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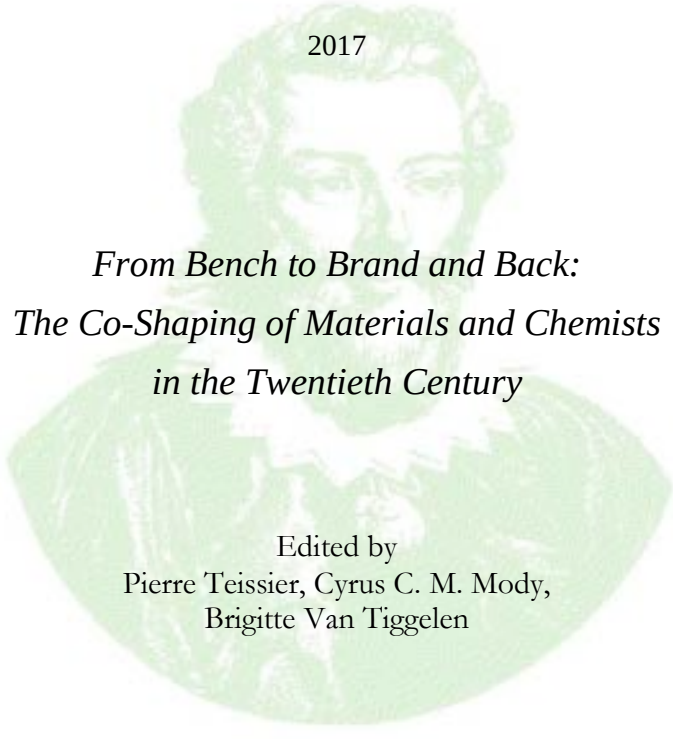

From Bench to Brand and Back: The Co-Shaping of Materials and Chemists in the Twentieth Century

Edited by
Pierre Teissier, Cyrus C. M. Mody,
Brigitte Van Tiggelen

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cahiers-francois-viete@univ-nantes.fr
www.cfv.univ-nantes.fr

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Pierre Teissier, Cyrus C. M. Mody
Brigitte Van Tiggelen

Short Story of the Collective Project

Increasingly since the 19th century, chemists' dual role in society has been to enhance natural knowledge by making new forms of matter and to improve the human condition by making useful substances or materials. Chemists have thus become architects of both matter and society. At the same time, materials have shaped chemists and their science by stimulating the founding or reorganizing of disciplinary fields, epistemic communities, instrumental toolkits, cognitive representations and experimental practices. We can therefore speak of a co-construction of the subject and the object of chemistry. New materials, and their chemist-advocates, help initiate new behaviors in society, such as the past century-plus reconfiguration of consumption habits around the ever-growing number of synthetic materials used in commercial brands. In addition, new materials and social configurations orient chemists to pursue some research questions and neglect others.

We had these ideas in mind in Spring 2012 when we planned the organization of an international meeting on this theme. Entitled "Materials and Chemistry from Bench to Brand and Back", the symposium took place the 26th of July 2013 during the 24th International Congress of the History of Science, Technology and Medicine (ICHSTM) in Manchester. It was organized by Brigitte Van Tiggelen and Pierre Teissier, under the auspices of the Commission on the History of Modern Chemistry. It was partitioned in four sessions with eight speakers, including Cyrus Mody, and four commentators and gathered an average audience of thirty scholars per session for an entire day. A second symposium on the same theme took place one month later at Uppsala. Entitled "Materials in the 20th and 21st Century", it was part of the 9th International Congress for the History of Chemistry, on 24th of August 2013, and featured four speakers and two commentators.

The first symposium raised the interest of the London based publisher Pickering & Chatto for a collective book for the "History and Philosophy of Technoscience" series edited by Alfred Nordmann. The theme of

Nordmann's series appealed to enough of the contributors to the two symposia that we started to work on a collective book dealing with the co-construction of chemists and materials in the 20th century. Unfortunately, the acquisition of Pickering & Chatto by Routledge (Taylor and Francis Group) in March 2015 significantly slowed down our editorial process, leading us to switch from a private to a public press, the *Cahiers François Viète*, an academic publisher from the (public) University of Nantes. This option had the advantages of being reliable, free and open access while keeping high academic standards through a review process including two referees for each chapter. Along the way, these circumstances and reorganizations co-shaped the volume and its object, as much as the rearrangements in the list of contributors.

The collective book gathers eight case studies related to the long 20th century and to the interaction between materials and people. The contributors work in six different countries (Belgium, France, Germany, The Netherlands, Switzerland, and United Kingdom). The cases are grounded in a variety of regions (France, Germany, United Kingdom, United States, Western world) and methodological perspectives (chemistry, history, literature, museum studies, philosophy). In addition to the more traditional sources of historians, including institutional archives and scientific articles, other kinds of documents have also been used: ads and illustrations (§1), artifacts (§2), oral archives (§5, 7), popular literature (§6). The contributions furthermore cover a wide spectrum of materials: inorganic, organic, biologic, arts materials.

Historiographic Position in the "Thing Turn"

The collective book instantiates the recent focus on material culture in academic research in general and in the history and philosophy of science in particular. In the last decades of the 20th century, Science and Technology Studies (STS) emphasized the co-construction of science and society. Since the turn of the century, though, a new trend has developed which focuses on the role of instruments, materials, and objects (Rheinberger, 1997; Baird, 2004; Daston, 2004). Chemistry and materials science represent fruitful ground for both the earlier and the newer directions of investigation – and for reflection on how the co-construction and materiality perspectives relate to each other. On the one hand, chemistry and materials science allow one to trace the changing relationships among bench scientists, production engineers, inventors, and markets. On the other hand, chemistry and materials science are inherently techno-scientific disciplines situated between knowing and making. Thus, these disciplines offer an

original perspective from which to explore the material culture of the "thing turn". Our volume brings the synthetic sciences – fields that both make *and* understand stuff – to the fore in both history of science and technology. The focus on materials allows our contributors to investigate the intermingling of facts and artifacts, knowledge and know-how, cognition and application. It also, following recent contributions (Bensaude Vincent *et al.*, 2017), further erodes the still-sharp distinctions between history of science and history of technology.

To address these topics, we have chosen to focus on the long 20th century. This has to be justified. The first reason is institutional and pertains to the history of science, since the two 2013 symposiums were organized under the auspices of the Commission on the History of Modern Chemistry, which fosters a particular emphasis on 20th and 21st century chemistry. The second reason is historiographical and more related to the history of technology. Our chapters examine the period bridging the "second" and "third industrial revolutions" (Caron, 1997). The "second industrial revolution", running from the 1870s to the 1920s, is commonly associated with the industrialization of electricity and chemistry in Europe and America based on the formalization of research and development (R&D), the building of electrical networks, and the invention of means for "scaling-up" chemical reactions. The "third industrial revolution" (Dosi & Galambos, 2013) is a fuzzier concept, but roughly it refers to late 20th century developments linked to the progressive integration of African, Asian and Oceanian actors into post-1980 neo-liberal globalization. With respect to the history of science and technology, the period between the second and third industrial revolutions was characterized by the presence of the "welfare state" and the "cold war". The perspective of "*temps long*" (long term) history, unfolding over around a century and a half, allows us to stress the continuity of phenomena and to soften the importance of ruptures. Indeed, most of our case studies overlap at least one of the two revolutions mentioned above without reifying ruptures between them. On the contrary, the long 20th century exhibits coherent features that weave in and out of most of the case studies: the consumer society; the developmental state; ideological confrontation between East and West; economic and military confrontation between North and South; the instrumentation revolution in chemistry; the capillarity of economic discourse spreading to all corners of society, including science; etc.

In spite of our strongly empirical perspective on history of science and technology, we would like to contribute to two STS debates. The first one deals with the changing organization of science and technology in society, related to the concept of "regimes of production of knowledge" (Pe-

stre, 2003a). This debate centers on whether the entanglement of science and technology is a recent (post-1980) phenomenon or has roots going back at least to the "second industrial revolution". A simple and much-cited framework adopted by Michael Gibbons *et al.* (1994) roughly discriminates so-called "mode 1", or traditional disciplinary sciences, from "mode 2", or modern trans-disciplinary ones. A number of strong critiques of this framework have been made, however, which offer more thorough interpretations of developments over the long term. For example, Dominique Pestre (2003b) argued for a long-lasting evolution since the 15th century in Europe. However, like Gibbons *et al.* (1994), he agreed that the 1970s mark a neo-liberal rupture in twentieth century science and technology. Other models have also appeared, such as the "triple helix of university-industry-government relations" (Etzkowitz & Leydesdorff, 1996) or the post-1980 "epochal break" (Nordmann *et al.*, 2011; also Forman, 2007).

We did not want to choose among the existing models but we acknowledge the fact that each highlights a certain facet of the problem. None of them, however, is able to capture the complex entirety of the co-shaping of chemists and materials. Some of our case studies might provide empirical data to facilitate the refinement of sociological models that explain late 20th-century transformations in science and technology. Instead of endorsing a model, we adopt the transversal conception of science offered by Terry Shinn and Pascal Ragouet (2005), which stresses that the research process is shaped not only by scientists but also by social and cultural features, including material and instrumental opportunities and constraints (Mody, 2011). Indeed, even though each of our cases examines a very localized and finite object of investigation (a material), all of the contributions do this in a historically sensitive way, bringing in the context of time and space, both local and global, and expanding the theoretical framework through comparisons.

The second debate is that concerning objectivity. Daston and Galison's (2007) groundbreaking work on *Objectivity* showed that scientific identity is co-produced with communally shared norms for robust knowledge production. Yet their equally influential claim that the making of technoscientific objects represents a new form of objectivity is more questionable. In contrast, our chapters demonstrate that in chemistry and materials science technoscientific objects have underwritten objectivity for well over a century. We follow here the literature on "techno-sciences", after Gilbert Hottois (1984), which emphasizes the close connection between science and technology since, at least, the "second industrial revolution".

From Bench to Brand and Back: Scaling and Trans-Operating

This collective book sketches the mirror dynamics between chemists and materials across a wide spectrum of interconnected fields and activities ranging from bench research through engineering processes and brand consumers to human cultures and the natural environment. It mainly focuses on the circulation and interaction of people, things, and words. The endless back and forth between bench substances and brand products exhibits two transversal concepts that permeate most of our case studies.

First, the importance of *scaling* in grasping the interaction between chemists and materials. By scaling, we mean movement both up and down along both natural and cultural scales, as well as the dynamic interactions between those scales. Chemists, more than most scientists, are often looking to scale up, to amplify what they do in the laboratory in order to build the factory and influence the mass-market. It is striking, when reading the eight following chapters, to realize the great diversity of the institutions involved in chemistry and materials science in terms of their sizes, organizational models, and goals: start-up companies, laboratories, universities, communities, trade unions, multinational firms, states, international markets, global networks, etc. Yet chemists are also just as often employed to scale down by grasping a bit of the world to isolate it and study it out of its normal context or to manipulate it and combine it in the mixed entities known as materials. They thus build an astonishing variety of heterogeneities and combinations, at scales ranging from the (sub)atomic to the macroscopic. The circular dynamic of scaling up and down becomes even more complex and stimulating when new materials enter the natural environment, posing unexpected challenges for regulation, clean-up, and recycling. We thus consider scaling as a process and scales as contingent and evolving things rather than essential and static objects.

The second transversal feature of our collective volume is situated at the conjunction of the transgressive character of chemistry and the operative dimension of techno-science – a conjunction we label *trans-operating*. Chemistry is transgressive in that it blurs traditional dichotomies between natural and artificial, making and knowing, realism and positivism (Bensaude Vincent, 2005; Llored, 2013). Like other techno-sciences, it is also able to operate on its surroundings. Chemists' hemi-synthesis of molecules from natural products, for example, is one of the characteristic practices of the artificialization of nature that we wish to highlight. A *trans-operating process* or *trans-operation* can thus be defined as a performative interaction between two entities usually considered to belong to separate spheres (nature versus culture, science versus technology, infrastructure versus superstructure, etc.). The circulation of materials from bench to brand and back

in the eight chapters makes apparent three types of trans-operation: between things and people (part 1); between knowing and making (part 2); and between things and words (part 3). Our concept of "trans-operation" thus provides a theoretical frame to organize the different empirical cases.

Editorial Organization of the Volume

The first part of the volume "The Plasticity of Things and People" is composed of two chapters which tackle the relation between science and design. In chapter 1, "Paint as a Material: The Transformation of Paint Chemistry and Technology in America (ca. 1880-1920)", Augustin Cerveaux recounts the emergence of modern paint chemistry and technology in the United States at the turn of the 20th century. He shows how legislative regulations and chemists' professional struggle for jurisdictions (Abbott, 1988) turned paint chemistry from a decorative art and craft to a techno-scientific field based on performance, while paint coats evolved from mere mixtures to brand materials. Chapter 2, "Quality Matters for Historical Plastics: The Past-Making of Cellulose Nitrates for Future Preservation" by Anita Quye, takes the practical problem of material degradation of cellulose plastics in contemporary museums as an opportunity to explore the plasticity of values according to places, times and communities. Thus, one material can lose its aesthetic value for heritage while acquiring both a bench value for conservation scientists in the future and an historical value for historians of science trying to understand the past.

The second part, entitled "Knowing by Making and Making by Knowing" shows how the interaction between material and conceptual aspects of materials fosters a feedback between the creation of materials and the creation of economic value in the market, or the creation of knowledge and techniques. In chapter 3, "Twentieth Century Fertilizers in France from Natural Mixing to Artificial Making (1890-1970)", Philippe Martin analyzes how the interplay of chemical and agronomic knowledge and know-how and consumption practices drove the gradual transformation of the French fertilizer industry over the course of eight decades. Martin investigates the trans-operations between the structure and composition of materials and the conceptions of rationality and modernity offered by industrialists and administrators who wanted to build faith in artificial materials. Jumping from industrial problems to academic communities, in chapter 4, Apostolos Gerontas considers "Chromatographs as Epistemic Things: Communities around the Extraction of Material Knowledge" during the 1960s and 1970s. By examining the production and dissemination of automated apparatus, Gerontas highlights the consequences that chromatographic technology

had for knowledge production in chemistry. New instruments turned the "separation" of molecules into a menial job, forcing a reorganization of analytic chemistry's division of labor. Similarly, chapter 5, "The Exotic Glasses of Rennes (France): Local Knowledge-Making in Global Telecommunication", by Pierre Teissier, shows how postwar research on materials was organized by a transatlantic division of labor, with new materials coming out of Europe and new physical phenomena manifested in those materials discovered in the United States. In Teissier's case study, the accidental production of "exotic glasses" in Rennes was shaped both by the bench culture of solid-state chemistry and by the telecommunications industry's support for international R&D.

The third, and last, part of the volume, entitled "Innovating and Recycling: Telling the Stories of Materials," exhibits the interplay between new stories and old materials, or between old stories and new materials. In chapter 6, "Making Sense of Chemistry: Synthetic Rubber in German Popular Scientific Literature (1929-2009)", Jens Soentgen analyzes a large set of German popular books to link changing representations of natural and synthetic rubber to changing political contexts. Rubber chemists were alternatively the heroes of industry, autarky, the working class, and the "apolitical" market from the Weimar Republic to the 21st century Federal Republic of Germany (BRD). With chapter 7, "Point and Line to Plan: The Ontography of Carbon Nanomaterials", Sacha Loeve draws a parallel between the modes of existence of three emblematic nano-materials (fullerenes, nanotubes, and graphene) and the three geometrical figures conceptualized by Vassily Kandinsky (point, line, plan). He shows how, from bench to brand, these materials are continually born anew in the space of indefinite technological possibilities saturated by promises of radical novelty: the "nanoworld". Finally, chapter 8, "The Diverse Ecology of Electronic Materials", by Cyrus Mody, investigates alternative histories of microelectronics by following two material alternatives to silicon that did not migrate from bench to brand nor from brand to bench: superconducting materials and fullerenes. This allows a better understanding of the evolving organization of the semiconductor (silicon) industry and, more generally, of changes in the relationship between industry and academia.

Concluding Remarks

Such an editorial project inevitably yields unexpected features which emerge from the collective efforts of the authors. We have identified at least four themes and questions which recur in stimulating if unanticipated ways across a number of contributions. The first is related to the study of

materials themselves and the making of materials researchers during the long 20th century. Most of the chapters develop the idea that materials are characterized by multiple features beyond their mere physical and chemical properties. Their forms are specifically investigated by chemists for applications (§1) and packaging (§3), in relation to their transformations over time, for worse (§2) or better (§7), their accidental morphology which can be selected (§5) and amplified, or even their systemic integration as devices (§8). All these forms are then brought within the one true dogma of materials scientists since the 1960s: the relationship between composition or structure and performance (§1, 2, 5). This dogma is not new, of course: metallurgists and chemists have formalized it for, among other things, the steels used for building railroads in the "second industrial revolution" (Misa, 1995; Chezeau, 2004). Yet as our chapters show, this dogma has been progressively formalized and expanded over the long twentieth century.

The second recurring theme of this volume stresses the importance of contingency in the historical process. Many of our chapters show that "it could have been otherwise" (§1, 3), "it was otherwise" (§5) or "it was told otherwise" (§6, 7, 8). However, in spite of a deep consciousness of alternative paths, several of our chapters also present linear narratives which convey the impression of a gradual determined evolution: for example, the drift toward a global neo-liberal order in the final third of the 20th century (§5, 8). Such a tension between determinism and contingency poses complications for sociological and economic models, which tend to favor the mechanical dynamics of social groups and markets. Yet the same tension also undermines the consensus in science and technology studies, which declares its faith in contingency and non-linear narratives.

Thus, tensions constitute the third recurring theme of the volume. Such dichotomies can be identified with respect to practices, such as the opposition between wet and dry syntheses (§8), as well as for moral discourses such as the good/evil dualism (§6). One crucial tension operates at a symbolic level between what is usual and what is new. Indeed, in any given chapter (§1, 3, 6), both the novelty of leading-edge research and the repetition of customs can play a role. More deeply, this tension underlies a second tension between tradition and modernity that runs all through the long 20th century. It would be worth studying the evolutions of the meaning of each end of these oppositions over time.

The fourth and last recurring theme deals with the generation of identity among chemists and their many stakeholders. Our authors treat identity as the upshot of a process involving both self and others, in which materiality and technology are implicated. This leads to the main theme of the volume: the shaping of beings confers identities upon things, and the

shaping of things confers identities upon beings (§1, 3, 4, 5, 6 are especially clear in this regard). This permanent, ongoing, mutual shaping of material substances and human societies also travels across all types of discourses on materials and people: commercial ads (§1), collective memory and myths (§2, 5, 7), political economy (§3), discipline-building (§4, 5), literature and propaganda (§6), and historical narratives (§6, 7, 8). Here again, mechanisms are complex. Disciplinary organization (Stichweh, 1994), boundary work (Gieryn, 1999), and commemorative practices (Abir-Am & Elliot, 1999) are central to the shaping of scientific identities. But many other dynamics are involved too (Teissier, 2014): things (devices, materials, brands), bench practices (concepts, instruments, know-how), professional organizations (companies, disciplines, networks, trade unions), collective memory and myths (monuments, narratives, testimonies). Chemists' identities are also built on a series of hierarchical differentiations whether between chemists and others (§1, 3, 5, 8) or among chemists themselves (§2, 4, 6). The latter often, again, reinforces binary dualism: dirty/pure (§1), wet/dry (§8), descriptive/predictive (§1, 3, 5), dull/exciting (§5, 7), self/other (§4), and so on.

Taken together, these four recurring themes offer a concise summary of our point. Materials, in both their form and function, are co-emergent with institutions, communities, organizations, networks, discourses, cultural hierarchies, and all the other ingredients of modern societies. Materials are also co-emergent with the individuals who populate those societies. In other words, the foundational 20th-century sociological debate over the primacy of structure or agency was always missing at least one other active pole: the materials which constrain and enable both social structure and individual agency. Crucially, the powers of materials are neither deterministic nor entirely contingent. Rather, materials mediate the entanglement of social structure and individual agency not just locally in any single interaction, but also through their never-ending circulation from bench to brand and back.

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