Digital Transformation in Plastics Industry: From Digitization Toward Virtual Material

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Abstract

Digital transformation occurs by digitalization or digitization, simply meaning the conversion of information into a digital data format. Up to 90% of all the digital data available today is estimated to been generated just over the past 2 years! At the same time, the processing power of computers is increasing exponentially, with the result that existing data can be processed in entirely new ways. Computational power increases further with development of new technologies, e.g., quantum computing. Today we are talking about the digital revolution or digital era, also in the sense of a technological paradigm that fuels innovation and affects society and economy, leading to digital transformation in all sectors. The chapter intends to first give some insights on the impact of digital transformation and the rising opportunities in the plastics industry, using partially the example of Covestro as a global supplier of plastic material and chemicals. It furthermore relates to the increasingly relevant topic of virtual materials. In the second part, this chapter provides some suggestion in how to explore, exploit, and experiment, proactively taking part in the digital transformation, again using Covestro as an example.

1 Introduction: What Is an Innovative Technology?

In which way digitalization and digital transformation can and may impact an industry that is the opposite to virtual in the sense of its main product by definition been a very physical, tactile, and tangible one? The intention of this

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chapter is to share the perspective on digital transformation with a focus on plastic materials and related technologies, respectively the chemical and plastics industry as such using where applicable the example of Covestro as a global player in this industry. My personal perspective and interest are driven by me being a material scientist and innovation manager by education and having gained academic and business experience in the area for over 20 years. It is not the intention to offer a comprehensive and scientific research-based review on the topic, thus it is to be seen as the elaboration of personal thoughts and opinions without targeting at all completeness and taking plastics industry and the case of Covestro as an example but not articulating any message or opinion representing the company. Joining my fellow coauthor in this book Michael Krause, I can only echo his statement that the plastics industry is undergoing transformation and change. In this chapter I will focus on how digital transformation based on innovative Information and Communication technologies (ICT) is changing drastically the plastics industry driving digitalization toward virtual materials.

Relating to the title of this book “innovative technologies,” I start with a definition of what actually is an innovative technology in my understanding and to elaborate on why the broader set of technologies summarized under Information Communication Technologies (ICT) has been chosen as an innovative technology in this chapter.

An innovative technology in my understanding is a technology that due to its rather recent (novelty as a dimension of innovation) development in at least a certain aspect triggers or enables an innovation. Singular individual technology-based innovations can be interconnected in technology systems, the latters furthermore can be interconnected into a technological revolution. A *technological revolution* according to Perez (2009) can be defined as a set of interrelated (often radical) breakthroughs, building a major set of interdependent technologies, or so to say a system of systems. ICT, often defined as the fifth industrial revolution, opened such a first technology system around semiconductors (material-based) and microprocessors. This initiated the formation of specialized suppliers and initial adoption in, e.g., calculators, gaming, and digitalizing of control panels, driven further more by miniaturization. This also gave rise to further increasing production of digital data. Processing and handling of this increasingly accessible and produced data led to an overlapping sequence of minicomputers and personal computers, software, telecoms and Internet that have each opened on their own new system’s trajectories in this system, initiating the formation of systems in system all being strongly interrelated and interdependent. According to Perez (2009), Five such meta-systems can be identified since the initial “Industrial Revolution” originating in England, followed by the age of steam and railway as a second, the age of steel, electricity and heavy engineering as third, the age of oil, automobile and mass production as fourth and finally the age of ICT, often seen as fifth industrial revolution.

According to Perez (2004) each new technology system not only modifies the business space but also the institutional context and even the culture (as disposable plastics did in the past and Internet and Internet of Things does now). New user behaviors and regulations are likely to be required and developed, as well as new competence building and other institutional facilitators (potentially disrupting the established ones). Each can be seen as inaugurated by an important technological breakthrough that opens a new paradigm of opportunity for innovation. A good example for this is the case the microprocessor, initiating the ICT revolution. The massive and increasing impact of the Information Revolution and the visibly increasing importance of innovation and entrepreneurship (e.g., IT start-ups) triggered a great interest in Schumpeterian ideas. In his definition of innovation Alois Schumpeter is one of the few economists who puts technical change and entrepreneurship at the base of economic growth. Schumpeter clearly differentiates between *innovation*, seen as the profitable commercial introduction of a new product or service, and *invention*, which relates to the fields of research and development or science.

The ICT revolution, understandable best as system of systems of technology which are interdependent and present various feedback loops and their role in innovation in the sense of profitable growth can thus be seen as truly innovative technology topic and furthermore some of the underlying technologies have been chosen as the subject for this chapter in the sense of enabler for the digital transformation in plastics industry. ICT is massively transforming all sectors and can be understood as also a technical economic paradigms, which according to Perez (2004) potentially fuel or imply also socioeconomic changes as mentioned above.

Whereas in the past megatrend(s) related to information and communication technology have been a lot formulated from a rather pure technology point of view (Internet of Things, supercomputing, robotics, etc.) or the adjacent area of applying the technology (e.g., dataism, big data, online and real time, etc.) on can observe recently that the megatrend is including much more the output or impact of ICT application and diffusion in all sectors (Z-punkt 2019; TrendOne 2019). The term "Digital Transformation" clearly indicate this.

2 The Perspective of Material Science

Material Science is a highly interdisciplinary field, including natural science-based disciplines and engineering among others. Concerning the megatrends impacting society, economy and environment new and improved materials are seen as key to solutions to cope with challenges of humankind nowadays and in future. New and advanced materials as well as related synthesis and production processes are expected to increase efficiency and effectiveness in production and usage over the whole product life cycle and beyond. In order to achieve this, the field of materials science relies nowadays on experiments and simulation-based models to understand the structure property relationships of different materials and their characteristics better and ideally in a fundamental way. The overall target is the discovery of new materials with improved or tailored properties and specific applicability, respectively efficient production and processing processes as well as recyclability.

Following the description of Agrawal and Choudhary (2016), in the beginning, for thousands of years, curiosity and belief led to experiments and further more to science. Historically science was empirical, and in early stage it followed more or less the trial and error approach. A few centuries ago came the paradigm of models, theories, and concepts in order to formulize of "laws" and concert these into mathematical equations. As science progressed and scientific problems became more complex, also the theoretical models turned to reach limits to deliver an analytical and accurate solution. Some decades ago, with the surge of semiconductors and computers as well as the relevant software developments the paradigm of computational (based or aided) science become more and more popular. The ever-increasing calculation performance of computers fueled by dynamic development of chips and their capacity allowed the computational simulation of complex real-world phenomena based on the theoretical models of the second paradigm (e.g., molecular dynamics simulations). Today these are popular as the branches of theory, experiment, and computation in almost all scientific domains, scientific methods and analytics as well as scientific results have been more and more digitized. The latter obviously leads to an ever-increasing amount of (digital) data which initiated a fourth paradigm of science over the last years—(big) data-driven science. It unifies the previous three paradigm (experiment, theory, and computation/simulation) and is becoming increasingly adopted in material science leading to a new field of what Agrawal and Choudhary (2016) call materials informatics.

The field of materials informatics can still be considered as in its early and emerging stage, much like what bioinformatics and genomics were 20 years ago. Interdisciplinary collaborations bringing together competencies and expertise from (analog) materials science and (digital) computer science. Thus, building an interdisciplinary skilled workforce are crucial to leverage the opportunities materializing and to enable timely discovery and application of new advanced materials for the benefit of mankind and solutions for the challenges mankind and the planet are facing.

In many areas of materials science in the past, there was more of a lack of data than a "big data" issue. Open, accessible and high quality data has been rather limited to be sourced, similar to the accessibility and usability of modern simulation tools and related. The Materials Genome Initiative is one of several examples of initiatives that are supporting and promoting around the world the availability and accessibility of digital data and the relevant tools in materials science. The activities include combining experimental and simulation data into a searchable materials data infrastructure and encouraging researchers to make their data available to the community. A subproject for example is the Materials Project (2019), which is leveraging the power of increasingly available supercomputing together with latest quantum mechanical theory to compute the properties of all known inorganic materials. The intention is to design novel materials apart of making the data available to the community, adding online analysis and design algorithms. Meanwhile it contains data for more than 70,000 materials and millions of associated materials properties (Jain et al. 2018).

Improvements in computational resources over the last decade are enabling a new era of computational characterization, prediction, and design of novel materials. This will further more ad to the (big) data pools or "lakes" as recently called and been build up on materials and processing data. The next but already present frontier is leveraging technologies and methods related to artificial intelligence and machine learning to harnessing the increasingly available data for automated learning and accelerated as well as more accurate discoveries. On artificial intelligence and machine learning please also refer to the related chapter in this book written by Patrick Glauner. Nevertheless analog experiments in particular in materials science will be needed to proof predictions and to transfer between the analog and digital world accordingly.

3 The Perspective of Covestro

Covestro is among the world leading suppliers of premium polymers. Covestro's materials and application solutions are found in nearly every area of modern life. Innovation and sustainability are the driving forces behind the continuous development of Covetsro's products, processes, and facilities. The backbone of its organization are in total 16,800 employees, who work at around 30 sites across the globe—from smaller technical centers to innovation hubs to large-scale production plants. All activities are coordinated from the corporate headquarters in Leverkusen, Germany. Covestro's core business comprises three segments that produce and continuously advance raw materials for polyurethanes and their derivatives, the premium plastic polycarbonate as well as coatings, adhesives, and other specialties. Covestro develops sustainable solutions to the greatest challenges of mankind: climate change, resource depletion, urban expansion, population growth, and the resulting increase in awareness of environmental issues.

The ITC-related technologies and innovation trends are opening up new options and opportunities for any industry, thus also for the plastics industry. Covestro addresses this in three dimensions of its activities: processes (both business and chemical), digital customer experience(s), and further more digital business models. In the following will describe these three dimensions in more detail and give some concrete examples (Covestro 2019).

- **Digital Processes for Internal Operations**

  As the chemical production and the related sites obviously are crucial for chemical and plastic manufacturing players, digitalization of the related process and the site's infrastructure including logistics is one of the biggest initiatives related to this dimension. The global *Optimized System Integration 2020* project targets digital operating processes in production. Its goal is to make the design, operations, and maintenance of global production plants more efficient and transparent. This is to be achieved within the next 3 years by means of data integration, coupled with the new thought processes and operating procedures associated with it. Predictive maintenance is to be carried out in the plants using mobile devices that deliver real-time data. Further digitalization of the production facilities will make planning, operation, and maintenance much easier.

The so-called *predictive maintenance* of systems, for example, becomes even more reliable in combination with machine learning and artificial intelligence. This is shown by a pilot project of the company. The temperature and vibration sensors installed in a large engine of the production plant transmit their collected data on the condition of the engine during operation to software. This enables to predict possible engine failure 8 months in advance. The aim is to be able to intervene precisely in the production processes on the basis of a clear presentation of all information and thus continuously optimize them. To this end, Covestro comprehensively analyzes data from ongoing production and maintenance in order to be able to assess the behavior of machines and materials in advance and make appropriate recommendations. The system learns automatically. The Integrated Plant and Engineering Platform (IPEP) creates a virtual data model and a *digital twin* of each production plant. The entire technical documentation of each plant is brought together in digital form in this type of database. This will benefit all production employees. IPEP will enable to work even more securely and efficiently in the future and to access all data quickly and easily.

- **Customer Experience—Communicating with Customers on All Channels**

  Covestro is also leading the chemical industry with its plans for fully integrated digital communication with business customers. They are to receive more effective after-sales support, from the first product idea to ongoing service, above and beyond all the digital channels. In 2018 the first milestone was a new internet presence with an enhanced product search function. Covestro is continuously enhancing its digital offerings to customers supported by intelligent analytics right where they are looking for solutions to their business challenges. Additionally, the company is increasingly making usage of automated marketing solutions and social networks such as WeChat, Facebook, LinkedIn & Co.

  Apart from the communication through digital channels and conducting (alternative) business or transaction processes by digital tools to create a digital customer journey and related experience, the challenge is how to virtualize the main element of the product, the material itself and being as analog and physical as it can be. A good example on bringing a virtual material-based experience to the customer is to introduce the digital twins approach not only for sites and devices but for material itself. One approach is the total appearance capture technology by X-rite Pantone that is been presented as an example in this chapter (see further proceedings in this chapter). Beside an increased digital customer experience of an analog material, the analogy to a pdf concerning written and picture content makes a digital data format such as AxF simulating the appearance of a material and the ability to usage in different rendering, simulation and design related software solutions potentially beneficial for improving speed and efficiency of workflows, higher quality in communication and ultimately interesting for new services and eventually business models, basically targeting to realize the concept of a digital twin of the material.

- **New Business Models Focus on the Customer**

  In addition to the digital commerce platform, there is for example a new business model called "digital technical services" that is critical to support efficient production processes for customers. Together with customers in the foam manufacturing industry, Covestro has been gaining experience for 10 years now with analyzing data to optimize production conditions. Algorithms are now supporting the expansion of these services. Customers will be in a position as a result to significantly cut production costs and operate more efficient and reliable.

A current emphasis of the new business models is the digitalization and optimization of process flows. In the simulating process steps, development times at customers and along value chains can be reduced considerably, and process flows can be designed more efficiently. With an easy-to-use web-based calculation tool, customers can enter the desired physical properties of the foam and wait for the matching formulas to be calculated based on our raw materials. To develop the digital tool, an interdisciplinary team at Covestro first manufactured various viscoelastic foams with the aid of predefined formulas and identified their properties. Based on these data sets, the team then generated an algorithm, which uses the properties of these foams to calculate other foam densities, hardness levels, and viscoelastic behaviors.

4 Virtual Customer Experience of Materials

Virtual customer experience is seen as one of the leading (mega) trends related to ICT according to the trend research consultancy TrendOne (TrendOne 2019). Virtual created spaces and simulations feel close and real when accompanied not only by sounds and images, but also enhanced by olfactory and haptic elements. Innovative input devices allow more and more to explore virtual situations and stories, as well as interact in them with others or even with the content. Experiences worth remembering are then no longer restricted to reality. Smartphones and special head-mounted displays like the Oculus Rift and Microsoft HoloLens are the first generation of devices to open the gateway to immersive worlds. But it remains a challenge already to “simulate” in virtual space in most realistic way the analog world (Guarnera and Guarnera 2018). Furthermore the challenge for a material supplier is how to transfer the customer experience related to it major product—the material, by definition purely analogous—to the virtual space. Digitization of information about the material or digital photography is not adequate. Potentially augmented reality (AR) and virtual reality solutions offer cost reduction and resource economies from social interaction and entertainment, to learning and working—through a remote presence, time savings through dynamic collaboration, danger minimization through simulation and empathy through immersion.

Capturing the material appearance data and using it to create customer experience in the digital or virtual space is a challenge for industries like fashion, cinema, gaming, automotive, and of course for material manufacturer in particular when it comes to rendering of virtual worlds in 3D (Fang 2011). The capture of all relevant data in a single, editable, portable file format is an obstacle in the virtualization of products, especially when consistency in appearance is required. AxF is the a format designed for system-independent communication of digital appearance and has been introduced by X-rite Pantone (2019). In this sense in the following part I will use it to showcase innovative digital technology as an example of how digital transformation and related technologies are affecting furthermore plastics industry.

Headquartered in Grand Rapids, Michigan, X-Rite Pantone is a global company with locations around the world. Experts in combining the art and science of color, focus on providing complete end-to-end color management solutions in every industry where color matters. In addition Pantone provides color systems and leading technology for the selection and accurate communication of color across many of industries. The company has around 800 employees and 17 offices worldwide. Founded in 1958, X-Rite was actually created by data-driven color scientists. Based on the technology developed by “sensible graphics” a start-up of the University of Bonn, Germany X-rite, who acquired the start-up in 2012, developed the Total Appearance Capture (TAC) system and commercialized it in 2016. Sensible Graphics is nowadays the development center for the TAC technology. In addition with the sponsorship of X-Rite the university established a Graduate School of Material Appearance and installed a new professorship focusing on digital material appearance.

The Total Appearance Capture (TAC) ecosystem, with the TAC7 Scanner at its core and the AxF file format as data format, enables designers to capture reality in a physically precise way. From special effects pigments to synthetic fabrics, it enables to capture and communicate physical appearance properties, such as color, gloss, and texture, digitally to experience a high degree of realism in 3D designs. The TAC7 scanner collects the appearance-relevant data of the materials sample to be compressed and translated by algorithm into the axf file format. The AxF stands for an universal file format that offers a way to capture, store, edit, and communicate complex color and appearance data of a material and make it accessible to a wide range of rendering, simulating, design, and engineering software solutions. AxF is used in product design, development, manufacturing, sales, and marketing. It is an industry first, and is helping brands reduce cycle time, control cost, and ensure consistency in color and appearance (Mueller et al. 2019).

To capture the exact physical appearance properties such as color, texture, gloss, translucency, and transparency in a digital format that makes it easy to experience unmatched realism in the virtual world enabling and advanced virtual material base customer experience and leading toward the realization of the concept of digital twin of a physical (analog) material. This adds an additional dimension to the topics of prediction, simulation, and characterization mentioned as digital enabled approaches in material science as well. This furthermore leads to different business models of nonmaterial supplier or apart data format and scanning hardware supplier (such as X-rite Pantone) providing data, e.g., for specific target groups such as creative industry and industrial designers (Brain of Materials 2019), processing-related materials data or offering in combination the necessary software tools and platforms to process them (Optis Ansys 2019). I presume we will see much more of this kind of service and platform (ecosystem) based business models in the near future.

5 Suggestions

As it has been stated already in the foreword of this book, this book intends to give insights and suggestions on how to invest in innovative technologies). Regarding the topics in this particular chapter, written from a view point of a material scientist and employer of a global plastic materials supplier and looking into examples of implementation and adoption of Covestro and beyond I believe that companies in many different sectors and industries are facing similar challenges and opportunities when it comes to digitalization. Challenges because new business models based on ICT paradigm have disruptive potential for any traditional players in general and opportunities because digital transformation leads to new options and opportunities for core businesses and new ventures. Thus, there is no way of not investing in the ICT technologies and their adoption mentioned in this chapter as examples. This appears to be common sense among basically all industries and common practice already, once considering the advanced and further developing adoption that can be observed.

But how to invest with which priority and timing is a challenging decision to make, as resources such as capital, knowledge (experts), and time are always limited—often scarce. Key for success to invest as a company is to holistically use the technologies for both (short term) improvement and efficiency gains, AND innovation in all areas. In the case of Covestro this is realized by the three dimensions approach plus the initiatives concerning digital R&D. The challenge is to create the set up and mindset, the culture of doing both exploring and exploiting and embracing experiments to try new ways out. The latter actually loops back in a way to the empirical age of science and key to success for former innovation driven by chemical industry.

Invest, Explore, and Exploit! On a macroscopic level to do so successfully organizational ambidexterity is needed. The term organizational ambidexterity refers to the ability of any organization to be efficient in its management of the traditional or today's business but at the same time also to be agile and adaptable with changes induced, in particular when it comes to a new transformational path or paradigm—just such as the ICT paradigm and the digital transformation. Similar to being ambidextrous (meaning to be able to use the right and the left hand equally) this in the case of any organization requires use both exploration and exploitation approaches to be successful. Pretty much it can be seen as a holy grail of modern management, in particular innovation management.

Using Covestro as an example but considering general applicability, organizational ambidexterity can be fostered by different approaches and initiatives. The following suggestions should give an idea but of course applicability depends on the organizational and industry context (and culture).

- Cross-Functional, Community, and Ecosystem Approach in Workstyle

  Looking into the challenges that come along with interdependencies of technologies and related system and the increasing complexity of processes cross-functional collaboration becomes crucial for efficient integration but also for any new approaches to be adopted. The later requires total system analysis which is enabled by internal and external collaboration. Entrepreneurial activities more and more also lead to ecosystems, e.g., in the start-up environment, thus open innovation and external collaboration is crucial.

- Intrapreneurship Initiatives and Entrepreneurial Mindset

  Coming back to earlier definition of innovation by Schumpeter and his focus on the role of the entrepreneur as driver of innovation, the entrepreneurial mindset and the organizational options to address intra and entrepreneurial activities in the company becomes important for topics and technologies' adoption that are more distant form the today's (core) business. Covestro addresses this through its "start-up challenge" wherein employees can suggest an entrepreneurial activity and topic as a team and are trained to formulate a business plan. One team is selected and gets awarded capital and time to realize the project. In addition internal ventures with respective organizational settings are in place. Another option are internal incubators and/or the collaboration with external incubators and start-ups. Furthermore Covestro collaborates on the Business Model Think Tank approach initiated by the University of St. Gallen (BMI Lab 2019).

- Design Thinking as Mindset and Methodology

  Design thinking puts the customer in the focus and aims to design the customer experience and to define the customer's problem first, then to work out the solution in the sense of a product. It is based on iterative approaches focusing on learning cycles by rapid prototyping and utilizing the concept of minimum viable product to be tested regarding the related assumptions. Training employees in design thinking (at Covestro this is called We create) and building a related culture and mindset is an important element of investing further in activities in digital transformation, as customer centricity and repaid learning cycles are essential for realization and exploration.

- Trend Watching and Foresight—Thinking in Scenarios and Options

  As pointed out, digital transformation is driven by a set of innovative technologies in many different fields. It is a dynamic and complex field regarding what actually is happening in development and in terms of adoption and innovation and on top the impact on many areas of business and ways of doing business is expected to be high and not always predictable. Apart from trend watching, scenario management is recommended as toolset for any kind of company. The adoption of innovative technologies in the ICT requires contextual thinking and the thinking in options, thus scenario management is viable tool to foster digital transformation. The future development is not foreseeable, to think in different scenarios enable an organization in effectuation beside the traditional causal logic. In addition it helps to look further ahead, creating ideas for new options and opportunities as well as been supportive for formulating and communicating a related vision internally and externally.

- Infrastructure and Hardware

  Investing means in a traditional way also investing in assets. Similar to other players in the industry Covestro is also increasing the processing capacity and is investing in advanced hardware as well as IT infrastructure and software including supercomputing.

- Experiments (!)

  Giving employees and partners the time and limited resources to conduct experiments as well as encouraging peoples curiosity and confidence to do experiments on where to apply digital technologies and tools in their area or adjacent is one of the key drivers to benefit from any kind of new technologies and to make them innovative. Covestro has curiosity and courageousness as key elements of its company culture.

6 Conclusion

As work makes up for a good portion of our personal and social life time and of course in many way affects the private life also outside working hours it becomes clear on how the digital transformation truly can be seen not "just" as technical revolution but as a sociotechnical economic paradigm as stated by Perez. One can observe improvements, disruption, and new opportunities basically in all sectors: science, economy and society and politics. For an material scientist by education and innovation manager in chemical industry it is an interesting field to invest with engagement, openness, and the experimental mindset to explore. For any chemical and materials manufacturer it has a great potential to innovate on product, service, and business model dimension and furthermore can be seen as an enabler to drive sustainability by system integration and efficiency gains in all areas of activities. Thus totally worthy to invest time, and capital and continue experimenting, learning and innovating.

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