

Monopoly Capital and the Rise of the Synthetic Age

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Few things have entered our world as quickly, and in such abundance, as plastics. Virtually nonexistent a little over a hundred years ago, plastics have become a monumental economic force, an apparent social necessity, and an ecological conundrum. The rise of synthetic plastics in the twentieth century as a ubiquitous aspect of modern life is often taken for granted as the inevitable outcome of science and technological progress developed in the process of meeting human needs. However, as Harry Braverman argued, technological development and the application of science take on various forms in relation to changes in broader sociohistorical conditions. “There are very few ‘eternal’ or ‘inevitable’ features of human social organization,” he noted, and “only by way of concrete historically specific analysis of technology and machinery on the one side and social relations on the other, and also of the manner in which these two come together in existing societies,” can we develop a fruitful understanding of their development and growth.¹

The production, application, consumption, and waste of plastics in its various forms can be analyzed effectively from a historical-materialist perspective. As plastic pollution piles up and despoils the planet, both on land and at sea, poisoning increasingly numerous forms of life and contributing to environmental changes on the broadest levels, these synthetic materials are having consequential effects on Earth systems and a multitude of organisms. Examining the rise of plastics – from its non-synthetic origins to its semi-synthetic and, finally, fully synthetic forms – provides socioecological insights for understanding the roots of the current ecological crisis and the ways in which the modern social metabolic order is transgressing the universal metabolism of nature.

The era of monopoly capitalism has had, and continues to have, significant implications for the developments of the social metabolic order of capital, especially during the twentieth century. In this article, we outline the rise of plastics from a marginal, but nonetheless materially im-

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portant, productive force in the nineteenth century to its emergence as a dominant raw material of production in the post-Second World War era and into the modern “Synthetic Age.”² We highlight the centrality of plastics as productive materials and as a significant part of the material foundation of the modern capitalist social metabolic order.

In what follows, we examine key moments of this historical process as they relate to: (1) political-economic development in the United States during the era of monopoly capitalism and imperialism, and (2) the shift from plastics of natural origin to synthetic plastics. These two points are interrelated: certain changes in the mode of production—how things were produced, the volume and scope of production, the scale of production, the productive relations, and so on—coincided with and influenced shifts in the nature of the productive materials. The need for raw materials with certain characteristics (for example, a rapid production time, as well as being moldable, compatible with a high capital-to-labor ratio, accessible, durable, inert, and lightweight) was intimately connected to the new possibilities, as well as the needs and demands, that arose with the further development of monopoly capitalism.

The Era of “Natural Plastics”

The history of the plastics industry can be divided into two different axes. The first is the natural/synthetic axis, the second is the thermo-set/thermoplastic axis. Historically, there is a clear succession from plastics of natural origins— which include rubber, gutta-percha, and shellac, among others—to the advent and widespread use of synthetics. Perhaps the best-known and most widely used plastic of natural origin is rubber. Originating from the sap of heava trees, rubber in some form or another has been used for millennia. However, it was not until the early nineteenth century that the rubber was converted into capital via technological developments that allowed it to be used for commercial purposes and incorporated into capitalist production as a raw material.³ Its commercial potential was limited until 1839, when Charles Goodyear introduced the process of vulcanization. Much of the machinery and labor processes used in the manufacture of vulcanized rubber goods (also known as “hard rubber”) were later used in the synthetic plastics industry.⁴

Another natural plastic, gutta-percha, also originates from the sap of a tree found in the tropics and has also been used for millennia. It has properties similar to rubber, except that it naturally contains oxygen. Because of its kinship to rubber, gutta-percha was seen as a potential rubber replacement or supplement. However, it cannot be vulcanized, and thus is significantly more limited than rubber in its possible uses. Gutta-percha,

unlike rubber, is dielectric – it can transmit electricity without conduction – and therefore is perfectly suited for underwater electrical wire insulation, and greatly superior to rubber for this purpose.⁵

The history of gutta-percha encapsulates much of the early capitalist history of natural plastics: the rapidity of technological and industrial development that generates a host of new material needs, the demand for raw materials for industrial production that quickly outstrips their supply, and the primitive methods of extraction coupled with increasingly advanced means of industrial production and organization.⁶ Gutta-percha as a raw material used in industrial production served a pivotal role in the further development and expansion of capitalism, to which it was uniquely suited. Telegraphy – the primary information and communications technology of the mid-nineteenth century, an era that preceded telephony, television, radio, or wireless communication methods – was “called forth” by the exigencies of empire, as was a material that could effectively insulate a massive network of underground and underwater electrical cables connecting much of the world. As John Tully explains,

It could take over six months by ship for messages to reach the imperial capital from the colonies. The problem was solved by the invention of the electric telegraph.... The key to the success of the new system was a natural plastic, gutta-percha...which proved indispensable as insulation for the submarine cables. However...the “gum” was obtained by profligate, inefficient, and ultimately unsustainable methods of extraction, which killed the trees in the process.... So great was the demand for the gum that the wild trees that provided it were almost extinct by the late nineteenth century, causing a flutter of panic in an industry that had taken it for granted.⁷

Gutta-percha played a key role in the global consolidation of capitalism during the era of industrialization, British empire-building, and colonialism directly preceding the era of imperialism and monopoly capitalism. It helped facilitate capitalism’s rise by laying the groundwork for a more globally integrated capitalist system. Gutta-percha’s brief, yet vital, story also highlights the shortcomings of natural plastics as capital in raw material form and the impetus to develop alternatives that transcended these shortcomings.

There are several additional natural plastic or plastic-adjacent materials that were important for the historical shift from natural to synthetic, including papier-mâché; materials such as ivory, tortoiseshell, and bone; and shellac. These so-called natural plastics, called proto-plastics, each have two things in common. The first is that except for hard rubber, they were largely replaced by synthetics in the twentieth century. Even rubber, while it continues to be used, was eventually supplemented by

a synthetic substitute. Today, roughly half the world's rubber supply is synthetic.⁸ The second is that the adoption of each of these substances portended the desire for a sufficiently pliable, moldable, lightweight, inert – in a word, plastic – raw material that could be applied to the production of the ever-increasing number of industrial and consumer goods demanded by the dictates of capital accumulation, particularly during the dynamic era of monopoly capital.

The first reasonably successful attempt at making a (partially) synthetic plastic for generalized use was the invention of celluloid. The original iteration of this material was produced in 1862 by British inventor Alexander Parkes.⁹ Dubbed “Parkesine,” its inventor aimed to create the first “plastic mass”: a widely used raw material that could be industrially molded, shaped, and mass-produced for a vast variety of commercial and industrial uses. “This matter of molding went straight to the heart of the Industrial Revolution, because a moldable material is ideally suited to mass manufacturing,” and can be produced “without having to resort to skilled artisans hand-tooling each article.”¹⁰ Parkes wanted to produce a material more cheaply and from more easily accessible raw materials that could compete with natural materials in the waterproofing, jewelry, consumer item, and electrical wiring insulation markets.¹¹ His attempts to do so were fraught and riddled with problems, particularly in regard to material quality, production costs, and the maker's uncertainty about his own product.

Following the development of Parkesine, John Wesley Hyatt formulated the process for making celluloid. As the first partially synthetic plastic material, celluloid generated greater interest in a synthetic plastic base material that was more widely applicable for industrial uses while simultaneously running up against its limitations in this regard. There are several reasons why celluloid was presupposed to be such a generalized plastic material while being unable to fulfill this role itself. Celluloid was, in part, developed out of a desire for raw materials for mass production that were not contingent on the vagaries of natural processes; for example, reliance on resources that were both far away from and out of reach to the centers of capital, geographically and/or politically. Celluloid, however, largely failed in this regard. The reliance on camphor sourced from East Asia made celluloid susceptible to many of the same problems as natural plastics and other raw materials. Many celluloid producers attempted to develop a synthetic substitute for camphor that could be produced domestically, to little avail.¹²

Celluloid was also developed in part with the aim of overcoming the constitutional limitations of natural materials – their inherent tendency to decay, degrade, and, with time, lose their structural integrity. While the partial synthetic transformation that occurred made it less susceptible to

these processes, akin to the rubber vulcanization process's effects on the structural integrity of rubber, celluloid was, nonetheless, still limited. It did not handle high temperatures well and had a flammability problem.¹³

Synthetic Plastics

The second classification method for categorizing plastics, after the natural-synthetic axis, is whether the material is thermosetting or thermoplastic. The first thermoset plastic (meaning that the plastic “sets” and takes form when heated and cannot be melted down and refurbished) was called Bakelite; this was also the first synthetic plastic. Conversely, thermoplastics, which include celluloid, as well as most of the synthetic plastics developed in the interwar period and widely introduced to consumer markets after the Second World War, can be melted down and refurbished.¹⁴ This made Bakelite and other thermosets ideal for industrial and electrical uses, as it forms a durable, rigid material once cured, and can be molded into a plethora of shapes and forms before being heated to meet an array of hardware needs. It also made Bakelite quite different from celluloid – in fact, most celluloid engineers did not at first understand how to work with it. This is because Bakelite was not just a new material, but also a new industrial process for producing raw materials and consumer goods – an important distinction between “product” versus “process” inventions.¹⁵ Bakelite represented an innovation not just of materials, but also of ways to produce those materials and of qualitative leaps in the field of organic chemistry, as well as the scientific methods of production and manufacture.

Invented by the Belgian-American chemist Leo Baekeland in 1907, Bakelite was also the first plastic that relied on fossil fuel production, namely coal, for its material feedstocks. The material was developed via the earliest successful chemical synthesis of phenol and formaldehyde, an enigma that had long stumped chemists. Phenol is a byproduct sourced from coal tar, while formaldehyde is derived from wood alcohol. Baekeland was initially less interested in developing a celluloid substitute and was instead more motivated to discover a synthetic replacement for the natural plastics of shellac and hard rubber, particularly for use as an electrical insulator, as well as for other industrial-electrical uses. In fact, the electrical insulation market was where Bakelite first found success, as it was vastly superior to natural plastics for that purpose. While celluloid helped generate new markets and ideas for plastic materials, its shortcomings prevented it from expanding in the ways that had been envisioned. Baekeland, an independent entrepreneurial inventor, “was more concerned with industrial applications,” as well as “producing raw materials for industry,” than he was concerned “with finding a substitute for

luxury plastics.” This was explicitly in contrast to celluloid, as “celluloid chemists focused primarily on consumer goods.”¹⁶

Bakelite fit many of the turn-of-the-century needs of capital accumulation by providing a crucial, if often overlooked, material throughput for the expansion of the electricity, telegraphy, telephony, phonography, radio, and automobile industries – all key to the emergence and consolidation of monopoly capitalism-imperialism. Regarding its use as electrical insulation, the precipitous explosion in demand for electricity, initiated by the discovery of the electrolytic cell between 1800 and 1810, generated a need for both a technically superior and more readily available raw material than shellac and gutta-percha.¹⁷

Shellac was sourced from the secretions of the lac beetle, native to Southeast Asia. As with gutta-percha, there were concerns about the stock of this natural resource sourced from the far-away East, dwindling in supply and relying on a labor-intensive extraction process. The extraction process was also dependent on the natural metabolic life activity of the insects and the trees upon which they secreted. All of this led Baekeland to search for a synthetic substitute.¹⁸ Not only was he able to replace shellac with a synthetic substitute seemingly divorced from reliance on nature’s metabolic cycles and labor-intensive processes, but he had produced one that was “vastly superior” as an electrical insulator “to any natural material on the market.” Comparing it to non-synthetic raw materials for use as electrical insulation, Stephen Fenichell, the author of *Plastic: The Making of a Synthetic Century*, states:

[Bakelite] was more electrically resistant than porcelain or mica; more chemically stable than rubber; more heat resistant than shellac; less liable to shatter than glass or ceramic; it would neither crack, fade, crease, nor discolor under the influence of sunlight, dampness, or salt air; it was impervious to ozone, contained no sulfur to cause the “greenling” (degradation over time) suffered by hard rubber, and could not be weakened by hydrochloric acid or blemished by alcohol. Contact with oil- or grease-stained fingers would not warp, mar, or disfigure it; it was virtually impervious to natural or human attack.¹⁹

This is what sociologist and historian of technology Wiebe Bijker called a “fourth kingdom,” consisting of synthetic, human-made materials not previously existing in the universal metabolism of nature – a kingdom neither animal, vegetable, nor mineral.

Bakelite’s first major use was as electrical insulation. But the notion that it was a superior alternative to the natural plastics it replaced is in fact acutely metaphorical. Its superior insulative qualities listed above betrayed the very characteristics that made it so valuable as a form of productive capital. The ability of human-made, synthetic plastic material to

resist the natural metabolic processes of aging, weathering, state changes of matter, and certain chemical alterations appeared to insulate it from nature itself. This reflected, in material form, the partial realization of a generalized tendency of the social metabolism of capital: liberation from the exigencies of the degenerative and atrophic cycles of the natural world. While baked into the very nature of capitalism, this drive to “insulate” from the constraints and degenerative processes of natural systems took a qualitative leap in the era of monopoly capital. This is in large part due to the further globalized nature of monopoly capitalism, along with the coincident need to communicate, travel, and ship goods over longer distances more frequently and with greater urgency. The development of more mechanically complex, sophisticated technology, which was central to the further development of capitalism and the shift to its monopolistic phase, often foreshadowed the necessity for more structurally durable, reliable, and inert materials that were abundantly available and cheaply produced. This further heightened the consequences of control by both nation-states and blocs of capital over access to crucial material inputs, such as fossil fuels, during the era of monopoly capitalism-imperialism.²⁰

As mentioned, Bakelite both provided a spur for and a crucial component in the further expansion and consolidation of the dominant information and communication technologies of the late nineteenth and early twentieth centuries, as well as transportation technologies, both of which were pivotal in the consolidation of globalized monopoly capitalism. The export of capital, an essential feature of imperialist monopoly capitalism, required greater and more efficient means of global transportation of machinery, production equipment, goods, and other material and energetic throughput.²¹ The substantial leaps in the rise of global finance at the turn of the century, with the United States in a favorable position after the First World War to dominate as the world’s leading creditor nation, also gave rise to new global communication needs.²² New forms of transportation, namely the automobile – one of the most central developments of the monopoly-capitalist economy – required a host of raw materials amenable to both the mass production methods of Fordist manufacturing as well as a range of industrial-electrical parts, gears, gadgets, and insulation material.

With intensified global trade came the need for faster, more reliable forms of both transportation and communication and information technology. A major obstacle to the development of these industries “was that natural raw materials could not always provide the properties and consistency of quality” required for them.²³ Specifically, the demand for electrical insulation – particularly for underwater trans-Atlantic telegraph

cables – the near depletion of gutta-percha stocks by the turn of the twentieth century, and the ongoing expansion of intercontinental telegraphy presented pressing material needs. In 1902, the president of the Institution of Electrical Engineers argued that it was precisely the problem of electrical insulation that was impeding further expansion of the distance of cables.²⁴ Thus, it is not merely that Bakelite was a better substitute for the natural materials that it replaced, but that it opened vistas for the expansion of telegraphy, electricity, telephony, automobilization, and a host of other industries that played an essential role in the expansion and intensification of the social metabolism of monopoly capitalism and ongoing capital accumulation.

Thermoset plastics were critical components in the industrial development of the first half of the twentieth century, fueling the electrical industry and the mass production of cars, radio, television, telephones, refrigerators, airplane travel, and information and communication technologies. It also set the terms for future plastic development and popularized plastic in the public consciousness. However, many of thermosetting plastic's characteristics that made it the ideal material for industrial hardware uses – extreme temperature stability, inertness, and the inability to remelt and remold – also limited its further market expansion.²⁵ Bakelite's further growth, particularly in the world of consumer goods, was also restricted by its narrow range of colors. Bakelite could only be colored black or dark brown. While fine for industrial purposes, it constrained its use for consumer goods, where bright, appealing colors and color variation were considered valuable for product appeal and marketing.²⁶

Another intermediary plastic that emerged between the thermoset and thermoplastic eras was cellulose acetate. Initially created as a non-flammable substitute for celluloid (cellulose nitrate), cellulose acetate eschewed camphor, thus avoiding celluloid's flammability issues. Cellulose acetate was made from cellulose, rather than coal tar byproducts. It also addressed some of Bakelite's limitations, including its relatively intensive production methods, and acted as a harbinger for the new wave of thermoplastics. This cellulose plastic helped shape the transition away from thermosets to thermoplastics primarily through the introduction of new methods of plastic production, injection molding, and the corresponding machinery and other productive forces.

Cellulose acetate, along with materials such as urea formaldehyde, functioned as stopgaps between the era of thermosets and thermoplastics, in a manner akin to celluloid's role as a bridge between the natural and synthetic plastic epochs. Both attempted to address some of the shortcomings of Bakelite – particularly its limited color range and its slower, more

labor-intensive production methods. Both highlighted many of the characteristics sought after in the synthetic thermoplastic boom, but neither fully broke through to become the principal form of plastic for the new era of capitalist production after the Second World War.

The New Thermoplastics

The chemical basis for new thermoplastics began to be established in the 1920s, with the scientific discovery that polymers were in fact large molecules containing hundreds of thousands of atoms with massive molecular weights. This recognition, as well as the discovery of long-chain theory explaining that the atoms in the large polymer molecules are connected by long chains, rather than networks or block formations, provided polymer chemistry with the foundational knowledge needed to produce this new class of plastics. From here, organic chemists could distinguish between thermosetting and thermoplastics based on their atomic structures, as well as distinguishing between different types of, and means of producing, polymerization.

The development of plastics such as Bakelite and celluloid was driven mainly by efforts to substitute raw materials that were either expensive, finite, rare, imported, or some combination thereof. Plastic developers of the late nineteenth and early twentieth centuries thus set out to produce a new plastic mass to meet a particular material need. In contrast, the development of new thermoplastics was more multifaceted. At times, this process started with a chemical monomer of which there was an abundance; and the petroleum and/or chemical company then sought to find a way to monetize it through transforming it into a polymer via the process of polymerization. This was in part a question of supply of chemical byproducts produced from the processing of fossil fuels rather than demand for new materials and stemmed from the rise of the petroleum and natural gas industries, industrial chemistry, and the marriage of the two, culminating in the petrochemical industry. Yet, the demand for raw materials played an important role as well, particularly during the Second World War, when access to many staple raw materials was restricted, spurring demand for domestically produced, synthetic replacement materials.

With the further consolidation of monopoly capitalism in imperialist nations such as the United States, the centrality of control over raw materials came to the fore in ways that diverge from pre-monopoly capitalism, heightening the importance of command over raw materials stock and supply. Here, material discovery also played a pivotal role, with the revelation of vast oil fields throughout North America and the Middle East, among other regions, as well as technical innovation, enabling petroleum to replace agricultural inputs and coal as the main synthetic

feedstock. Similarly, the significance of the sales effort to monopoly capitalism played a critical role here too, in convincing both the producers of producer and consumer goods, as well as consumers themselves, of the desirability of plastics. This two-pronged sales effort aimed at producers and consumers of goods – albeit in different ways and using different methods of persuasion – on the part of the plastics industry generated demand for new products and for the replacement of traditional raw materials with plastics. This required convincing the public of the benefits of synthetic plastics. These efforts played a part in ushering in the origins of disposable consumption on a mass scale, along with increased consumption generally, and included massive public relations campaigns promoting the safety and superiority of plastics for a variety of uses.

Synthetic, petrol-based thermoplastics were completely dependent upon the rising oil industry – its infrastructure, industrial processes, and high demand – and the emerging science of petrochemistry. Thus, thermoplastics were part of an “integrated materials production system,” in which oil and natural gas refining provide the raw materials for plastic production. Plastics as competitive, abundant, relatively cheap raw materials owe much to the fact that they are produced from fossil fuel byproducts. “The history of integrated production systems is often a history of by-product management,” argues Kenneth Geiser, a specialist on hazardous waste and toxic pollution policies, “because the profitable utilization of waste materials is a frequent determinant of a successful process.”²⁷ The stories of oil and plastics, from the interwar period up to today, are thus intimately and inextricably linked.

While Germany was the unrivaled global leader of organic chemistry throughout the late nineteenth and early twentieth centuries, the birthplace of the modern petrochemical industry is the United States. The United States, unlike Germany, had vast oil and natural gas reserves, and thus U.S. companies were on the cutting edge of the use of petroleum and natural gas byproducts and feedstocks for chemical production. Four giant U.S. companies – two chemical, and two petroleum – were the primary players in the rise of its petrochemical industry. These were Union Carbide (the company that acquired Bakelite in 1939) and Dow Chemical on the chemical side, with Standard Oil of New Jersey (one of the independent regional companies formed after Standard Oil’s court-mandated break up, which later became Exxon, and then ExxonMobil) and Shell on the petroleum side.²⁸ These four companies were ahead of the curve, as most of their chemical and petroleum peers in the United States remained loyal to coal feedstocks and were not interested in transitioning over to petroleum and natural gas, a shift that was not fully consummated until the Second World War.

The oil companies provided the feedstocks for chemical companies, with chemical and oil companies coming together to form a new monopolistic mega-industry, based on the chemical knowhow of the former and the materials of the latter. The petrochemical industry formed the industrial basis for new thermoplastics, and for the precipitous rise in plastic production, consumption, and raw material market domination in the second half of the twentieth and twenty-first centuries. It also played an essential role in the consolidation of U.S. imperialism and the domination of the global monopoly-capitalist system following the Second World War.

While many of these new plastics first emerged in the period between the two world wars, they were initially of limited use. Upon entering the Second World War, the United States directed massive government funds to further their development. Access to foreign raw materials like natural rubber and silk were cut off, spurring demand for domestically produced materials to serve the war effort. With large amounts of petroleum being used as fuel for military purposes, there was incentive to use the chemical byproducts produced in the extraction and refining processes. Here, the case of rubber serves as an illustrative example of the role of petrochemical-based plastics in producing war materials, the competition between Allied and Axis powers to develop them, and the ultimate rise of the United States as the global imperial hegemon within the framework of monopoly capitalism, *vis-à-vis* the traditional imperialist powers of England and France and competitor powers like Japan and Germany.

The Second World War, Synthetic Rubber, and Thermoplastics

Synthetic rubber was one of the first synthetic polymers produced in large quantities from petroleum feedstocks and was critical to the rise of the U.S. petrochemical industry. Yet, it was initially Germany that developed a working synthetic rubber. With the British blockade of the First World War, Germany had lost its supply of rubber, obtained in largest part from Malaya and Brazil, a significant military problem. Further, Germany had an advanced coal industry, and Adolf Hitler's plan for German autarky had stimulated domestic production. In 1934, German companies BASF and Bayer produced Buna-S rubber, a copolymer made from the monomers of butadiene and styrene, produced from coal-tar derivatives.

The United States was the world's top user of natural rubber in the late 1930s, accounting for about half of the total consumption globally.²⁹ By 1941, the United States was consuming close to two-thirds of the world's rubber, largely because it also had 80 percent of the world's cars, with their pneumatic rubber tires.³⁰ The overwhelming majority of that rubber was imported from Southeast Asia, mainly Malaysia and the Dutch East

Indies. After hostilities commenced between the United States and Japan, the Japanese closed off access to these sources of rubber.

The U.S. government began a reclamation project for rubber tires, but it did not bring in enough rubber required for the war effort. This forced the United States to jump start its incipient synthetic rubber program, which it had already begun in anticipation of this scenario. The Rubber Reserve Company, a creation of the Reconstruction Finance Corporation, the agency in charge of the U.S. rubber stockpile, “had in 1941, requested the four largest rubber companies, Goodyear, Goodrich, Firestone, and U.S. Rubber (later Uniroyal) to each build a 10,000-ton Buna-S plant. Shortly after the war broke out, this was raised to 30,000-ton plants for each company.”³¹ The U.S. government – led by petrochemical and rubber capital – developed its own version of Buna-S, which proved to be superior to Germany’s version. U.S. access to large oilfields and their petroleum stocks was an essential advantage. U.S. synthetic rubber consumption grew from almost nothing in 1941 to comprising 85 percent of total U.S. rubber consumption by 1945. Its production reached 900,000 tons in 1943, thus duplicating global rubber capacity in just two years.³²

While synthetic rubber represented the pinnacle of polymer production during the Second World War, it was far from the only plastic that played a critical role in the war economy. Wartime production of plastics increased overall production, spearheaded the shift from coal and cellulose to petrochemical feedstocks, innovated the application of plastics in their use, and increased the concentration – spurring both vertical and horizontal integration – of the plastic industry, while simultaneously reducing the power of small-scale plastics molders and fabricators. As the supply of more traditional raw materials was compromised severely, both well-known plastics like Bakelite and a host of new thermoplastics came to replace them, often-times proving to be superior in cost, weight, and performance.

Polyethylene came to supplant both natural plastics and Bakelite as insulation “for coating the new high-frequency, multichannel coaxial cable,” which was essential for the “new era of high-speed, multiplex telecommunications.”³³ Polyethylene enabled the Allied Forces to reduce the weight of their radar stations, allowing airborne radar detection of German air bombers by 1940. Germany was unable to develop polyethylene during the war, which meant that, “for the remainder of the conflict, their airplanes and ships were at a distinct disadvantage in tracking enemy attackers at sea and in the air.”³⁴

Synthetic plastics replaced brass in the production of military bugles and steel in helmet linings. Nylon, the synthetic fiber produced by DuPont, was used as a substitute for natural and semi-synthetic fibers, including

silk – the supply of which was cut off by the Japanese during the war – in the making of parachutes and rope. Polymethyl methacrylate, a type of acrylic thermoplastic that includes Plexiglas, was used for the covers of airplane cockpits and gunner enclosures as a replacement for glass. Vinyl was used in place of natural rubber for its waterproofing and flameproofing qualities, including for military-issued raincoats and boat upholstery. Saran, made from vinyl, was used for insect-proofing mesh tent equipment. Teflon, or polytetrafluoroethylene, was used in weapons-making, including for the Manhattan Project.³⁵ Without a doubt, the development of new plastics and the scaling up of previously marginal plastic production was pivotal in the U.S. war effort.

World Wars and Monopoly Capitalism

The Second World War was, perhaps, the decisive moment in the history of the plastics industry, with plastic production in the United States nearly tripling between the years of 1940 and 1945.³⁶ After the war, production skyrocketed further as domestic markets began absorbing plastic production previously directed to the war. The rise of synthetic thermoplastics and the “changing of the guard” of world hegemon from the United Kingdom to the United States were interrelated processes, both within the context of an inter-imperialist world war and in tandem with a “changing of the guard” of raw materials from naturals to synthetics.

Because the epoch of monopoly capitalism is one in which the global contest over “spheres of influence” (for example, access to labor and commodity markets and raw materials sources, as well as destinations for capital export), inter-imperialist rivalry is an ongoing feature, with the potential for either proxy or direct wars omnipresent. When such contests do break out, they impact and shape the entire configuration of the world capitalist system, economically, politically, socioculturally. Economically, all-out global war efforts bring a level of state command and control to capitalist economies that would be considered heretical to free-market orthodoxy in times of peace. For example, the sudden, rapid production of synthetic rubber in the United States during the Second World War was not primarily driven by the anarchy (or “invisible hand”) of the market and its underlying law of value. It was directed by the Franklin D. Roosevelt administration, which, after auditing the nation’s rubber supplies, determined that the U.S. rubber stockpile – including reclaimed rubber scrap – would only last about six months. By 1943, synthetic rubber production facilities had been created to meet the administration’s goal of producing one million tons of synthetic rubber. This was coupled with spartan rationing of the domestic use of national rubber supplies.³⁷ This precipitated the fall in natural rubber use

in the United States from 99 percent of total rubber used in 1941 to only 11 percent by the end of the war.³⁸

Other synthetic plastics already existent in nascent form during the interwar period were brought online *en masse* in similar fashion. The combination of several factors led to the incorporation of synthetics into production on a significantly increased scale. These factors included: shortages of foreign raw materials through denial of access to supply stocks; the outsized role of petroleum fuel for the war effort; an explosion in demand for materials to produce a plethora of wartime commodities; and decisions made by state leaders to use petrochemicals rather than agricultural products as the raw materials for plastic production, even in the face of intensive pressure and lobbying from the agricultural industry. Like the war itself, the injection of new, fossil fuel-based synthetics into the economy to serve the war effort was not inevitable. Nor was it predetermined by the inexorable march of history, the development of the productive forces, or technological progress. Rather, the social changes tied into the dynamics of monopoly capital-imperialism and the very properties of synthetic plastics made them favorable for such selection. The conjunctural nature of these crises, and their ability to shake up, bend the rules of, and intensify normal economic functioning through spurring demand; redirecting large volumes of capital from one sector to another; bringing online new raw materials, fuels, technologies, and production methods; and injecting vast sums of capital from the state into private enterprise, with state direction and planning – together with the material productive advantages of synthetics – gave production of plastics an enormous boost.³⁹

As Paul A. Baran and Paul M. Sweezy argued, the two world wars were “epoch-making” events in that “not only [did] total production rise to the limits set by available resources but the whole pattern of economic life [was] drastically altered.”⁴⁰ The political-economic impact of these wars extended beyond wartime itself and can be divided into two distinct yet interrelated phases, the combat and aftermath phase. The combat phase, as can be seen with the example of synthetic plastics, gives impetus to all manner of new production methods, ways of organizing social production, and the use of novel (or previously marginal) forms of constant capital such as machinery or materials. This occurs within the overall framework of redirecting and increasing production to serve the war effort and the changed conditions brought on by the war (such as restricted supplies of markets and materials). In the postwar aftermath phase, there was a massive backlog of civilian demand that had to be met, much of which could not be produced simply “by converting war factories to civilian use.” Instead, those war facilities largely needed to be scrapped and

new ones constructed.⁴¹ Yet, not only the new materials, technologies, and production methods, but also the entire reshuffling of the global political order triggered by these wars set the framework for this new phase of postwar development. It is impossible to separate the origin of the Synthetic Age and the plastic breakthrough of the Second World War from the rise of the United States as the top global imperialist power.

The shift from the combat to aftermath phases of the Second World War, which culminated in an explosion of new markets, uses, production methods, and types of synthetics, did not automatically follow from the combat phase. The mere fact that new synthetic thermoplastics were vital to the wartime effort, and that their production thus grew greatly during the conflict, did not guarantee their continued application and proliferation after the war. There was a determined struggle waged on the part of the plastics and petrochemical industries, targeting both consumers and the producers of commodities, to ensure that plastics filled the role of the new material foundation of the postwar era. This injection of synthetic plastics into the scaffolding of the economic structure of society also represented more than a change in the type of material used in production; it expressed a qualitative alteration in the modern social metabolic order.

Conclusion: The Commodification of Science and the Synthetic Age

Synthetic plastics did not only coincide with and help spur forward the further consolidation and growth of monopoly capitalism. They have changed, on a fundamental level, humanity's relationship with the rest of nature. Driven by imperatives of capital, efforts to develop new materials to meet particular production needs have resulted in a product that is an omnipresent substance in modern life. In 1950, global plastic production reached roughly 2 million tons. By 2019, this had ballooned to over 459 million tons, an annual growth rate that outpaced virtually any other material.⁴² The vast majority of plastic materials are not recycled. They end up as non-biodegradable refuse throughout numerous ecosystems, as "matter out of place."⁴³

As engineered substances not previously known to the Earth system, plastics can be characterized as a "novel entity" in the planetary boundaries framework.⁴⁴ Up until recently it was unknown to what extent humanity is exceeding this boundary, or indeed, what quantitative measures could be used to assess this in the first place. While many uncertainties remain, natural scientists have concluded that we have sufficient evidence to establish that humanity is currently outside the safe operating space, and that the "increasing rate of production and releases of larger volumes and higher numbers of novel entities with diverse risk

potentials exceed societies' ability to conduct safety related assessments and monitoring."⁴⁵ Plastics are highlighted as an issue of particular concern in this matter. They will "provide a geological record of humanity's rise to global prominence."⁴⁶

Into the farthest corners of the Earth system, synthetic plastics have contaminated ecological systems and the organisms that make them up. Recent research suggests that the ecological effects of plastic pollution "include changes to carbon and nutrient cycles; habitat changes within soils, sediments, and aquatic ecosystems; co-occurring biological impacts on endangered or keystone species; ecotoxicity; and related societal impacts."⁴⁷ These substances have toxic effects on organisms, causing health consequences that can be lethal. Yet, the extent of the ecological and health effects is still not entirely clear.⁴⁸

Developments within the social metabolic order of capital must be understood historically. The invention and mass production of these materials was advanced during a period of scientific-technical change, steered in large part by forces of commodification and capital accumulation. In the late nineteenth and twentieth centuries, various social conditions prompted efforts among agents of capital to seek or make use of new materials for production and consumption. Scientific efforts and technological developments were subsumed within the drives of capital accumulation as scientific research was increasingly transformed into capital.⁴⁹ New synthetic materials were sought out to address concerns around shortages of existing (natural) materials, their lack of access, costs, and ecological or biophysical limitations, which were driven by the logic of global capital and, underlying this, imperialist ambitions.

With the growing application of science to industry, an effort to expand commodity production systems through a "scientific-technical revolution" developed in earnest in the late nineteenth century. The expansion of "electrical industries, entirely the product of the nineteenth-century science and in the chemistry of the synthetic products of coal and oil" were clear examples of the "early symbiosis between science and industry."⁵⁰ By the twentieth century, capital "systematically organize[d] and harnesse[d] science," facilitating the expansion of giant corporations into global enterprises. While this process initially grew in earnest in Germany, the center of the commodification of scientific efforts later shifted to the United States. As Braverman wrote, "The corporate research laboratories of the United States begin more or less with the beginning of the era of monopoly capitalism."⁵¹

During the interwar period, the growth of giant corporations and the establishment of the U.S. petrochemical industry opened opportunities to further consolidate the synthesis between capital and science. By the

Second World War, with the massive expansion of production employed for the war effort and, at the same time, the limited access to new materials for production due to the conflict, the United States pushed enormous amounts of state resources into scientific and technological developments that would not only produce substitutes for needed materials, but new uses. After the Second World War, the massive growth of productive infrastructure and capacity in, for example, the petrochemical industry, required the continued development of production and consumption of the materials, and, in the case of petrochemicals, the incorporation of ever-growing byproducts of fossil fuel production.

The social metabolic order of capital during the emergence of the monopoly-capitalist era fused science and capital to advance a Synthetic Age. Numerous forms of plastic materials were sought to overcome the limits and boundaries that resulted from biophysical or social obstacles. Capital knows no bounds. New materials were engineered. Each step of the development of plastics has been geared toward meeting new productive goals, expanding the application and reach of these substances, with the ultimate aim of accumulation. The outcomes of the massive efforts of production and deployment of these toxic compounds has been overwhelmingly harmful to Earth systems and various lifeforms – including ourselves.

Notes

1. Harry Braverman, *Labor and Monopoly Capital: The Degradation of Work in the Twentieth Century* (New York: Monthly Review Press, 1998), 12.
2. John Bellamy Foster, *The Vulnerable Planet: A Short Economic History of the Environment* (New York: Monthly Review Press, 1999). The notion of the "Age of Synthetics," related to developments in organic chemistry and plastics and implemented by large-scale capitalist firms, was introduced in an anonymous monograph on "The Scientific-Industrial Revolution," published by the Wall Street investment house of Model, Roland & Stone in 1957. The anonymous author was Marxist economist Paul M. Sweezy, editor of *Monthly Review*. This work heavily influenced the analysis of the scientific-technical revolution in Part II of Braverman's *Labor and Monopoly Capital*. Paul M. Sweezy (published anonymously), *The Scientific-Industrial Revolution* (New York: Model, Roland & Stone, 1957).
3. John Tully, *The Devil's Milk: A Social History of Rubber* (New York: Monthly Review Press, 2011).
4. J. Harry DuBois, *Plastics History U.S.A.* (Boston: Cahners Books, 1972).
5. Colin J. Williamson, "Victorian Plastics—Foundations of an Industry" in S. T. I. Mossman and P. J. T. Morris, eds., *The Development of Plastics* (London: Royal Society of Chemistry, 1994), 1–9.
6. Tully, *The Devil's Milk*.
7. John Tully, "A Victorian Ecological Disaster: Imperialism, the Telegraph, and Gutta-Percha," *Journal of World History* 20, no. 4 (2009): 560.
8. Tully, *The Devil's Milk*, 21.
9. Stephen Fenichell, *Plastic: The Making of a Synthetic Century* (New York: HarperBusiness, 1996), 18.
10. Fenichell, *Plastic: The Making of a Synthetic Century*, 33–34.
11. S. T. I. Mossman, "Parkesine and Celluloid" in *The Development of Plastics*, 10–25.
12. Wiebe E. Bijker, *Of Bicycles, Bakelites, and Bulbs: Toward a Theory of Sociotechnical Change* (Cambridge, Massachusetts: MIT Press, 1995).
13. Robert Friedel, *Pioneer Plastic: The Making and Selling of Celluloid* (Madison: University of Wisconsin Press, 1983).
14. Jeffrey L. Meikle, *American Plastic: A Cultural History* (New Brunswick, New Jersey: Rutgers University Press, 1995).
15. Bijker, *Of Bicycles, Bakelites, and Bulbs*, 12.
16. Bijker, *Of Bicycles, Bakelites, and Bulbs*, 148.
17. Kenneth Geiser, *Materials Matter: Toward a Sustainable Materials Policy* (Cambridge, Massachusetts: MIT Press, 2001).
18. Ernest J. Parry, *Shellac: Its Production, Manufacture, Chemistry, Analysis, Commerce and Uses* (London: Sir Isaac Pitman and Sons, 1935).
19. Fenichell, *Plastic: The Making of a Synthetic Century*, 91.

20. Harry Magdoff, *The Age of Imperialism: The Economics of U.S. Foreign Policy* (New York: Monthly Review Press, 1969).
21. See V. I. Lenin, *Imperialism: The Highest Stage of Capitalism* (London: Lawrence & Wishart, 1948); Raymond Lotta, *America in Decline*, vol. 1 (Chicago: Banner Press, 1984); Magdoff, *The Age of Imperialism*; John Smith, *Imperialism in the Twenty-First Century: Globalization, Super-Exploitation, and Capitalism's Final Crisis* (New York: Monthly Review Press, 2016).
22. Lotta, *America in Decline*.
23. Percy Reboul, "Britain and the Bakelite Revolution," in *The Development of Plastics*, 26.
24. Reboul, "Britain and the Bakelite Revolution."
25. Meikle, *American Plastic*.
26. Jeffrey L. Meikle, "Materia Nova: Plastics and Design in the U.S., 1925–1935" in *The Development of Plastics*, 38–53.
27. Geiser, *Materials Matter*, 75.
28. Peter H. Spitz, *Petrochemicals: The Rise of an Industry* (New York: John Wiley and Sons, 1988).
29. Peter Morris, "Synthetic Rubber: Autarky and War," *The Development of Plastics*, 54–69.
30. Fenichell, *Plastic: The Making of a Synthetic Century*.
31. Spitz, *Petrochemicals*, 143.
32. Tully, *The Devil's Milk*, 326.
33. Fenichell, *Plastic: The Making of a Synthetic Century*, 202.
34. Fenichell, *Plastic: The Making of a Synthetic Century*, 203.
35. J. P. Tilly, "Versatility of Acrylics, 1934–1980," in *The Development of Plastics*, 95–104.
36. Meikle, *American Plastic*, 1. Also see Thomas Hine, *The Total Package: The Secret History and Hidden Meanings of Boxes, Bottles, Cans, and Other Persuasive Containers* (Boston: Back Bay Books, 1995).
37. Spitz, *Petrochemicals*, 141–43; Tully, *The Devil's Milk*, 324–26.
38. Tully, *The Devil's Milk*, 320.
39. Lotta, *America in Decline*.
40. Paul A. Baran and Paul M. Sweezy, *Monopoly Capital: An Essay on the American Economic and Social Order* (New York: Monthly Review Press, 1966), 224.
41. Baran and Sweezy, *Monopoly Capital*, 224.
42. Organisation for Economic Cooperation and Development, "Plastics Use in 2019," n.d., oecd-ilibrary.org.
43. Roland Geyer, Jenna R. Jambeck, and Kara Lavendar Law, "Production, Use, and Fate of All Plastics Ever Made," *Science Advances* 3, no. 7 (2017); Susan Freinkel, *Plastic: A Toxic Love Story* (Boston: Houghton Mifflin Harcourt, 2011).
44. Will Steffen et al., "Planetary Boundaries: Guiding Human Development on a Changing Planet," *Science* 347, no. 6223 (2015).
45. Linn Persson et al., "Outside the Safe Operating Space of the Planetary Boundary for Novel Entities," *Environmental Science and Technology* 56, no. 3 (2022): 1510–21.
46. Aron Stubbins et al., "Plastics in the Earth System," *Science* 373, no. 6550 (2021): 51–55.
47. Matthew MacLeod, Hans Peter H. Arp, Mine B. Tekman, and Annika Jahne, "The Global Threat from Plastic Pollution," *Science* 373, no. 6550 (2021): 61–65.
48. Rolf U. Halden, "Plastics and Health Risks," *Annual Review of Public Health* 31, no. 1: 179–194.
49. Braverman, *Labor and Monopoly Capital*; Richard Levins and Richard Lewontin, *The Dialectical Biologist* (Cambridge, Massachusetts: Harvard University Press, 1985).
50. Braverman, *Labor and Monopoly Capital*, 110.
51. Braverman, *Labor and Monopoly Capital*, 112.



Ever since the dawn of history, man had been discovering or mastering new materials to make him strong in battle and more productive in work. So crucial has this activity been, that the sciences of man have long divided the early stages of development...into periods marked off by the mastery of new materials – the stone age, the iron age, and the bronze age. If we were to follow this practice today, ours might appropriately be known as the age of synthetics. The age of synthetics owes its birth to the marriage of science and production effected by the German organic chemical industry in the decades before World War I, and came to full maturity during World War II when whole areas of the economy that had hitherto been untouched – metals, glass, ceramics – were subjected to the transforming alchemy of science.... When the long, variable molecules called polymers were mastered, an almost limitless field of new plastics, fibers, foams, rubbers, coatings, adhesives, and detergents opened up.

– PAUL M. SWEEZY (PUBLISHED ANONYMOUSLY),
The Scientific-Industrial Revolution
 (New York: Model, Roland & Stone, 1957), 36.