Plastics, materials and dreams of dematerialization

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'Plastics happen; that is all we need to know on earth.' This remark is extracted from *Gain*, a novel by the American novelist Richard Powers (2001: 771). At the end of the story of a successful family enterprise that grew into a big international company, a woman living nearby, Laura Bodey, is dying from ovarian cancer – presumably induced by a fertilizer produced by the chemical plant. To her husband, who has advised her to sue the company, Laura replies that even if the products manufactured by this plant did actually cause her condition, they have given her everything else and moulded her life. It is therefore impossible to balance the costs and gains of plastics. In her view, it does not make sense to blame plastics because they are an integral part of our world, of our lives.

In quoting Laura's reply in *Gain*, Philip Ball (2007: 115) comments that, 'Plastic stands proxy for all our technologies: Plastics generated an entire industrial ecosystem, a technological large-scale-system, which can no longer be controlled.' Taking Ball's stance in a different direction, in this chapter I will argue that plastics have also shaped a new concept of technological design and a specific relation between humans and materials. In particular, they have encouraged the dream of dematerialized and disposable artefacts.

Plastics are more than just ubiquitous manufactured products that are used all over the world. As plastics began to spread in the daily experience of billions of people, new concepts of design were developed that reshaped our view of nature and technology. The phrase 'Plastic Age' – often used to characterize the twentieth century – has been modelled on the categories of Stone Age and Iron Age. Such phrases suggest that the materials used for making artefacts shape civilizations, and that new materials propel a new age. Although our experience of materials is often occulted in daily life by the prevalence of the shapes and functions of the artefacts we use – phones, computers, automotive cars, aircraft – materials *do* matter. They are the core of technological advances and artistic creations; they drive economic business and the social distribution of wealth. Each substitution of a material for another one – for instance, iron, aluminium and plastics – engages new relations between nature and artifice, and determine specific relations between science and technology. Cultural historians have described the interaction between plastics and American civilization. For Robert Sklar (1970), the Plastic Age started after World War I when the traditional values of refined society gave way to mass culture, while Jeffrey Meikle (1995) convincingly argues that plastics gradually came to be identified with the American way of life and culture in the second half of twentieth century, with the emergence of a new aesthetics and new societal values.

This chapter aims to provide a better understanding of the interplay between the materiality of plastics and their anthropological dimensions. Previous materials, such as glass, wood and aluminium, are referred to by the name of the stuff of which they are made. By contrast, the common name of synthetic polymers derives from one of their physical properties. The adjective 'plastic' may be a predicate of humans as much as it is of things. The phrase 'Plastic Age' was already in use in the 1920s in the title of a film, and seems to refer to the malleable teenage years, when someone can be changed through life experience. A few years later, in his *Chemistry Triumphant*, William J. Hale announced the 'Silico-Plastic Age' (Hale 1932). The linguistic preference for the term 'plastic' is an indicator that plasticity gained a cultural meaning in the twentieth century. This requires a closer look at the physical and chemical properties of the class of materials gathered under the umbrella 'plastics', as well as at their production process. The entanglement between material, technical and cultural aspects shapes artefacts themselves, and reconfigures the relation between nature, artefacts and culture.

Following a brief historical sketch about the emergence of plastics-as-plastics and reinforced plastics, the chapter will describe how synthetic polymers contributed to the emergence of a new relation between technology and matter as they generated the concept of materials by design and 'materials thinking' – a new approach to materials in technological design. The next section looks more closely at the cultural values associated with the mass consumption of plastics, such as lightness, superficiality, versatility and impermanence. I will emphasize the utopian dimension of plastics and the striking contrast between the aspirations to dematerialization or impermanence and the neglected process of material accumulation upstream and downstream, which are respectively the precondition and the consequence of the Plastic Age. Finally, taking up the traditional issue of the relations between the natural and the artificial, I will consider how plastics are reconfiguring the contemporary vision of nature.

Expanding technological capabilities

In the twentieth century, plastics have replaced and displaced wood and metals in many commercial applications. This was by no means a natural and easy movement of substitution. While natural gums and resins such as *gutta percha* were manufactured in the nineteenth century for their insulating properties in electrical appliances, semi-synthetic polymers – such as parkesine, presented by Alexander Parkes at the London World Exhibition in 1862 and the celluloid manufactured by John Wesley and Isaiah Hyatt in the 1870s – were promoted as alternatives to more conventional solid materials. Lightness and versatility were their most striking novelty. Celluloid was described as a 'chameleon material' that could imitate tortoise-shell, amber, coral, marble, jade, onyx, and other natural materials. It could be used for making various things, such as combs, buttons, collars and cuffs, and billiard balls. However, as the historian Robert Friedel (1983) argues, parkesine and celluloid did not bring about a revolution and did not easily overtake more traditional materials. Celluloid was viewed as just one of a myriad of 'useful additions to the arts' (xvi). Iron, glass and cotton continued to be produced in the millions of tons, while the light celluloid never exceeded hundreds of tons. In addition, the fact that celluloid made out of cellulose and camphor could be given a variety of shapes, colours and uses did not strike consumers as a sign of superiority; on the contrary, its versatile and multi-purpose nature was viewed as a major imperfection. The alliance between one material and one function – still visible in common language when we use phrases such as 'a glass of wine' – was seen as a mark of superiority. This traditional view of nature was reminiscent of Aristotle's view when he claimed that the knives fashioned by the craftsmen of Delphi for many uses were inferior to nature's works because 'she makes each thing for a single use, and every instrument is best made when intended for one and not for many uses' (Aristotle DATE: 1252b). In this traditional view, multifunctional instruments are for barbarians who don't care for perfection, whereas distinction and discrimination signify the perfection and generosity of nature. Eventually – and despite its flammability – celluloid managed to win a place on the market when it was recognized that it was ideal for a number of applications, such as photographic films. Materials meeting all demands, purposes and tastes were not regarded as dignified. Far from being praised as a quality, plasticity was the hallmark of cheap substitutes, forever doomed to imitate more authentic, natural materials. It is only in retrospect, in view of the ways of life and the values generated during the Plastic Age, that we have come to value multifunctional artefacts.

Today, plastics are no longer considered cheap substitutes. They are praised because they can be moulded easily into a large variety of forms and remain relatively stable in their manufactured form. Certainly, the success of plastics-as-plastics is due to the active campaigns of marketing conducted by publicists who promoted them as materials of ‘protean adaptability’ that could meet all demands and bring comfort and luxury into everyone’s reach (Meikle 1995). Chemical companies in America presented plastics as a driving force towards the democratization of material goods. In the 1930s, chemical substitutes were also praised as pillars of social stability because they provided jobs and fed the market economy: ‘a plastic a day keeps depression away’ (106).

Enhancing the performances of plastics

In addition to the social benefits expected from plastics, a number of technical aspects related to their process of production account for plastics overtaking more traditional materials. Wood and metals pre-exist the action of shaping them: wood is carved or sculpted; metals are ductile and malleable – they melt at high temperatures, then the molten metal can be cast in a mould or stamped in a press to form components into the desired size and shape. By contrast, plastics are synthesized and shaped simultaneously. The process of polymerization is initiated by bringing the raw materials together and heating them – it is not separate from moulding. In more philosophical terms, matter and form are generated in one single gesture. This specific process is due to the ability of carbon atoms to form covalent bonds with other carbon atoms or with different atoms. Thus a chain of hundred carbon atoms can make a single macromolecule. The resulting thermosetting polymers are rigid, with remarkable mechanical properties; furthermore, unlike celluloid they are not heat sensitive. They are lightweight, have a high-strength-to-weight-ratio, are corrosion resistant, remain bio-inert and have high thermal and electrical-insulation properties. However, they cannot be reheated and moulded again. Soon a newer category of polymers came on to the market: these form weaker chemical bonds, and consequently can be reheated, melted and reshaped. These thermoplastic polymers, such as the polyethylene manufactured in the 1930s, are less rigid and more plastic than thermosetting polymers.

The synthetic polymers manufactured after World War II were already more plastic than early plastics and thermoplastics – such as polyethylene, polypropylene, polyester and PVC — and undoubtedly had a wide spectrum of applications. However, the plasticity of plastics can still be enhanced because various ingredients are added to the raw materials and included in the process of polymerization. Pigments were regularly added to produce a variety of colours, which became a distinctive feature of plastic materials in the 1930s; inorganic fillers of silica were also used to make cheaper materials. Other additives can improve various properties: thermal or UV stabilizers increase resistance to heat and light; plasticizers are added to make them more pliable or flexible (Andrady and Neal 2009); improved mechanical properties are obtained thanks to the addition of reinforcing fibres. Glass fibres were first added to reinforce plastics in the 1940s for military applications such as boats, aircraft and land mines (Mossman and Morris 1994). Reinforced plastics enabled expansion of the market in plastics in the 1950s for civil applications such as electric insulators and tankers. Initially, reinforced plastics were introduced for the purpose of weight saving and cost reduction in transport and handling. However, they generated a deep change in design, and facilitated a new approach to materials research.

Composites and materials by design

Because the mechanical properties of heterogeneous structures depend upon the quality of interface between the fibre and the polymer, it was crucial to develop additive substances favouring chemical bonds between glass and resin. The study of interfaces and surfaces consequently became a prime concern, and gradually reinforced plastics gave way to the general concept of composite material (Bensaude Vincent 1998). Although most commercial composites are made of a polymer matrix and a reinforcing fibre, composites may be made of metal and fibre The concept of the composite that came out of plastics technology has been extended to all materials associating two phases in their structure where each one assumes a specific function: steel or iron is used as a support for toughness; plastics are useful for weight saving; and ceramics are included for heat resistance and stiffness. Creating a composite material means combining various properties that are mutually exclusive into one single structure. Composites were created initially in the 1960s for aerospace and military applications. In contrast to conventional materials with standard specifications and universal applications, they were developed with both the functional demands and the services expected from the manufactured products in mind. Such high-tech composite materials, designed for a specific task in a specific environment, are so unique that their status becomes more like that of artistic creations than standard commodities.

While reinforced plastics were aimed basically at adding the properties of glass fibre or higher-modulus carbon fibres to the plasticity of the polymer matrix, composites did reveal new possibilities and generated innovations. For instance, the substitution of old chrome-steel bumpers of the cars of the 1950s for plastic bumpers did not immediately entail the cost reduction that was expected because the composite had opened new avenues for change. Manufacturing and shaping the chrome steel were two successive operations, in the case of plastic they became one and the same process. Car designers were consequently free to curve the bumper along the line of the shell. Instead of a separate part that had to be manufactured independently and then welded to the car, the shield was integrated with the body of the car like a protective second skin. In addition to protection, other functions could similarly be integrated. Thus ventilators and radiator grilles were combined with the same unit at the front. Integration proved useful because it reduced the number of parts and assembly steps. New concepts thus emerged that gradually integrated more and more functions into the same structural part. However, local change in the material structure of one part called for redesigning the whole automotive structure and, thanks to the synergy between structure, process and function, composites contributed to the development of a new specific approach to designing materials. The interaction of the four variables – structure, properties, performances and processes – is such that changes made in any of the four parameters can have a significant effect on the performance of the whole system and require a rethinking of the whole device. Engineers had to give up the traditional linear approach to innovation ('given a set of functions, let's find the properties required and then design the structure combining them') and convert to 'materials thinking'. They simultaneously had to envision structure, properties, performance and process.

Thanks to the enhancement of the intrinsic chemical and physical properties of plastics through materials thinking their market expanded to profitable and successful applications in transportation, sports items and a wide range of other products. Materials thinking also played a crucial part in the emergence of a new relationship with materials and matter in general. For materials designers, 'materials thinking' basically refers to a systems approach – a new method of design that takes into account all parameters simultaneously rather than sequentially. It has no connection with the phrase 'material thinking' in the vocabulary of social scientists, which mainly refers to the materiality of thinking (Carter 2004; Thrift 2006). Despite the divergence of references, the rapprochement between the two contexts is interesting in terms of opening the question of the meaning to be given to this new practice of design. Social scientists use the expression 'material thinking' in order to emphasize the active participation of materials in the mental activity of thinking. Similarly, the designers of artefacts could insist on the role of the physical and chemical properties of plastics that afford new opportunities in terms of design. They could emphasize that materials become active participants in the design process rather than passive objects of manipulation. However, in their discourse, materials have no say in the creative process. On the contrary, engineers and designers seem to emphasize that materials are no longer a prerequisite for design, as they adopt the phrase ‘materials by design’. This phrase suggests that they are emancipated from the constraints and resistance of matter.

Materials themselves can be purposefully tailored to perform specific tasks in specific conditions. For instance, in the 1960s space rockets required never-seen-before combinations of properties: they had to be lightweight, and resistant to both high temperatures and corrosion. Early composite materials were designed for such applications, and a number of them have been transferred successfully to everyday commodities such as sports articles or clothes. Materials are no longer a prerequisite for the design of artefacts, and would no longer limit our possibilities of creation. Thanks to the enhanced plasticity of composites, designers could feel emancipated from the constraints of matter, free to create artefacts, buildings or haute couture clothes according to their own inspiration.

Composites encouraged the quest for the ideal material, with a structure in which each component would perform a specific task according to the designer’s project. Matter came to be presented as a malleable and docile partner of creation – a kind of Play Doh in the hands of the clever designer who informs matter with intelligence and intentionality. Just like the *demiurgos* in Plato’s *Timaeus*, the material engineer can impose forms on a passive, malleable chora. For instance, in the 1990s a French company manufacturing sheet-moulding compounds for making composites advertised its products with the image of a plastic toy car and the following comment: ‘What is fantastic with Menzolit play doughs [sic] is that one can press, inject, twist them, they lend themselves to all your ideas’. The plastic resin being shaped and informed by human intelligence becomes a smart composite material. The ad proudly concluded: ‘Grey matter [is] the raw material of composite materials.’ (Menzolit, 1995)

Designing materials with in-built intelligence is the ultimate goal of a number of research programs launched in the 1990s. Smart or intelligent materials are structures whose properties can vary according to changes in their environment. They are plastic insofar as they can adjust to changing conditions or self-repair in case of damage. For example, materials with a chemical composition that varies according to their surroundings are used in medicine to make prostheses. This requires them to have embedded sensors (for strain, temperature or light) and actuators so that the structure becomes responsive to external stimuli.

The stuff that dreams are made of

Plasticity, the distinctive property of synthetic polymers has permeated through culture. The French philosopher Roland Barthes (1971) devoted a few pages to plastics in his review of the mythologies of modernity. 'Plastics,' he wrote, 'are like a wonderful molecule indefinitely changing.' (171–2) Plastics are shapeless; they have pure potential for change and movement. They connote the magic of indefinite metamorphoses to such a degree that they lose their substance, their materiality, to become virtual reality. Plastics have thus encouraged the utopia of an economy of abundance that could consume less and less matter by using cheap, light, high-tech plastics. Although Barthes witnessed only the debut of the flood of cheap fashionable and disposable products, especially designed to become obsolete after a few uses, he saw the coming of a new relation of our culture to time. Whereas gold or diamond conveys a view of permanency and eternal faith, plastics epitomize the ephemeral, the ever-changing. They invite us to experience the instant for itself as detached from the flux of time.

In his remarkable study of plastics in American culture, Jeffrey Meikle (1986) emphasizes that plastics have often been presented as 'utopian materials', and that they gradually came to epitomize a kind of dream world. The rapprochement between plastics and Disney World not only rests on the abundance of fibreglass-reinforced polyester structures in the amusement park at Orlando; it is also justified by the cultural values developed along with the use of plastics in everyday objects, from Bic pens to razors, telephones and credit cards. The daily experience of plastics transformed American culture: 'Increasingly that culture was seen as one of plasticity, of mobility, of change, and of open possibility for people of every economic class'. (1986: 45) The counter-culture movement, which criticized the American way of life, used the term 'plastic' as a metaphor for superficial and inauthentic people whose life was driven by a passion for consumption and change.

They could also point to the inherent paradox of plastics. These light, colourful and cheap materials, apparently liberated from the constraints of gravity, from rigid shapes and duration, are inextricably linked to the accumulation of huge quantities of matter and energy. As Jean Baudrillard (2000) points out, plastics instantiate the contradictions of a society oriented towards the mass manufacture of more and more disposable products. About 300 million tonnes of plastics are produced each year. These ephemeral commodities generate tonnes of durable waste, since thermoplastics can persist for extended periods of time in the environment (Barnes et al. 2009). From urban suburbs to the most remote places in the countryside, they have invaded the natural habitats of living species on earth and in the oceans. Furthermore, as most synthetic polymers are made out of fossil fuels, they use about 4 per cent of the world's oil. Plastics irreversibly consume the vestiges of plants accumulated over thousands of years. The two processes of accumulation surrounding the short life of plastic commodities clearly indicate that their ephemeral character is delusory. Despite its hedonistic inclinations, the Plastic Age developed a mathematical notion of time as an abstract space consisting of a juxtaposition of discrete points or instants, blurring all issues of persistence and permanence. Plastics are supposed to be ephemeral only because – like the flying arrow of Zeno's paradox commented on by Bergson (1946) – they are supposed to be at rest, as moments of being. By contrast, our Plastic Age confronts the issue of duration. The ephemeral present of plastics is not just an instant detached from the past and the future. It is the tip of a heap of memory, the upper layer of many layers of the past that have resulted in crude oil stored in the depths of the soil and the sea. The cult of impermanence and change has been built on a deliberate blindness regarding the continuity between the past and the future. Plastics really belong to Bergson's duration; they cannot be abstracted from the heterogeneous and irreversible flux of becoming. The present is conditioned by the accumulated traces of the past, and the future of the earth will bear the marks of our present. While the manufacture of plastics destroys the archives of life on the earth, its waste will constitute the archives of the twentieth century and beyond.

Plastic nature

According to cultural historians, the Plastic Age culminated with the fashion for artificial fabrics, paintings and dyes. In the plastic items manufactured in the 1960s and 1970s, shining, fluorescent and flashy surfaces prevailed over the traditional preference for pastel colours that looked more natural or genuine. The cult of the artificial exemplified by Andy Warhol paintings broke with the early plastics, which desperately attempted to imitate wood, horn, shell or ivory in appearance and colour. They had no intrinsic value – they were praised only for their cheapness and their potential for the democratization of comfort. They were also occasionally valued because synthetic substitutes could spare the life of tortoises, elephants and baby seals. For instance, Williams Haynes (1936: 155) claimed that, 'The use of chemical substitutes releases land or some natural raw material for other more appropriate or necessary employment.' The synthetic was thus a useful detour in the conservation and protection of nature.

The Plastic Age radically transmuted the cultural values attached to the natural and the artificial, and reinforced the cultural stereotype associating chemists with Faust or the alchemists who challenged nature. At first glance, it could be expected that, by design, the light, quasi-immaterial materials would reinforce the culture of the artificial initiated by thermoplastics in the mid-twentieth century. What could be more unnatural than composite materials as light as plastic with the toughness of steel and the stiffness or heat-resistance of ceramics? Like the centaurs invented by the Ancients, they combined different species into one body, into their inner structure. They could consequently revive the mythical figures of Prometheus or Faust. Indeed, the Promethean view of engineers 'shaping the world atom by atom' has been revitalized by the promoters of nanotechnology. The slogan of the US 2000 National NanoInitiative announced an era when materials would be designed and engineered bottom-up, with each part of the structure performing a specific task (Bensaude Vincent 2010). The ambition to overtake nature with our artefacts is still very much alive today.

It is nevertheless counterbalanced by a back-to-nature movement that emerged in the 1980s. The more pressing the quest for high performance and multifunctional plastics, the more materials chemists and engineers turned to nature for inspiration. Most of the 'virtues' embedded in materials by design – such as minimal weight, multifunctionality, adaptability and self-repair already exist in natural materials. Amazing combinations of properties and adaptive structures can be found in modest creatures such as insects and spiders. Spider webs attracted the attention of materials engineers because the spider silk is made of an extremely thin and robust fibre which offers an outstanding strength-to-weight ratio. Wood, bone and tendon have a complex hierarchy of structures, with each different size scale – from the angström to the nanometre and micron – presenting different structural features. Their remarkable properties and multiple functions are the result of complex arrangements at different levels, where each level controls the next one. Nature displays a level of complexity far beyond any of the complex composite structures that materials scientists have been able to design. In addition, nature designs responsive, self-healing structures that quickly adapt to changing environments. And above all, the plastic structures designed by nature avoid the vexing issue raised by human-made plastics, namely accumulating tonnes of litter all around the world. They are degradable and recyclable.

Finally, what materials designers most envy is nature's building processes. Synthetic chemists managed to get polymerization and moulding, matter and form, into one single operation. Nature goes even further, thanks to the self-assembly of molecules. While synthetic polymers are built with strong covalent bonds, molecular self-assembly is a spontaneous organization of molecules into ordered and relatively stable arrangements through weak non-covalent interactions. Molecular self-assembly is extremely advantageous from a technological point of view, because it generates little or no waste and has a wide domain of application (Whitesides and Boncheva 2002). Self-assembly appears to be the holy grail for designing at the nanoscale, where human hands and conventional tools are useless. It is the key to a new age: 'The Designed Materials Age requires new knowledge to build advanced materials. One of the approaches is through molecular self-assembly.' (Zhang 2002: 321)

Because molecular self-assembly is ubiquitous in nature, nature seems to capture all the attributes of plastics. Whereas, in the early twentieth century, natural structures were characterized as rigid, stiff, resistant and resilient in contrast to synthetic polymers, one century later, the same natural structures investigated at the nanoscale are characterized as 'soft machines' (Jones 2004) – highly flexible, adaptive, complex and ever changing.

Despite their admiration for nature's achievement, biomimetic chemists are not inclined to revive natural theology and its celebration of 'the wonders of nature'. Rather, biomimicry proceeds from a technological perspective on nature. Nature is depicted as an 'insuperable engineer' that took billions of years to design smart materials. They study the structure of biomaterials and the natural process of self-assembly with the conviction that nature has worked out a set of solutions to engineering problems. With its exquisite plasticity, nature affords a toolbox to inventive designers of advanced materials. Atoms and molecules are functional units useful for making nanodevices such as molecular rotors, motors or switches. Biopolymers provide smart tools: the two strands of DNA are used to self-assemble nano-objects; liposomes are used as drug-carriers. Living organisms such as bacteria are being re-engineered or even synthesized to perform technological tasks. 'E-coli moves into the plastic-age' was the title of a research news item announcing that plastics which are part of our lifestyle would be synthesized by E-coli bacteria with no waste disposal, and no more pollution or contamination of the environment (Lee 1997).

Conclusion

In following the migrations of the term 'plastic' from the realm of materials to the realm of humans and to nature throughout the twentieth century, this chapter has emphasized the interplay between materials and culture. From a view of nature as a stable, rigid order, our culture has shifted to a view of nature as plastic, versatile and based on the ever-changing arrangements of molecular agencies. The success story of plastics, which combined the specific features of synthetic polymers and the markets in which they flourished, deeply reconfigured consumer practices as well as those of design. Because plastics are objects of design, they are more than polymers. The classical terminology of polyethylene, polystyrene, polypropylene, phenol-formaldehyde and so on is not really adequate, since the properties and uses of plastics depend on plasticizers, fillers, UV protectors and the like. The traditional classifications of materials become obsolete when plasticity is so highly praised that design embraces materials themselves. Thus plastics renewed the ambition of shaping the world according to our purposes with no resistance from nature.

This chapter has also pointed to the blind spots generated by the Plastic Age. In cultivating plasticity as a chief value, the twentieth century had to develop a sort of blindness about the impacts of material consumption on the environment and on the future. Indeed, mass consumption in general requires no concern with the afterlife of commodities, however much the cult of disposability and ephemerality associated with plastic reinforced and perpetuated this denial. The cultural history of plastics must be completed by agnotology studies pointing to the social construction of ignorance necessary for the mass diffusion of plastics (Proctor and Schiebinger 2008). This sort of ignorance is a denial – a self-deception – that allows us to live in a fools' paradise.

Although the twenty-first century seems to be more aware of environmental issues and more concerned with the future, plastics retain their utopian nature. Plastic items may have acquired a very bad reputation for many people, but the concept of plastic, malleable matter is still extremely attractive. The emerging economy of biopolymers and biofuels designed at the molecular level is based on the vision of nature as a limitless field of potentials. Design from bottom up, proceeding from the ultimate building blocks of nature, is supposed to meet no resistance and to afford a free space for creativity. It encourages the view of matter as purely plastic, passive and docile, subject to the designer's purposes. The techno-utopia of the Plastic Age is not over. It continues through the denial of the constraints imposed by matter and nature's laws. Just as 'the light dove, cleaving the air in her free flight, and feeling its resistance, might imagine that its flight would be easier in empty space', contemporary designers cherish Plato's illusion that we could be free from matter and venture beyond it on the wings of ideas. In paraphrasing Kant's (2003) criticism of Plato, one could say that the Plastic Age will be over when the dove-designer realizes that resistance might 'serve as a support upon which to take a stand to which he could apply his powers'.

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