO, the European Committee of Organic Surfactants and their Intermediates, and Surfactants R&D Director at Nouryon, provides a status report on the surfactants business and technology.


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More than 50% of the surfactants which are sold in the EU are used for household detergents, by far the largest application in terms of volume and total market value. We assume that approximately 10% are used for personal care as well as for textile finishing. Another 5% are I&I application — so we can say that three quarters of the total volume are sold to four fields of applications. The remaining 25% are used in many specific applications, e.g. crop protection, leather and paper manufacturing, oilfield or the construction industry. In terms of sales value, the picture is quite similar, though specialized performance products tailored to specific applications will trade at a higher unit value.

A Mature Business with Modest Volume Growth

What we can derive from the published production figures of our industry, the overall market situation for surfactants in Europe is stable, with limited growth in specific areas. This situation has been consistent over the past few years. But if we look into the different surfactant groups and applications, there is a general trend from commodities to specialty surfactants, which makes it even more important to develop surfactant systems that are specifically focused on the customers' needs.

Staffan Asplund, president, CESIO Executive Committee

Whether there is a recession or a peak in our business trends, the consumers still need food, do their laundry, wash the dishes, use personal care products and wear textiles. They may spend more money in a booming situation and buy less or cheaper products in a downturn, but we can say that the overall surfactant market in Europe is a mature business with modest volume growth.

New capacity has come on stream but the trend from commodities to specialties has led to more complex chemistries requiring more processing time, which has compensated the growth and stabilized the total output of surfactants on a high level.

Nevertheless, our growth expectations are "restrained positive" — in the past we have discovered new applications for existing surfactants and industry continues to innovate in this way. We develop new business models that are not necessarily based on growing volumes, but on higher effectiveness of the surfactant systems.

Performance — Solution — Success — Surfactants

The congress theme of CESIO 2019 is „performance — solution — success — surfactants". Surfactants in solutions and at interfaces — scientifically just fascinating! But surfactant science is not an end in itself — surfactants are the basis to solve challenges involving all kinds of interfaces and applications. Surfactants are the key to providing successful solutions for consumers, e.g. related to cosmetics or household applications, or for professional uses such as I&I or agrochemicals and many others. This is because surfactants, are fundamental to achieving the desired product performance. And just as surfactants work across interfaces, so innovation happens at interfaces, not only between the science and application, but also between different disciplines and applications. That is why it is crucial to meet and communicate across bor-

"Just as surfactants work across interfaces, so innovation happens at interfaces."

ders! The CESIO 2019 congress wants to demonstrate that there is an ongoing process in our industry to better understand the application conditions of the future surfactant value chain.

Challenges Open Up New Opportunities

The more complex the product formulation, the more surfactants are needed as key ingredients that help to combine substances, which otherwise would be incompatible or adversely affect the components' value. In the field of household detergents, our customers have been quite successful in substituting chemicals in their formulations by enzymes. Many producers of surfactants have started to test and develop systems that contain surfactants together with enzymes. In other applications, customers are looking for processes and formulations that are more energy-efficient and need less resources overall, like crop protection requiring less active ingredients to achieve the same result or recycling road surfaces to save on energy and natural resources. These challenges demand better insight into the interaction of surfactants and other ingredients, and this in turn opens up new opportunities.

Hot Topics in Surfactants Innovation

There is a multitude of drivers of surfactant innovation as surfactants are used in many applications, each with their own specific drivers. Trying to generalize a bit, there are a few clear trends: eco-friendly solutions and bio-based products is an important trend although surfactants have been made from bio-based raw materials for many years. Related drivers are sharper regulations and voluntary certifications like eco-labels, providing clarity and confidence to downstream users in a variety of markets, including cleaning, personal care, asphalt and agrochemicals. Also important are solutions that allow users to use less resources, be it material or energy. Examples include low-temperature cleaning, laundry technology with reduced water use and more energy-efficient industrial processes. To capitalize on these trends, surfactant suppliers will need a thorough understanding of their target applications as well as the ability to innovate in collaboration with customers and technology providers.

Talking about the hot topics in surfactants R&D, an important overriding theme is the deeper understanding of complex mixtures of surfactants and other components like polymers, enzymes and small particles. These advanced formulations are scientifically fascinating and offer exciting business opportunities. Biosurfactants are already mentioned as an important area where there is a lot of activity both on the products themselves and on biochemical production routes.

Maybe the next innovation leap will not be a new class of surfactants or even chemicals, but rather come in the way we develop and manufacture our products. Think of the lightning-fast development we now see in fields like artificial intelligence and computing power. We are at the verge of a

Continued Page 12 ▶

revolution, which is likely to transform every field of industry, including chemicals, and of course surfactants.

Sustainability is More than a Buzz Word

Sustainability is critically important to the whole industry. Until now the surfactant industry has mainly focused on the ecological aspect, we use renewable raw materials, develop more biodegradable products etc. Sustainability has two other important pillars though, and it is becoming more and more clear that the challenges we are facing involve all three pillars; ecological, social and economic aspects.

If we look at raw material sourcing it is obvious to strive for renewable sources but this only works if the supply chain of the needed biomaterials come with sustainable social and economic conditions. A clear example is oils & fats; while surfactant production is a relatively small use compared to food or bio-fuels it is still critically important for our industry to establish a sustainable supply chain of natural oils like palm, coco and soy.

If we look at the product side the public debate, or "buzz" probably has most direct impact on value chains ending up in private consumption like home- and personal care although industrial users are also looking for sustainable solutions. A key here is communication along the value chain. Many consumers are increasingly looking at the origin of products, requiring transparency from suppliers and development of reliable and manageable certification standards for e.g. fair trade and eco-labels.

Natural raw materials are already used, and their importance will increase further. As just discussed though, "bio-based" is not sufficient to make a raw material source sustainable. Scientists, regulators and industry stakeholders are trying to determine what is truly sustainable — clearly a challenging situation.

Having said that, new raw materials bring a lot of new opportunities and it is not just about oils and fats. The emerging bio-economy is providing building blocks with new functionality and a different pricing logic than traditional chemicals. We also see new synthesis opportunities and altogether this opens paths to novel surfactants with unique properties.

"We develop new business models that are not necessarily based on growing volumes, but on higher effectiveness and quality."

Surfactants are fascinating materials with their affinity to interfaces, tendency to form aggregates and interaction with other ingredients. This also means that they are challenging to handle and "standard testing" for regulatory purposes can even be misleading. An important aspect of our industry organization, CESIO, is to provide knowledge and ensure that regulations are developed based on facts, science and correct testing.

Staffan Asplund, RD&I director Surface Chemistry, Nouryon, Stenungsund, Sweden; president, CESIO Executive Committee

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The R&D Footprint of the Chemical Industry

Chemical R&D Spending Generates Long-Term Benefits for Society at Large

A new ICCA report based on a study by Oxford Economics acknowledges the chemical industry as a crucial contributor to the world's Gross Domestic Product (GDP).

According to the report titled "The Global Chemical Industry: Catalyzing Growth and Addressing Our World's Sustainability Challenges" the sector is making an estimated $5.7 trillion contribution to the global GDP through direct, indirect and induced impacts, equivalent to 7% of the world's GDP, and supporting 120 million jobs worldwide.

Directly, the chemical industry added $1.1 trillion to world GDP and employed 15 million people, making it the fifth-largest global manufacturing sector. For every dollar generated by the chemical industry, a further 4.20 dollars is generated elsewhere in the global economy. Companies in the chemical industry spent an estimated $3 trillion with their suppliers in 2017, buying goods and services used in the manufacture of their products. This supply chain spending contributed an estimated $2.6 trillion to global GDP and supported 60 million jobs.

In addition, in 2017 the global chemical industry invested an estimated $51 billion in Research & Development (R&D), supporting 1.7 million jobs and $92 billion in economic activity. China was home to the largest chemical R&D spend, with an investment of $14.6 billion, followed by the US and Japan, with a $12.1 and a $6.9 billion investment, respectively.

Oxford Economics calculates that this R&D spending supported 1.7 million jobs and $92 billion in economic activity. Furthermore, the innovations that emerge from such R&D activity invariably offer "spillover" benefits that spread far wider than the chemical sector itself, raising productivity levels across the global economy. The chemical industry's innovation and R&D activities often lead to the development of new products and processes.

R&D spending generates long-term benefits for society at large. The chemical sector's research boosts the global economy through the development of new technology, processes, and products that enhance efficiency and productivity, and can have wider social benefits. While the industry's R&D efforts are obviously aimed at commercialization of research results, societal benefits by far outweigh the private financial returns from innovation. (mr)

The Need for Innovation in Pharmaceutical Manufacturing

Single-Use Technologies and IIoT Solutions in Biopharmaceuticals Manufacturing

The global pharmaceutical industry is evolving with the rising need for novel therapies in the changing disease landscape. As a result of rising prevalence of chronic infectious diseases as well as growing cancer incidence, market needs are shifting from traditional small molecules (chemicals) to large molecules (biologics). The five big themes that are currently being observed in the bio-pharma manufacturing market are highlighted in figure 1.

However, biopharmaceutical processing involves unique complexities in the overall process such as long running batches, batch automation and product quality which cannot be measured in real-time. To address the issues related to biopharma manufacturing, companies opt for different types of manufacturing techniques to avoid batch contamination and in turn maintain product quality, leading to the adaptive manufacturing of biopharmaceuticals.

Single use and modular technology along with a continuous processing approach is not only modernizing the industry but also minimizing the risks associated with making changes to the existing system. Single use bioreactors are being widely used in upstream biopharmaceutical manufacturing processes. Disposable technologies for downstream processes are making rapid advances, e.g. disposable, pre-packed chromatography columns. These provide seamless and scalable implementation to upstream and downstream operations in biopharmaceutical manufacturing.

Disposable production methods are generally used for lower volume manufacturing for clinical and commercial requirements. The disposable technology does not involve processes such as cleaning and sterilization of the bioreactor and hence saves time and reduces stress on the manufacturing staff. The capital expenditure is much lower compared to stainless steel bioreactor technologies but involves higher variable costs due to the need for replacement of disposable components. Key products consist of single use mixers, bag assemblers, disposable aseptic connectors, pre-packed chromatography columns etc.

The single use/disposable bioreactors enable multi-product flexible manufacturing, easy transfer of operations, fast changeover, busy facilities and lean operations. Therefore, we are witnessing a shift to flexible, small-volume manufacturing comprising of single-use systems with bio-analytical capabilities, and exploring continuous processing technologies in modular facilities.

Decentralized Manufacturing

About 40% of the total growth in the pharma market will be attributed to oncology, cell and gene therapy, rare diseases, and neurosciences. Two multibillion-dollar biotechnology deals have already been announced in the new year resulting in the busy start to global deal making. Namely, Eli Lilly agreed to buy Loxo Oncology for about $8 billion and Bristol-Myers Squibb's $74 billion takeover of Celgene. In early 2018, Celgene had bought Juno for a record $9 billion to boost their cancer pipeline and compete in the adoptive T-Cell (CAR-T) market with both Novartis and Gilead. In addition, there are over 400 cell and gene therapies (C&GT) in preclinical to phase III development, and approximately 1,700 clinical studies are underway globally.

Despite the large market opportunity, issues with product variability and a deficit in large-scale C&G therapy manufacturing capability ramain, with reported waiting time of 1.25 years before the commencement of manufacturing. Additionally, autologous therapies require special handling under very stringent temperature requirements. They are also typically time sensitive and must be delivered within clearly agreed time frames.

Biopharma companies will increasingly need to decentralize and outsource manufacturing of low volume-high complexity C&GT and collaborate with contract development and manufacturing organizations (CDMOs) dedicated to supporting commercialization of therapies. As more C&GT transition from clinical trials to commercial markets, CDMOs will increasingly employ single-use technology (SUT) in entirety or hybrid models to achieve decentralized manufacturing closer to the patient and meet challenging supply chain demands. SUT developers in turn will develop scalable solutions taking into account the challenges of extractable, leachable and reproducibility.

> *„The requirement for the commercial-scale cell and gene therapy manufacturing will propel growth in single-use technology adoption."*
>
> Unmesh Lal, Frost & Sullivan

While 100% implementation of SUT in upstream processing will reduce the total cost of goods sold (COGS) by 15–20%, it will also reduce the initial capital outlay and net investment cost (clean-in-place, water for injection) by 35–40%. The proportion of SUT to total industry capacity is less than 10%, but new installations for C&GT manufacturing will witness between 25% and 30% application of SUT. Therefore, Frost & Sul-

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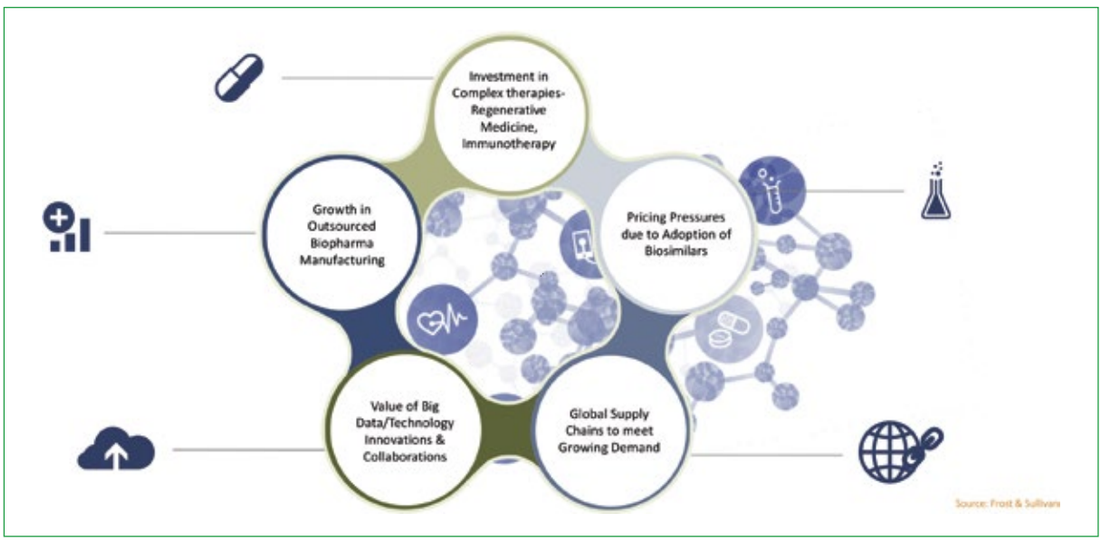

Fig. 1: Five big themes for biopharma manufacturing

livan predicts that the requirement for the commercial-scale cell and gene therapy manufacturing will propel growth in single-use technology adoption by 22% in 2019.

IIoT in Manufacturing

Over the past few years, several fundamental changes in the biopharma manufacturing process have occurred. By leveraging right first time and manufacturing 4.0 principles, the industry is looking to improve manufacturing efficiency, quality by design and compliance. Revolutionary disruption powered by an incredible shift in technologies is impacting many industries that will drive transformation in biomanufacturing. As depicted in figure 2, all of these changes are creating a paradigm shift in pharmaceutical manufacturing to more predictive and adaptive facilities that leverage modular technology disposable components, the Industrial Internet of Things (IIoT), smart objects, remote control, and augmented reality. These techniques greatly influence design, construction, layout, and operation of a plant — and, consequently, the timing and cost of the overall project while maintaining regulatory compliance.

IIoT has the potential to transform the pharma industry by offering value propositions such as faster time to market, and cost optimization, thereby ensuring higher productivity.

IIoT also permits smart warehousing and routing of products along with predictive maintenance of machine and equipment. Benefits include lowered costs, reduction in waste production and real-time visual feedback, thereby improving operational efficiency. IIoT is expected to find application in end-to-end digital integration across the manufacturing and drug delivery value chains.

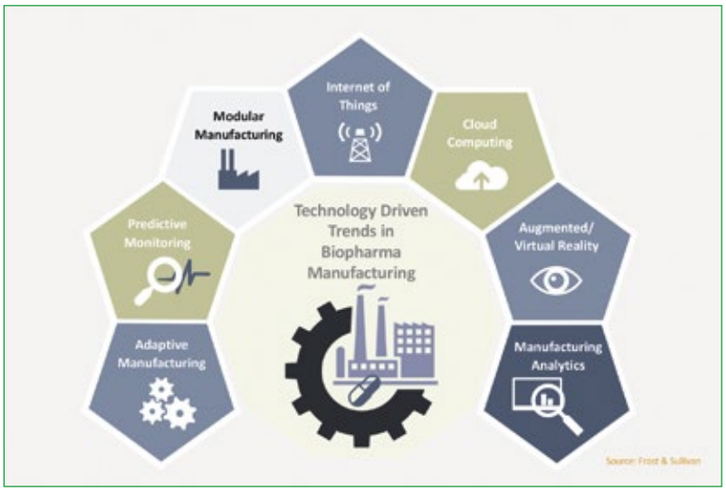

Fig. 2: Role of technology in biopharma manufacturing: innovating to zero to make manufacturing error free.

Reduce Costs, Increase Efficiency

The future of biopharma manufacturing lies in connecting data and processes, involving components of adaptive and modular manufacturing in a predictive and cognitive plant. This shall result in higher quality, efficiency, regulatory compliance and enable optimization, customization of processes and collaboration between all stakeholders involved in the manufacturing value chain. Additionally, there shall be a reduction in time to market for biologics, errors due to process variability and associated costs, thereby giving manufacturers the competitive edge to stay on the growth trajectory.

With the changing market landscape, CDMOs are adopting advanced manufacturing technologies such as single-use/disposable bioreactors, continuous, modular POD manufacturing, and so on with the integration of IT-based solutions implementing IIoT by means of strategic collaborations and partnerships. Larger participants are resorting to mergers and acquisitions (M&As) in order to gain specific therapeutic and technical expertise from smaller, niche Bio-CDMOs. As a result, CDMOs are shifting toward providing value-added services by establishing themselves as a one-stop-shop for their pharma clients.

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Biosimilars: The Price Challenge

Market Prices Have Come Down Significantly — How Much Can Copycat Makers Really Earn?

Biosimilars are conquering the pharmaceutical market, the producers of biopharmaceutical follow-on drugs are competing for revenues and market shares. With the launch of copycats for Humira in late 2018 prices fell fast and sharply. Now biosimilar companies might wonder if their business models really pay off.

It has been a far-reaching experience for the pharmaceutical industry: In October 2018 the patent of the world´s best-selling drug Humira (adalimumab) expired in the European Union. Abbvie, the company who in 2017 made revenues of $18.4 billion with the rheumatoid arthritis product, immediately was confronted with a wave of biosimilar competitors — copycats of the biopharmaceutical medicine.

Sandoz launched its biosimilar Hyrimoz, Biogen came up with Imraldi, Amgen with Amgevita and Mylan with Hulio. All of them competed hard on prices: Just a few days after market launch of its biosimilar, Sandoz doubled the price discount for Hyrimoz. After an original price reduction of 21% it then offered a rebate of up to 40%. Amgen initially had announced a reduction of 18% for Amgevita. A few days later the company raised the discount up to 39% compared to Abbvie´s reference drug.

Discounts up to 80%

Abbvie's CEO, Rick Gonzalez, noted in late October 2018, that biosimilar versions were available at discounts ranging from 10–80%. "The discounting has been on the higher end," said Gonzalez. This went in line with the German lobby organization Pro Biosimilar who expected the competition "to be intense because of the large number of competitors launching at the same time."

A significant price erosion can also be seen with other biosimilars. Ronny Gal, analyst of New York investment company Bernstein, says that the Remicade (infliximab) market saw a 73% price decline in the 3.75 years since launch of biosimilars in major markets. Prices in the Enbrel (etanercept) market fell by 45% in just 2.75 years since biosimilar launch.

With adalimumab the race of the biosimilars has definitely taken off with high speed. Currently more than 50 biosimilars are being marketed in Europe, 17 in the US. Health care data specialist Insight Health reports that biosimilar prescriptions in Germany nearly doubled in 2018 from 0.7 million to 1.3 million. Although the overall level is still low, the earnings are significant. The rise of the biosimilars is good for the health care systems which can save millions — if not billions — of euros and dollars. Warwick Smith, director general of the British Biosimilars Association (BBA), said in an interview that in the UK — due to biosimilars — in some indications one third more people are being treated at half the previous cost.

How Much Can They Really Earn?

Meanwhile developers and manufacturers in this industry ask themselves if they really can make as much money as they have expected? In contrast to generic drugs the development of a biosimilar requires significant time, knowledge and investment. Other than classical generics, which have a simple molecule structure, biosimilars are made of living cells and have a complex architecture. While generic companies usually spend some few millions of euros for development, biosimilar companies have to invest up to €150 million for each product. Although biosimilar companies can compensate lower prices to a certain degree by a wider range of patients they reach with their products, the core question remains: How far can they go down with their prices until the business doesn´t make sense anymore?

"If prices would drop further biosimilar companies could have difficulties to cover their costs."

Carsten Brockmeyer, CEO of the Munich, Germany-based biosimilar developer Formycon usually communicates that he expects biosimilar prices 15–20% below originators costs at the beginning of the biosimilar marketing phase. In the further course biosimilar companies calculate that prices might drop up to 30–50%. The business models are being built on these assumptions. If prices would drop further biosimilar companies could have difficulties to cover their costs for 7–8 years of research and development, for clinical studies, for the application process of their drugs and the marketing costs.

There are others threats too, especially for small and mid-sized biosimilar companies with limited financial possibilities. The biosimilar industry often emphasizes that producers of originator drugs will mostly withdraw from the market once biosimilars have come up. The copycat representatives argue that the retracted manufacturing processes of the original biological drug makers are based on standards that existed 15 or 20 years ago. Today biosimilar

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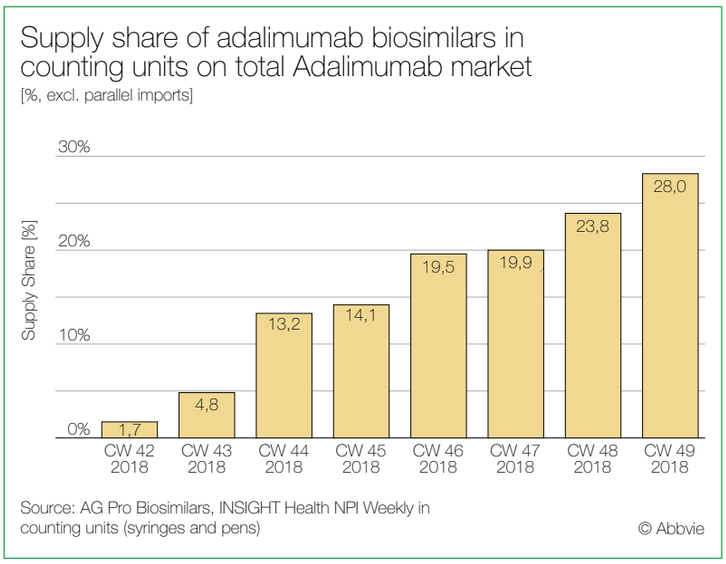


Further increasing acceptance and intense competition for Adalimumab biosimilars: Just 8 weeks after market entry, the supply share (Biogen/Samsung Bioepis — Imraldi, Mylan — Hulio, Hexal/Sandoz — Hyrimoz, Amgen — Angevita) is already just under 30%.

companies with their latest production processes have much lower costs than the "old" pharma industry.

The Humira case demonstrates that things can evolve differently. Abbvie dropped prices for its adalimumab by 80% in some European countries as several media and analysts reported. If this were true — Abbvie didn´t comment on this — such a price would be a clear declaration of war on biosimilar producers. Under such circumstances many companies will be forced to scrap their calculations. Some market experts mention that there is indeed no real reason why originator companies shouldn´t go down with their prices in order to stay in the market. As they had the market for their products to themselves for many years, their investments generally have been written off. No further significant investments are necessary, so they just could let the production run as they did all the years before.

"[Some] CDMOs position themselves as specialists for biopharmaceuticals."

Samsung Bioepis: the Korean Force

Some may argue that adalimumab is a special case due to the high number of biosimilar competitors. But even with other biopharmaceuticals running out of patent there is mostly more than just one biosimilar company trying to get a piece of the cake. Formycon for example points out, that it is clearly ahead of others with the development of its Lucentis (ranibizumab) biosimilar. Clinical phase III has been completed, market entry in the USA is planned for 2020. On the other side Korean Samsung Bioepis has also began a phase III study in April 2018 for its ranibizumab biosimilar.

Today Samsung Bioepis, which was newly established just in 2012, has already four biosimilars approved and marketed across Europe. It has gained more than 60% of the adalimumab market in Germany with its Humira biosimilar. In 2018 the company's accumulated sales for three of its biosimilars in Europe reached $545.2 million. Furthermore, the company recently signed a joint venture with C-Bridge Capital to develop and commercialize next-generation biosimilars in China. In this way, Samsung Bioepis paves the way to enter one of the biggest pharmaceutical markets in the world. The agreement covers Samsung Bioepis' third-wave biosimilar candidates to Lucentis and Soliris, respectively. With this track record in mind competitors shouldn´t underestimate the Koreans.

The pricing model of biosimilar companies may be questioned even from another point of view. Many European nations have implemented policies that require a mandatory reduction of the reference product's list price after biosimilar entry. If the price of the reference product gets under pressure the prices for biosimilars might be forced to fall further down as well.

Profitability to Be Questioned

Hamzah Aideed, a senior business insights analyst who joined the World Biosimilars Congress USA in May 2018, pointed out that some presenters questioned whether the 30–40% net discount, which is commonly referenced as a likely price threshold for biosimilars, was even sustainable for biosimilars companies in the long run. Discounts as high as 70% less than the reference brand were proposed in order for biosimilar companies to gain meaningful market shares, he wrote on a platform called decision-resourcesgroup. "If they gain significant profitability at this level can be severely questioned", argued Aideed. "Hearing data like this begs the question: How many companies are willing to take such a risk pricing their biosimilars with massive discounts to garner a high market share?" And Warwick Smith, the British BBA director, warned that "if you get a race to the bottom … that is not a sustainable market."

While biosimilar companies face the whole cost-related risks of development and marketing one group in this industry finds itself in a more comfortable position. Contract development and manufacturing organizations (CDMOs) as Lonza, Catalent, Patheon, and Alcami position themselves as specialists for biopharmaceuticals. In recent years such companies also have used acquisitions to build end-to-to end service models that provide both active pharmaceutical ingredient and drug-product development and manufacturing. Their advantage: They don´t have to negotiate market prices.

Thorsten Schüller, CHEManager

Cheaper, Faster, Smaller, Cleaner

Prospects of Flow Chemistry for Fine & Specialty Chemicals and Pharma

Developed and technically proven around 1995, micro reaction technology was probably highly overestimated for the first 10 years and underestimated for the next 10 years. Meanwhile it is on its way to an established process technology, not only in research and laboratory, but also in large scale production.

In flow chemistry, a chemical reaction is run in a continuously flowing stream in contrast to batch production. The subfield of micro process engineering, that deals with the design of micro-structured reactors for chemical reactions, is also known as micro reaction technology.

The technical advantages of continuous operation in micro- and milli reactors compared to batch reactors include:

- Ultra-fast mixing
- Highly efficient heat transfer
- Short and defined residence times
- Simple process control due to low system inertia
- High operational reliability due to minimum hold-up
- Improved safety
- Short development times

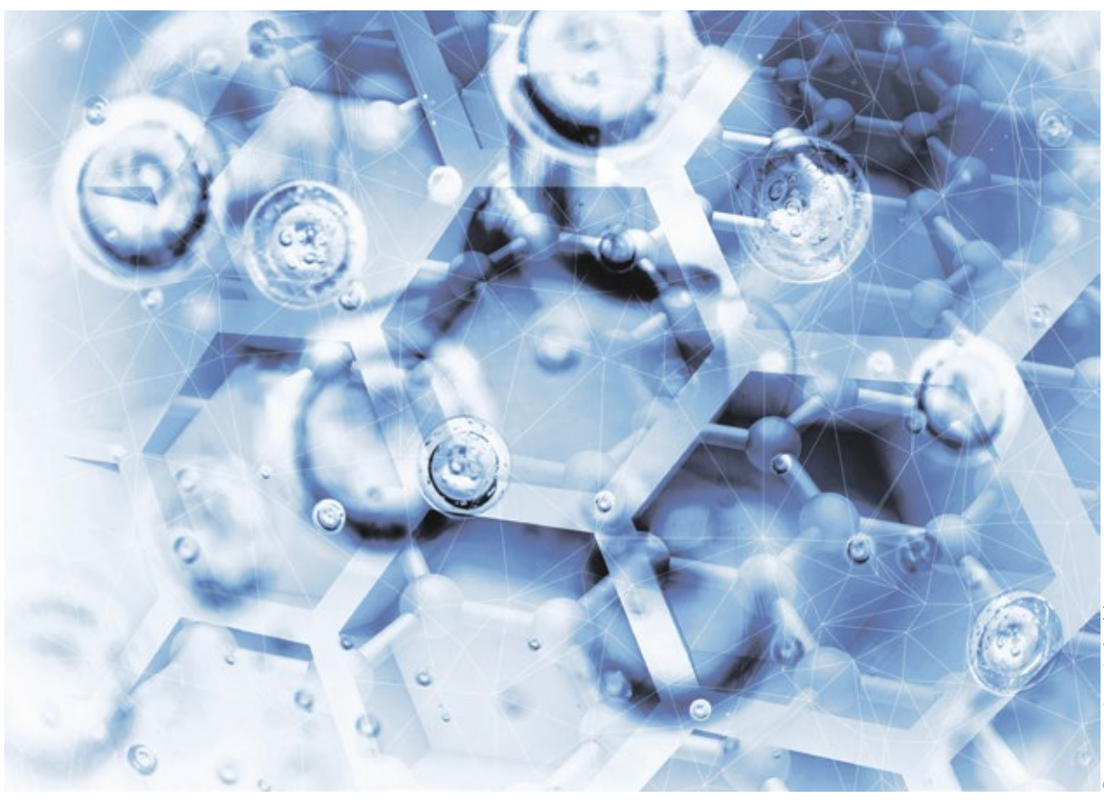
Especially with respect to rapid, highly exothermic, explosive or toxic reactions, whose safety risks make batch reactor use very challenging or even impossible, the characteristics of continuous flow micro and milli reactors offer clear benefits.

"Our Miprowa technology offers a time-efficient and integrated scale-up based on established equipment concepts."

Anne Kaaden, key account manager, Ehrfeld Mikrotechnik

The economic advantages of micro reaction technology (MRT) compared to batch technology can be described with the term ''process intensification". It may sound like catch phrases, but the ''cheaper, smaller, cleaner" and ''making more with less" has been proven in different applications — not only in research and laboratory, but also in large scale production. This makes MRT today more interesting than ever before, not only for economic reasons but also for sustainable development.

In terms of "time to market" — in pharmaceutical and fine chemical industries of special importance — it is noteworthy to point out that the scale up from laboratory to production can be carried out more simply compared to other established technologies. The characteristic performance features of micrometer-scale laboratory apparatus correspond widely to those of millimeter-scale equipment, and further upscaling is done with numbering up.



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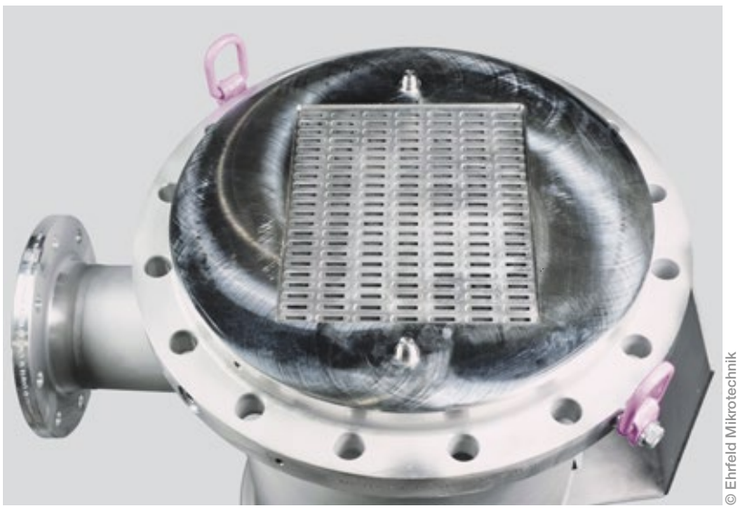
MRT in Research and Labs

In Brazil, the Technology Center for the Chemical and Textile Industries of the National Industrial Training Service (SENAI), located in the state of Rio de Janeiro, is an organization which focuses on education and technological innovation for process industries. One of the main activities of this center is to offer research-applied services to innovate in processes and products for the chemical industry. SENAI Innovation Institute (ISI) for Biosynthetics (one of the center divisions) for example will have a pilot scale unit that, for some sectors of the chemical industries, like paper or petrol, can be used for investigation and design of an industrial scale unit. Other clients who aim at bigger productions are asking to estimate industrial scale costs and setting technical targets for process development. Joao Bruno Valentim from ISI Biosynthetics is convinced of a huge potential for flow chemistry in the chemical industry. Once they prove it works technically, it is a matter of matching the expectations of cost reduction and reducing the impact of scale on chemical plants projects.

At the University of Graz in Austria, Oliver Kappe is professor of chemistry and scientific director of the Center for Continuous Flow Synthesis and Processing (CC FLOW) at the Research Center Pharmaceutical Engineering (RCPE). CC FLOW as an academic lab cannot provide commercial scale manufacturing but search for novel flow chemistry routes to molecules of interest. Kappe sees a lot of interest in flow chemistry both from the academic world but also in pharma and other industries. He is convinced that, given the enhanced safety and expanded process windows, there is so much you can do in flow that you cannot do in batch. The vision obviously is not that all batch chemistry will be replaced by flow, but in future there will be many more safe, reliable, and automated flow processes available to practitioners interested in both lab and commercial scale.



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Rectangular channels for optimized heat transfer in a Miprowa reactor.

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Integration of the continuously running Miprowa flow reactors into the existing building infrastructure at Shaoxing Eastlake in China.

In Australia, the Commonwealth Scientific and Industrial Research Organization (CSIRO), which is the national research organization, has a mandate to assist the Australian chemical industry. Using the latest in flow chemistry and process technology, CSIRO can provide manufacturing solutions to rapidly synthesize small molecules and polymeric materials. Christian Hornung of CSIRO says that many of their industrial customers plan to take their synthesis route into production using continuous processing. With the new FloWorks facility opening its doors at CSIRO Clayton early in 2019, they will continue to be a center of excellence in flow chemistry working with Australian and international chemical manufacturers. He believes the new facility will help extend their offer to improve chemical manufacturing processes for companies that have not adopted or heard of flow chemistry yet.

Milli Reactors in Production Scale

Shaoxing Eastlake High-Tech is an agrochemical producer founded in China near Shanghai in 1990, which not only serves the Chinese market, but also exports its products to more than 20 countries, including the US and EU. The company provides active ingredients to the global agrochemical market segment.

In 2016, Shaoxing Eastlake commissioned a milli reactor which was designed, manufactured and supplied by Ehrfeld Mikrotechnik in Wendelsheim, Germany. The decision for their Miprowa technology was driven by achievable product quality, significantly improved yield, safety aspects and a short return on investment, says Anne Kaaden, key account manager at Ehrfeld. The continuously operated production reactor with a capacity of up to 10,000 t/y is using millistructures on a production scale and was designed for a highly exothermic alkoxylation reaction. The reactor has a nominal width of 400 mm and a length of 7 m and contains about 150 rectangular reaction channels with exchangeable static mixers. It replaced more than 20 batch reactors while doubling the original capacity.

In November 2018, Eastlake started implementing two additional milli reactors of same size, thus tripling their production capacity at its Shaoxing site up to 30,000 t/y. These three production reactors are a visible reference for micro reaction technology in production applications.

Volker Oestreich, CHEManager

Executives and industry experts dealing with flow chemistry share their insights on the current status and future potential of this technology. Read their statements on the following pages.

Flow Chemistry: Key Technology for Sustainable Processes

Experts Discuss Challenges and Opportunities of Micro Reaction Technologies

You can call it flow chemistry or micro reaction technology (MRT) — both terms describe a technology with enormous advantages for many process engineering applications. It replaces discontinuous batch processes with a continuous method in which reactions take place in extremely miniaturized structures.

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Transforming process engineering production from the batch principle to continuous flow processes based on micro and milli reactors may not always be so easy for production staff to accept — despite its advantages. Adopted by the pharmaceutical industry in recent years, the technology platform offers potential in many respects, but although the technology as such is not at issue it experiences acceptance problems.

Especially with respect to rapid, explosive, toxic or highly exothermic reactions, whose safety risks make batch reactor use very difficult or even impossible, the characteristics of continuous flow reactors offer clear benefits. Nevertheless, MRT has yet to gain popularity. CHEManager asked executives and industry experts dealing with flow chemistry to share their opinion on the current status and future potential of this technology. We wanted to know:

- In your opinion, what are the strongest drivers (success factors) of the implementation of flow chemistry processes?
- Which barriers are slowing down or impede the implementation of flow chemistry processes?
- In which fields do you expect flow chemistry to find future applications in the process industry?
- What does it need for flow chemistry to be recognized as a breakthrough technology?

Read the insightful answers of the experts here.

A Technology Whose Use is Indispensable

Ralf Boehling, senior manager Process Development, Process Screening/Kinetics Lab, BASF

The existing market situation has already led to a shift in strategy from large quantity chemicals to highly innovative specialties. For many syntheses you can use classical batch vessel. But if you are handling highly toxic, hazardous substances or the syntheses have to run under high pressure, high temperature or the products are thermally unstable, or the syntheses includes a gas phase step, you preferably have to work under continuous flow conditions. So, for BASF there is a need to open these process windows. But one of the major problems to face is that the process development for a continuous plant from lab to production plant is not quick enough and causes high development cost. Additionally, it takes a long time for construction and building the technical plant. Especially for small scale plants the cost is prohibitive if building the plant traditionally on site step by step. This, however, severely increases the investment risk for new products because the market needs and price structures cannot be realistically foreseen. Therefore, to shorten the process development time and to reduce cost and time for building small scale continuous plants is a platitude but of course is the key for new innovative processes, reactors and products.

Increased Process Performance and Safety

Olaf Wachsen, head of Group Process Technology, Group Technology & Innovation, Clariant

It took about two decades after micro and milli reactor technology has reached the production scale with significant production volumes. Now, curiosity and openness of chemical companies grow significantly to benefit from this technology's potentials like access to new and better products, increased process performance and significantly better process safety.

A Boost to Efficiency, Adaptability and Responsiveness

Walter Linhart, head of sales and managing partner, Microinnova

The main drivers are the need to be competitive and free up batch production capacity. Fine and specialty chemicals producers are increasing their interest in flow chemistry, as experienced on half of the projects that Microinnova has worked on.

Our expertise is combined with risk assessments at early stages to increase chances of success and ease the transition to continuous manufacturing.

Misconception one: Limited type of reactors: Flow chemistry can be achieved not only through the use of milli and micro reactors, where you have a limitation to mainly fast liquid/liquid reactions with low viscosity, but also through the use of other technological alternatives. These alternatives can be plug flow reactors, static mixers, reaction columns, extruders and others. Even other energy sources can be used to enhance the benefits of continuous manufacturing, such as ultrasound and microwave.

Misconception two: Only batch manufacturing is flexible: The introduction of new modular plants has combined the benefits of batch manufacturing and flow chemistry. These types of plants offer the flexibility of batch processes, while simultaneously being able to work continuously, which gives a big boost to the chemical industry regarding efficiency, adaptability and responsiveness to the market.

Disciplines separation: Typically, chemists fix the synthetic route and engineers develop the process, taking over the project at pilot stage. For a successful production implementation of a flow process it has been noticed, that companies who have implemented a continuous processing strategy have started forming interdisciplinary teams for this very reason.

Availability of production capacity: Especially in the area of CMOs, there is a serious chicken-egg problem. More and more continuous processes are being developed by big pharma companies. It is an increasing market, but production capacities at CMOs are missing. CMOs do not get the projects, because they lack experience and production capacities with continuous processes, and in turn they do not invest in the technology, because of the missing projects.

Flow chemistry is already being applied in the fine chemicals industry, where we have developed several projects in different areas, like for the production of additives for lubricants, phenolic resins, acrylate polymers and crosslinking agents, anionic surfactants, silicone release agents and primer and wax mixtures.

For flow chemistry and continuous manufacturing to penetrate the industry it will require some more patience. However, both academia and industry have increased their interest in and support for this technology.

Further Development Will Increase Confidence

Peter Poechlauer, innovation manager Pharma Services, Patheon

Originators discover new drug candidates by screening substance libraries containing only a few milligrams per substance. Many synthetic methods employed in library synthesis are not scalable: during further development, they have to be modified or redesigned to deliver quantities for further testing. At this point, custom development and manufacturing organizations (CDMOs) such as Patheon offer to perform the respective process development and manufacturing tasks. In this environment, flow chemistry provides various opportunities, for instance, to scale up even demanding synthetic steps without the need for a re-design, to control synthesis processes to deliver products with predictable quality at all required scales while the ultimately required production scale is still uncertain, to speed up process development through quick screening of reaction parameters, and to intensify processes, which reduces investment and variable, e.g. solvent and raw material costs.

Production of many APIs has moved to the East, freeing up conventional cGMP-rated manufacturing capacity in the West. This hampers decisions to invest in new technology developments that tend to reduce the utilization of this manufacturing capacity further.

In response to the growing number of newly developed APIs with a reduced volume per API the industry will shift towards concepts of manufacturing and quality assurance based on flow processes in flexible modular plants that are quickly reconfigured to supply the variety of small-volume products in the required quality and on short notice.

Further successful implementation of flow chemistry processes in cGMP manufacturing environments will increase confidence in this technology. It will convince manufacturers of APIs to consider developing flow processes or to team up with CDMOs with proven experience in this field.

Unsurpassed Heat and Mass Transfer Properties

Stefan Brand, head of Process Innovation, Group Technology & Innovation, Group Process Technology, Clariant

Flow chemistry, based on milli and micro reactors, is a powerful production process technology with unsurpassed heat and mass transfer properties. It is especially beneficial for fast chemical reactions and in cases where an effective mixing of the reaction medium is required.

Major drivers for the application of flow chemistry are: globally increasing process safety requirements, the possibility to enter new reaction paths and the opportunity to produce tailor-made chemical products, which is known as product-by-process concept. To a large extend, the quality of polymeric compounds depends on their manufacturing conditions. As an example, the molecular weight distribution of polymers can be much better controlled with flow chemistry than during batch processes. The small reactor volume of milli and micro reactors is the reason for inherent safe production processes and allows the exploitation of new process windows, e.g. use of raw materials which are not suitable for batch reactions.

Prerequisites for the implementation of flow chemistry within a chemical company are an overall innovative mindset as well as readiness to invest in new production technologies. Additional convincing examples of the successful realization of flow chemistry plants for producing e.g. specialty chemicals will speed up the expansion of this promising technology.

A Technology on the Upswing

André de Vries, commercial director, Innosyn

There are a number of drivers to implement flow chemistry processes over batch operations.

Firstly, a very much improved heat and mass transfer. Millimeter-sized tubular reactors have a much higher surface-to-volume ratio than batch vessels, intensifying heat and mass transfer dramatically. Highly exothermic reactions can be executed (almost) isothermally.

Secondly, a safe operation of hazardous and unstable reagents. Thanks to a continuous operation the volumes of flow reactors are typically several magnitudes smaller, and there is no, or hardly any, hold-up of these unstable compounds.

Thirdly, the operating window can be beyond "normal", especially temperature and pressures, allowing the safe use of for example toxic gases, previously avoided on large scale. Also superheating of common low-boiling solvents to speed up the reaction kinetics can be executed safely.

And finally, process monitoring and control is improved with continuous processing, leading to a lower level of impurities.

Implementation of flow chemistry processes, however, is hampered by the already widely available batch vessels of all kind of sizes and a well-established culture to run chemical processes in such assets. In addition, many chemical products are being used in a heavily regulated domain, with tight specs, and any change in production process will lead to new validations and alike. To overcome some of the hurdles Innosyn is using 3D metal printing (selective laser melting), as method of choice for manufacturing the most fit for purpose reactors for flow chemistry processing. This technique gives maximum flexibility to introduce specific features like static mixer elements and temperature probe inlets; one can iterate designs rapidly to tailor to the specific chemistry at hand; and is cost-efficient since only the metal ending up in the reactor is consumed.

We see the use of flow chemistry processes being applied successfully, especially in those fields where it can make a severe difference compared to batch processing. In practice this entails any sort of organometallic chemistry, and the safe use of hazardous reagents and reaction mixtures, enabling shortcut routes to special chemicals, alternatively produced by lengthy routes preventing the use of those hazardous compounds.

Benefits across Different Industries and Applications

Omar Jina, chief commercial officer, Syrris

For discovery groups and academia, it is undoubtedly about the ability to perform chemistry that is not possible by traditional techniques; flow chemistry allows the implementation of multistep reactions and incorporation of techniques such as electrochemistry or photochemistry. In process or scale-up chemistry, the strongest drivers lie more in the ability to seamlessly scale reactions, thereby reducing the time and cost of the process. Many companies are focusing on scaling processes of a hazardous nature, such as nitration; continuous flow processes that use smaller mixing volumes while still maintaining the desired scale are a very attractive proposition.

Flow chemistry has come a long way in the last 10 years and is fast becoming an accepted technology in industry, but there are still barriers to overcome. It is always very important to start with education; flow chemistry needs to be included in undergraduate chemistry courses to provide future chemists and chemical engineers with the foundations to solve chemistry problems by employing the most suitable tool – batch, flow or other techniques — for the application. A lack of commercially available pilot plant/manufacturing scale systems is also a barrier to large scale implementation, requiring very large custom projects and considerable capital outlay from industry. This is now being addressed and we should see technology become much more accessible in the very near future.

I believe that to become recognized as a breakthrough technology, flow chemistry needs to be widely adopted in multiple industries. At present, there is a rapid drive for implementation in the pharmaceutical and chemical industries. However, the technology can offer fantastic benefits to many other industries, including nanotechnology, flavor and fragrances, food and biotechnology. Academia has played a vital part in the adoption of flow chemistry and there are now numerous publications showing the benefits of the technology across different industries and applications.

A Visible Reference of Production-scale Micro Reaction Technology

Joachim Heck, managing director, Ehrfeld Mikrotechnik

For us, the barrier of implementing and recognizing micro and milli reactors as breakthrough technology can be taken by production-scale reference projects we are able to show in China. Ehrfeld Mikrotechnik designed, manufactured and supplied three Miprowa production reactors to Shaoxing Eastlake High-Tech Co. for a production capacity of now up to 30,000 t/a. These Miprowa milli reactors have a throughput of up to 1 m^3/h each with a nominal width of 400 mm and a length of 7 m. Meanwhile, the first of these installed reactors has been under stable operation since 2016 without any disturbances. Every reactor contains about 150 rectangular reaction channels with exchangeable static mixers. The fast and strong exothermic reaction is of alkoxylation type. The company's decision for the Miprowa technology was driven by achievable product quality, significantly improved yield, safety aspects and a short return on investment. Eastlake serves the global agrochemicals market segment based on their production of active ingredients. The three Miprowa production reactors are a visible reference of the micro reaction technology in production scale.

Unique Opportunity for Innovation and Improvement

Luigi Vaccaro, professor, Laboratory of Green Synthetic Organic Chemistry, Dipartimento di Chimica, Biologia e Biotecnologie, Università di Perugia

Both academic and industrial research is attracted by solid opportunities to create innovation while improving the competitiveness of the chemical production. At this concern, flow chemistry has become a pivotal key enabling technology that offers the unique opportunity to both innovate and improve the efficiency of synthetic methodologies leading to customized effective processes. Therefore, flow chemistry is a successful tool for researchers to disclose highly relevant publications and/or patents while creating new opportunities to excel in both academia and industry.
While the cost of flow equipment is often mentioned at this concern, in my opinion this is not the real barrier that prevents flow chemistry to establish itself. I consider more important the cultural barrier consisting in the lack of knowledge about the general utility of this technology. I believe that a new generation of professionals needs to be trained to master flow chemistry and eventually consider it as a common effective laboratory tool. Universities and companies will have to cooperate at this aim via specific industrial Master and PhD programs.

Flow chemistry is able to improve the efficiency of processes allowing the manipulation of unsafe toxic intermediates and reagents and offering a unique opportunity to design innovative protocols for the preparation and manipulation of fine chemicals and active pharmaceutical ingredients. Flow chemistry will consolidate its role in this arena but also find novel opportunities in emerging areas of research as, for example, in the manipulation of biobased chemicals and in biomass valorization where academia and industry are both looking for cost-effective access to a new generation of safe chemicals that can be produced in larger scale.
Real case applications can confirm the wide general utility of this technology and therefore further research in several different directions is crucial. To achieve this result multidisciplinary international consortia of universities and companies should be created to train next generation of professionals and apply flow chemistry principles in several different areas as green/sustainable chemistry, pharmaceutical chemistry, materials for energy and fuels.

A Holistic System Approach

Andreas Haubrich, head Process Engineering Laboratory, deputy head Process Engineering, Sanofi-Aventis

Flow processes have to be handled as a holistic system approach. Diverse applications of flow chemistry in pharmaceutical environment demonstrate the value of this strategy towards every aspect ranging from synthesis, in-line analysis and purification to final formulation and tableting.
Introducing such a way of thinking early into a development pipeline can give significant simplification during the scale up. The increasing demand of material needed for the different stages of development phases can be reached efficiently and finally the building of a large-scale facility is straight forward.
Focusing the continuous flow approach to a late stage process or a large-scale manufacturing plant limits the opportunity significantly. At these stages stringent timelines often limit the opportunity to optimize the specific reaction process and to apply flow in a strategically impactful way.
In order to step in continuous flow earlier there is a need for cultural changes due to lack of training or education in this area.
The entire processing sequence, considering reaction, quenching, work-up, extraction and purification etc. as part of the holistic design of the preparative route needs to be worked out differently. The ability to install real-time monitoring leads to rapid identification current process status and/or upcoming of trends/issues. Furthermore, the use of direct in-line purification and analytical techniques can be implemented, thus generating a more streamlined and information enriched reaction sequence.
As flow chemistry is not a plug and play technology a thoroughly process analysis, including each unit operation of a process, has to be performed to identify e.g. key cost driver's and most challenging obstacles.
All this makes the interaction of different working disciplines – chemists, engineers, analysts, statisticians and many more necessary, in order to end in an overall economic beneficial process design. By installing interdisciplinary working teams this flow chemistry will be able to capture full benefits.

Chemical Sales Going Digital: What to Expect?

Are the New Digital and Global Opportunities in Chemicals more Threat or Possibility?

Chemicals and digitalization are everywhere in our daily life, whether we pay attention or not. By coming up with creative ways of innovation, industry professionals can take their business to the next level. Independent B2B platform Pinpools has taken advantage of this possibility and offers a digital solution for chemical sales.

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According to CEFIC, the European Chemical Industry Council, the chemical industry is one of the largest sectors at global level, and it is going to increase even more. The estimate for the worldwide chemical market is to reach €6.9 trillion by 2030. Globalization is definitely going to be a key factor for companies' success stories because digital solutions enable them to expand the business from the domestic market to the international level.

For most people working in the chemical industry, the shift to the use of digital channels might sound too much of a challenge but it should be taken as an opportunity. The so-called millennials are slowly conquering all company departments, and since they were born into the world of digital devices they are not afraid to take advantage of these opportunities. Especially these people with a digitalized mindset are more willing to try out new practices, which is going to be a changing factor for chemical business. The millenials have developed an expectation with regard to their way of working that they have immediate access to every human being at all times. By having this mindset when doing business, they expect to receive the same fast and smart solutions also as customers. However, so far, the industry has been slowly adapting to the changes, so transformation to chemical digitalization is not going to happen quickly.

Digitalization is a real thing: Roland Berger and Google Deutschland suggest in a study that 60% of almost 3,000 B2B sales managers think that digitalization is a critical success factor. Since it is considered an important part for the business, actions towards digitalization need to be implemented in order to survive and succeed in the global competition.

Independence and Transparency

Pinpools was founded to take advantage of chemical digitalization by creating a B2B online platform for selling and buying chemicals. Within just a few years, the company has grown rapidly and is currently the only independent B2B platform in Europe, i.e. it is not owned by any other bigger chemical company. Transparency of the website secures trust among the companies doing business on the platform since their contact information is available for both parties. The threat of digitalization is often seen when it comes to privacy and security issues. This emphasizes the need for each company's mindset to be focused on strengthening the key areas such as cyber security, regulatory and policy issues. The two factors, fresh mindset and stronger key areas, are going to help by using advanced technology, e.g. cloud services and big data analytics. They are also going to improve continuous development of data management, process optimization, innovation, and better supply chain management.

Continuous Analysis of Global Industry Trends

There is no doubt that the purchasing power is going to shift more and more from global leaders to customers, which is the reason why chemical companies need to analyze ongoing trends affecting to the customers' behavior and the way they make decisions. These trends define what strategies companies should put into action to secure business growth.

Smart Solutions

Making smarter decisions and coming up with better solutions is going to help with innovation. Cost effective practices help companies to invest money in the right places which can be achieved by pre-management and better planning process.

Using the B2B marketplace can help chemical suppliers and buyers to grow their business network. The platform offers the possibility to approach multiple companies faster than ever before: By posting a request for quotation a buyer can be contacted by suppliers and then choose the one who offers the best price.

Data Security

Cloud services, which have become common in the past years, enable a faster data transfer. Data security is a hot topic when talking about new digital devices or platforms. This requires a company to carefully protect its information and data online.

Alexander Lakemeyer, Pinpools

The fact that Germany's Federal Cartel Office launched an investigation on Amazon due to possible problems with data security shows that even global leaders are struggling with these challenges. Pinpools, functioning as a digital B2B marketplace, values the privacy of its customers and ensures that the data is safe on the platform. The trust factor provided by the platform is the transparency that allows buyer and supplier to see each other's information when doing business on the platform.

Think Outside the Box

Chemical companies need to wake up to do business faster and more efficiently and thus save time and money. There are many possibilities, but it takes to have a fresh mindset and innovative approaches, and to think outside the box. While there are threats such as data security, it is up to people to decide whether they feel that these threats outweigh the benefits. One thing is for sure: To secure the growth and success of business, digital solutions need to be implemented.

Alexander Lakemeyer, CEO, Pinpools, Haan, Germany

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Analyzing Pores Deep-Down

Quality Control of Porous or Granular Substances with Modern Image Processing

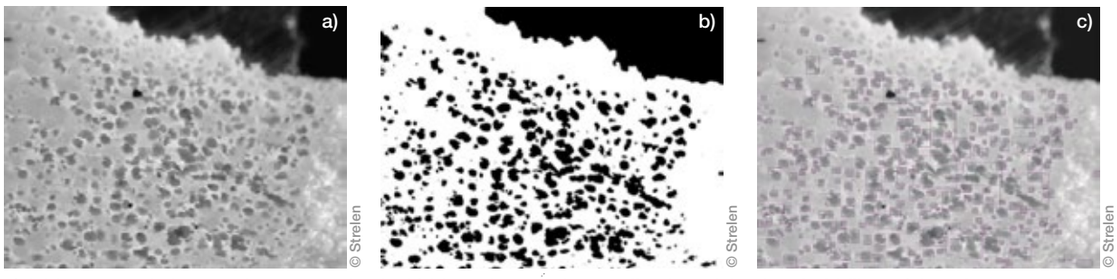
Autonomous vehicles, self-learning machines, interconnected systems of production and storage units or self-stocking warehouses: The digitalization of society and the industrial revolution are moving relentlessly forward and offer technologies and innovations with a bright and promising future that are already reality or just one step away. And in all industrial sectors the relevance of image processing is continuously on the rise.

Image processing includes the capturing, modification and analysis of images, for instance in the context of production or packaging processes. The main objective is to extract relevant information from the images in order to steer processes, test products, document completeness or integrity or perform general quality control.

For a long time, the potential to use image processing to gain information and steer processes was very limited indeed. In recent years this boundary has been steadily pushed outwards and previously unimaginable performance has become possible. For the largest part this is due to the greatly increased capacity of computer processors and graphic chips. Additionally, image processing is of relevance to the development of artificial neural networks, which are relentlessly gaining in importance since they further the development of artificial intelligence (AI). Combining AI and image processing in the context of machine learning enables the advancement of systems that help users to identify the criteria which are relevant to quality in the first place. A self-learning system can be fed with data relating to production, surroundings and images together with information about quality parameters, error classes or other assessment values. While running, the system gathers all the data of the production process and assesses these autonomously. These assessments can subsequently be corrected by the user if needed. Over time such a system will increase its precision progressively. Parameters that are critical for the quality can thus be identified among all incoming data as well as parameters that do not correlate with quality at all.

The fourth industrial revolution brings great challenges — as mentioned above, digitalization and networking of production — and solutions based on the analysis of digital images are subsequently becoming more and more popular. The market for companies offering image processing solutions is still young but has grown rapidly in the last few years — with no end in sight. The chemical sector is especially eager to use so called "machine vision" systems. One example of a practical application is determining the chemical composition of substances with the help of hyperspectral imaging.

Daniel Balser, Strelen



a) 8-bit grey-scale image of a porous plastic; b) binary image after application of the threshold filter; c) found pores are marked in purple.

So-called blob analysis is a further example. It is used in many applications that fulfil requirements of the chemical industry, such as examining porous and granular substances in order to define relevant quality parameters, respectively verify these. Before, these kinds of analyses would have required a lot of time and personnel, if they were even possible at all. Blob analysis is based on digital images taken by industrial cameras. As a rule, these are grey-scale images which means each pixel can be represented by a brightness value. If we take an 8-bit grey-scale image, each pixel can have 28, or 256, different values of brightness. A value of 0 represents a black pixel, 255 a white one. In order to gain further information using blob analysis, the grey-scale image needs to be transformed into a binary image which only contains the values 0 and 255. The first step is to use filters on the original grey-scale image in order to eliminate errors or to highlight specific aspects which will later be recognized by an algorithm. It might for instance be an advantage to increase the contrast of the image so that light or dark parts can be separated more easily later on.

The next step is the creation of the binary image by using a so-called threshold-filter. It is called this because it is based on a threshold to which the brightness value of each pixel is compared. Is the value below the threshold, the pixel is assigned the value 0, meaning it is turned black. All other pixels are assigned the value 255 and subsequently turn white. After applying the filter, the image finally consists of only black and white pixels. It is of great importance for the subsequent quality and precision of the blob analysis that the threshold is set to a suitable value.

The binary image can then be evaluated using analytic algorithms. Blob analysis helps to find image areas where the brightness differs from the background. These can be dark areas on light background or vice versa — e.g. impurities or pollution on a surface. If dark areas need to be detected in light surroundings, the algorithm finds black pixels and compares them to their immediate surroundings to establish connected areas of black pixels which form a so-called blob. In this way each black pixel is assigned to its own specific cluster and can thus be sorted, differentiated and statistically analyzed. It is possible, for example, to only evaluate blobs with a certain dimension, a minimum roundness or blobs in defined, distinct areas of the image. All blobs which meet the criteria can be assigned specific values such as quantity, area, height, width, circumference, roundness and a number of values derived of these. It is thus for instance possible to calculate what percentage of the total area is covered by the blob or the size of the blob in relation to position. But not only porous materials — such as foamed plastic or construction materials, packaging, foam material or bakery products — can be analyzed in this manner. It is also possible to detect and analyze foreign particles differing in color or suspended solids in a carrier medium.

This technology is employed in Safe-Ident Cell, which is the new product of image processing company Strelen Control Systems. The system offers the solution for offline test stations which need to quickly and simply determine the composition of a material, the number and size of pores or the presence, frequency and quality of particles. The software uses data logging to guarantee an overview of all collected data and determines time trends in production quality. By offering the implementation of varying cameras and optics this solution can be adjusted to different object sizes, operating distances and monitoring stations, thus allowing for customized solutions. This kind of solution is in high demand in the industry and it is universally applicable, as is shown by the successful implementations in the cosmetic, chemical and pharmaceutical sectors, where the company is currently working on the realization of a particle detector.

Daniel Balser, project engineer, Strelen, Griesheim, Germany

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Afyren and SPI Industrial Projects Fund Create JV

Afyren, a French biochemicals company, and Bpifrance, through its SPI industrial projects fund, have finalized the agreements for the creation of their joint subsidiary Afyren Neoxy. This company, backed by a capital of nearly €50 million, will house the first industrial unit based on the biomolecule production technology developed by Afyren, which successfully completed a final pre-industrial phase in 2018, validating the efficiency of its non-GMO and zero-waste biological processes.

This agreement follows the €21 million of funds raised in January 2019, and is part of the €60 million global financing program, with which Afyren wants to take its industrial project forward through to its market release. The SPI fund will invest €23 million for a 49% stake in Afyren Neoxy, with Afyren holding the remaining 51% of its capital.

The new plant will be based at the Chemesis industrial park in Carling-St. Avold, France, to benefit from industrial synergies with the platform's major operators, one of them being energy and petrochemicals company Total. Based on co-products from the sugar industry, this unit will produce a range of seven organic acids with an initial capacity of 16,000 t/y. This project is expected to contribute to the region's reindustrialization and the development of green chemicals with the Chemesis platform. Afyren Neoxy plans to generate 60 new jobs by 2021.

Nicolas Sordet, Afyren's CEO: "Through this joint initiative with Bpifrance, we will be able to benefit from the financial resources needed to industrialize our technology and the confidence and trust of a major institution, which will be a key factor supporting our development. (rk)

BASF Opens Catalysts and Process Research Center

BASF has inaugurated a research center for catalyst and process development at its Verbund site in Ludwigshafen, Germany. The new facility will be operated by the global research unit Process Research & Chemical Engineering. The new pilot plant houses highly automated experimental facilities for process development and testing of new process catalysts. According to BASF, the modernized lab features a modular construction of the testing facilities, the use of digital technologies to better visualize and manage the pilot plants, and a digitalized working environment.

To implement this concept, a 60-year old building was completely gutted and modernized over the past 2 years. While research can now be carried out on the ground floor of the building, the renovations will continue on the next floor. According to BASF, the company is investing a single-digit million euro sum per year in this project.

After completion of the modernization, which is expected to take several years, this building is planned to become the central hub for experimental work with automated pilot plants for liquid and gaseous substances.

"With the increasing importance of the BASF segments Chemicals and Industrial Solutions, there is a growing need for product research and especially process research," said Detlef Kratz, head of the research unit Process Research & Chemical Engineering.

The concept of the new pilot plant also includes professional data management. The seamless integration of process and analysis data should enable automatic data integration and evaluation of processes. (rk)

Chemspec Europe

Chemspec Europe will take place on June 26–27, 2019, in Basel, Switzerland. A key platform for manufacturers, suppliers and distributors of fine and specialty chemicals, the event showcases products and services to a dedicated audience of professionals in the industry sector. The product portfolio of this international exhibition covers a maximum range of fine and specialty chemicals for various industries. Networking opportunities and conferences presenting the latest results of ongoing R&D projects round-off the show. **www.chemspeceurope.com**

ChemOutsourcing

ChemOutsourcing, to take place on Sep. 16–18, 2019, in Long Branch, NJ, USA, addresses chemists, business development personnel and buyers from the pharmaceutical, biotech, chemical, and chemistry services industries. It focuses on API development spanning early drug discovery through chemical development and commercial supply. Attendees are executive scientist "buyers" from pharmaceutical companies responsible for sourcing starting materials, intermediates, active ingredients, and commercial supply. **www.chemoutsourcing.com**

Specialty & Agro Chemicals America

On Sept. 4–5, 2019, Specialty & Agro Chemicals America, to take place in Charleston, SC, USA, focuses on the chemical products and technologies that have specific applications for the agrochemical and specialty chemical manufacturing markets. The event narrows the focus and renews the value for chemical industry attendees. Participants cover a diverse range of chemical end-uses including adhesives & sealants, agriculture & crop protection, coatings & paints, cosmetics & personal care, flavors & fragrances, oilfield & lubricants, pharmaceuticals, plastics & composites, and water treatment. **www.chemicalsamerica.com**

CPhI Worldwide

CPhI Worldwide, taking place on Nov. 5–7, 2019, in Frankfurt, Germany, houses six individual pharma events covering all industry sectors. 2,500+ exhibitors from more than 150 countries gather at the event to network and take advantage of free industry seminars. Every sector of the pharmaceutical market is represented under one roof. In 2019, two new podiums will be introduced: Natural Extracts, based in the Natural Extracts zone, with content that covers this segment of the industry; and World of Pharma, which will look mainly at regional trends and updates. **www.cphi.com**

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