CHAINS OF OPPORTUNITY

Ohio History and Culture

Mark D. Bowles

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THE UNIVERSITY OF AKRON AND THE EMERGENCE OF THE POLYMER AGE 1909–2007

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

In memory of my father
Donald L. Bowles

PREFACE

As a child in the 1970s, I seemed to grow up at the University of Akron. My father was an administrator there for over thirty years and on Saturdays he would take me with him to his office and share stories of its past. While he worked, I would sometimes play on the winding double-staircase of Buchtel Hall, dropping my toy astronauts over the railing, thinking the place was immensely austere and breathtaking. At the dinner table each night, he invoked iconic names in the school's history, like Auburn, Morton, Sumner, and Kelley, and recounted tales of their exploits. This was an exciting era of construction at the university, and I can remember making a wager with my father over what building would be completed first, E.J. Thomas Performing Arts Hall or Bierce Library. I lost the bet but realized later that he probably had some inside information since he worked in the facilities planning office. My father's love of the university was infectious, and there was never a question of what I was going to do after high school. Instead, the question was what major I would someday choose at the University of Akron. I picked history and earned my first graduate degree there.

My father concluded his career at the university in 1990 as the first associate dean of the College of Polymer Science and Polymer Engineering. Over the years, "polymers" had become an almost magical word in our household. They were the material of the future, a worthy academic pursuit, and a potential savior for the Akron region. Sadly, my father was diagnosed with cancer soon after his retirement. In 2001, as I sat with him during his final few days in the hospital, the

Goodyear Polymer Center stood like a guardian in the distance. In the emotional silence of the room, my faraway gaze often focused on the building as I recalled my father's strong voice and his active life. At one point I whispered to him, "You know, dad, you have the best room in the hospital because you can see the polymer building from here." He turned to me slightly and smiled. It was the last time I would ever see my father's smile.

Today, on the east side of the Goodyear Polymer Center, lies a place that pays tribute to my father's life—the Donald L. Bowles Memorial Garden. It sits on what was once Buchtel Avenue in the pedestrian walkway he helped to create, and in the shadow of the building that was so dear to him. The building is a symbol of so many things—polymer excellence, scholarly distinction, civic renaissance—but for me it will always be a symbol of my father. Whenever I see the building on the Akron skyline, especially when it is glowing at night, I can see my father in his tie and hardhat, carrying a tube of blueprints and engaging a group of people about the exciting future that lay ahead. When Dean Frank Kelley contacted me in June 2004 and asked me to write a book recounting the history of the rubber chemistry and polymer programs at the university, I eagerly accepted the challenge. The project was an irresistible opportunity to contribute my voice and perspective to this special place and, in a personal sense, reconnect with the memory of my father.

Books like these are never the product of just one person. There are numerous people who contributed a great deal to this project, and I would like to thank them. First and foremost is Dean Frank Kelley, who invited me into his college and asked me to tell its story to the world. He has been an inspiring leader at the university, and he has played a significant role in establishing its international reputation today. Current University of Akron President Luis M. Proenza has also been a visionary leader who has successfully transformed the campus, physically and aesthetically. I thank him for his participation in this book. Former President William Muse played a critical role in working with Dean Kelley to establish the College of Polymer Science and Polymer Engineering and in building the Goodyear Polymer Center. I deeply appreciate the time and materials he shared with me to support this project, as well as his friendship with my father over the years. It was also a pleasure talking to Priscilla Simmons about her father Hezzleton Simmons, who was president of the university from 1933 to 1951.

Many other people were interviewed for this book and for an earlier DVD project that commemorated the fiftieth anniversary of the first Ph.D. program in polymer chemistry at the University of Akron. These individuals included Stephen Cheng, James D'Ianni, Mark D. Foster, Alan Gent, Lloyd Goettler, H. James Harwood, Sadhan Jana, Joseph Kennedy, Charles Rader, and James White. Those who provided on-camera laboratory interviews at the Goodyear Polymer Center included: William J. Brittain, Gustavo A. Carri, Ali Dhinojwala, Mark D. Foster, Crittenden Ohlemacher, Coleen Pugh, Judit Puskas, Darrell H. Reneker, Alexei P. Sokolov, and Bojie Wang. Laboratory interviews at the Sidney L. Olson Research Center included Mukerrem Cakmak, Kevin Cavicchi, Lloyd Goettler, and Mark D. Soucek. Tayba L. Tahir spoke on the Akron Polymer Training Center. Charles Wilkes shared his thoughts on EPIC with me. The Rubber Division of the American Chemical Society played an important role in supporting this book, and I thank Ed Miller and the Rubber Division for its contributions. Also instrumental from the Akron Global Polymer Academy were Jason Miller and Justin Molenaur, who coordinated and captured many of the interviews on digital media.

Historians always rely heavily upon the skills and resources of archivists and librarians. John V. Miller and Craig A. Holbert at the University of Akron Archives, which houses an excellent collection of university documents, always provided a welcome place for research. Christopher J. Laursen, manager of the John H. Gifford Memorial Library, provided a great deal of assistance for my research. He is a valuable asset to the Rubber Division. I also thank Frank Bove, a reference librarian at the University of Akron's Bierce Library. Rosemary Kolton, senior administrative assistant to Dean Kelley, answered my numerous questions over the course of this project. Kent Marsden, assistant to the dean, assured me that I had all the tools I needed for my research at my disposal. Melissa Bowman and Sarah Thorley assisted with gathering of alumni data. Lynn Patterson transcribed the interviews conducted for this book, and as always I appreciate her professionalism and friendship.

I would also like to extend my gratitude to the University of Akron Press—especially interim director Elton Glaser, production coordinator Amy Freels, business coordinator Carol Slatter, and copy editor Elizabeth Armstrong—for enhancing this manuscript and guiding it through the publication process.

This book was written at a time of transition for the College of Polymer Science and Polymer Engineering. Dean Frank Kelley stepped down in December 2006 after nearly thirty years of service. I would like to thank Stephen Cheng, who was selected as Kelley's successor in August 2007, for sharing his thoughts with me about the new challenges that awaited him.

It is often said that everyone who lives in Akron has a relative who has worked in the rubber industry. My family is no exception. My grandfather, Charles Putman, began a forty-year career at B.F. Goodrich in 1928. My father had close ties to the polymer program at the University of Akron and devoted his life to the school. John Putman, his wife Kay, and son Matthew (my uncle, aunt, and cousin) established Tech Pro, a manufacturer of rubber-testing instruments and software, in Akron in 1983. I thank them for allowing me the opportunity to serve in Tech Pro's administration for the past five years. My mother, Joan, has cared for all of us throughout our lives and supported us in all of our endeavors, all the while managing to keep her hands free of carbon black.

Finally, none of my historical musings would be possible without the love of my wife, Nancy. One of our daughter Isabelle's favorite places to picnic is what she calls "Grandpa Don's Garden" located outside the Goodyear Polymer Center. There we often sit amidst the young birch trees, talk about the past, watch the clouds reflected in the mirrored building, and admire the new Chihuly sculpture at the heart of Frank Kelley Plaza. Those moments of quiet reflection are essential in life, and it is my sincere hope that this book inspires the reader to take time to do the same and reflect upon Akron's rubber and polymer heritage. It is an important part of who we all are, for those of us who still live with its legacy.

INTRODUCTION

Archaeologists have defined past civilizations by the materials that predominated in their societies. The evolution of the use of these materials—stone, bronze, and iron—enabled significant and concurrent changes in the cultures that mastered them. The ability to develop, shape, and use these substances has been one of the measures of a civilization's capabilities, so much so that we now identify them as the Stone Age, Bronze Age, and Iron Age. Historians have also associated the comings and goings of other, more recent, periods with the prevalence of particular types of materials. Brooke Hindle identified America's pre-Civil War period as its "Wooden Age," and he characterized the society as one that was "pervasively conditioned by wood."[1] This dependence slowly subsided after 1850 and was replaced in part by metals and the corresponding products of industrialization.

There was one common characteristic that defined these former ages. The materials in question all came from nature. However, at the dawning of the twentieth century, scientists and engineers began to master a new class of materials called polymers. Although some of these occurred in nature (like spider silk or natural rubber), other polymers were made in laboratories and factories and had properties superior to those existing in the natural world. Over the past century, the ability to create and manipulate natural and synthetic polymers has resulted in a revolutionary transformation of our own material culture. One hundred years ago, the artifacts of everyday life were made of wood, stone, glass, or metal. This is no longer the case, as polymers now often replace these substances and enhance the quality of the products made with them. The result is that polymers have become one of the most significant scientific and engineering achievements in the past century. The father of polymer education, Herman Mark, suggested in 1982 that society was "coming to an age in polymer science."[2] In 1976, an author in *Chemical Week* simply christened this the "polymer age."[3]

Although it is often difficult and arbitrary to pinpoint dates of when "ages" like this begin or end, it might be argued that the Polymer Age matured in the late 1970s. While the realization that polymers were macromolecules took place in the 1920s, it was not until a half century later that the consumption of synthetic polymeric materials overtook metals in the United States.[4] In 1973, the United States produced the same amount of synthetic polymers as it did steel—15.5 million cubic meters.[5] In 1976, the United States consumed more plastics than metal on a per volume basis for the first time, and plastics became the most used synthetic material in the country.[6] The rapidity with which polymers became so prevalent is an astonishing story. In 1900, only a handful of chemists concerned themselves with materials that would later be known as "polymers," and none knew what they truly were. In the 1930s, the United States produced virtually no synthetic polymers. Forty years later, it produced twenty-three million metric tons. Statistics like these were strong indicators that a new material age had begun. Today half of all chemists work with them.[7]

Cultural indicators also point to a dramatic change since the 1970s in how we value polymeric products (plastics, rubber, and textiles). Consider how plastics were viewed by Hollywood and pop music stars in the 1960s. In the 1967 film *The Graduate*, Benjamin Braddock (played by Dustin Hoffman) was told by one of his father's colleagues that the future lay in one word—"plastics." To Braddock, this suggestion conveyed a sense of conformity, selling-out, boredom, and cheap imitation. The audience of the 1960s easily understood how the mere suggestion of "plastics" symbolized the dull life Braddock would eagerly try to escape. It reminded viewers of a similar song released that same year by pop duo Sonny and Cher, who sang about the "plastic man." Their lyrics warned about a man not to be trusted, like someone selling cars on television. He was working day and night, not disclosing he was recruiting everyone for his commercial desires. They sang, "He's doing everyone he can . . . Plastic Man." The Beatles *Rubber Soul* album, released in the mid–1960s, further exemplified the negative connotation of another polymer.

But, an important cultural shift has occurred since then. By the 1970s, the image of plastics began to lose its substandard connotations and instead conveyed the belief that polymers represented a new and potentially better way of life. Symbolizing this phenomenon was an unlikely musician who recognized polymers as a new, dominant material. From 1976 to 1979, legendary punk rock singer Marianne Elliot-Said adopted the pseudonym "Poly Styrene" to make a statement about the significance of the changes she saw around her.[8] She created a character who idealized the glamour of plastic and echoed a youth movement that would eventually come to embrace a new polymer world. She chose the name Poly Styrene for this persona as she herself became infatuated with "plastic" society. One of her songs, a top-thirty hit in London, was called "The Day the World Turned Day-Glo"; in its lyrics she observed that polymers were taking over society. She sang:

I clambered over mounds and mounds of polystyrene foam
Then fell into a swimming pool filled with fairy snow

And watched the world turn Day-Glo
You know you know the world turned Day-Glo you know

I wrenched the nylon curtains back as far as they would go
Then peered through Perspex window panes at the acrylic road

I drove my polypropylene car on wheels of sponge
Then pulled into a wimpy bar to have a rubber bun

The x-rays were penetrating thru latex breeze
Synthetic fibre see-thru leaves fell from the rayon trees

The song was a virtual encyclopedia of the new material world she encountered: polystyrene, Day-Glo, nylon, Perspex, acrylic, polypropylene, latex, and rayon. Polystyrene, known by many trade names, e.g., Styrofoam, is a plastic used for a variety of products, including utensils, CD jewel cases, and models. Day-Glo was created in 1946 after the discovery of new polymer dyes and resins that produced unprecedented bright colors for the plastics, paints, coatings, and textile industry. Nylon was one of the first synthetic polymers, produced in 1935 by Wallace Carothers and used soon thereafter for such products as toothbrush bristles and women's stockings. Perspex is the trade name for a type of acrylic polymer, also called Lucite or Plexiglas. Polypropylene is another thermoplastic polymer used in numerous products. Latices are natural and synthetic polymers disposed in water. These are used in the manufacture of clothing and paint. Rayon is derived from cellulose and was first used as an artificial silk in the 1920s. Metaphorically, as Marianne Elliot-Said (or Poly Styrene) observed, the world did turn Day-Glo (more than just the color: it became polymeric) and remains so today.[9]

This song paralleled the dawn of a new material era—the Polymer Age. The extent of the ubiquity of polymers is best understood by taking a look at a typical day in our own lives, with attention to how often we both knowingly and unknowingly encounter polymers. In 2006, Ed Noga, the editor of *Rubber & Plastics News*, did just that and observed the various ways in which he touched polymers over the course of an average day.[10] He awoke in the morning by pressing the thermoplastic elastomer snooze button on his alarm clock. He had to press it a number of times because his latex foam mattress was too comfortable to leave, without a fight. While getting ready for his day, he encountered numerous other polymer materials well before he even left his house: toothbrushes, combs, razor handles, rubber mats, and shower enclosures. He put on his rubber-soled shoes and clothes made with synthetic fibers, while also likely standing on polymer fiber carpeting. He prepared a breakfast with food that had been stored in rubber-sealed containers. It was a rainy day, and he made sure his children had rubber jackets and boots to keep them dry. He then drove himself to work in a vehicle with polymer components too numerous to mention—hoses, belts, o-rings, gaskets, and tires. These were made of EPDM, natural rubber, silicone, or fluoroelastomers. As he drove, he noticed a road crew applying rubberized asphalt, while another used a polymer paint for the yellow striping down the center of the road. He continued over a bridge with rubber expansion joints and then almost unknowingly drove over a smooth rubber railroad crossing. Once at work, he used his pencil's rubber eraser to eliminate mistakes, made a transatlantic telephone call over fiber-optic wires insulated with ethylene-propylene rubber, and rode an elevator whose vibrations were dampened by rubber. Of course, his mouse, keyboard, and computer were all encased in plastic. After work, he picked up his daughter from soccer practice and lost count of the essential polymer products that she used: rubber balls, plastic shin guards, foam-rubber padding, and rubber-cleated spikes on her shoes.

Noga's experience is typical. Our interactions with polymers are overwhelming and increasing by the day. Polymers now unquestionably dominate our material culture on earth. They have also shaped one of the central images of our brief presence on the moon, as Neil Armstrong's famous "one small step" was made with the imprint of his rubber-soled spacesuit boot. And polymers have become an enthusiastic subject of study for students of all ages, including children creating numerous science fair projects and university-level polymer science and engineering graduates preparing for careers in academia and industry.[11] Graduates of today eagerly seek out the same plastic, polymer industry that Dustin Hoffman's character found to be so hollow and uninspiring.

Ironically, although polymers are now prevalent in our lives, few people can actually state with any accuracy what they are.[12] The word polymer derives from the Greek words *poly* meaning "many" and *mer* meaning "parts." The "parts" are small molecules (monomers), "many" of which can combine to form a very long molecule (polymer). This process is called polymerization. The polymerization process is their most important feature and is analogous to a long necklace (polymer) made from many thousands of beads (monomers). Admittedly, even with this simple definition, the concept of a polymer may still be hard to grasp.

One way to understand polymers is to compare them to metals. Though it might be difficult for the average person to provide a dictionary definition of a metal (a class of elementary substances, crystalline when solid and typically characterized by ductility, opacity, conductivity, and a unique luster when freshly fractured), everybody knows one when they see one. Much as the term "metal" describes a range of materials—gold, silver, or copper—so, too, does the term "polymer." Plastics, resins, rubbers, coatings, and adhesives are commonly made from synthetic polymers. There are also natural polymers such as rubber from trees, silk, spider webs, and skin. Even DNA, the molecule that carries the genetic code, is a polymer.

Another way to understand polymers is to see how their properties change as molecules become longer. For example, the element carbon can take the form of any of the three states of matter (solid, liquid, or gas) simply by changing the length of its polymer chain.[13] When a carbon atom is by itself, along with its bonds to four hydrogen atoms, it is a gas—methane. Increasing the length of this carbon chain to eight atoms and it becomes a liquid—gasoline or octane. Increasing the polymer chain to twenty carbon atoms and the result is a solid—candle wax or eicosane.

It is through the polymerization process that these materials have become so vital to our lives. By arranging monomers (anywhere from eight hundred to one hundred thousand of them at a time) together in many different ways, scientists and engineers are making new polymeric materials to replace wood, stone, glass, and metal. Polymers continue to replace traditional materials because they are often less expensive, more durable, and lighter than their natural counterparts.

While it is now nearly impossible to go about a normal day without encountering polymers, they have ironically often become an unseen substance. Steve Love, Akron journalist and coauthor of *Wheels of Fortune*, wrote, "Polymers have an identity problem. They are, comparatively speaking, invisible. . . ."[14] A characteristic of many great scientific and technological discoveries is that, after they have moved into the mainstream, they transition from sublime wonder to an almost forgotten realm. The electric light bulb is an obvious example—an invention that inspired awe in the nineteenth century, today it is simply an assumed part of our lives.[15]

The history of polymers has this character. After the process of vulcanization was established in 1839, natural rubber quickly became a vital material. The dependence upon it became so great during World War II, that the United States realized if it were cut off from natural rubber sources, its military operation would grind to a halt. Without rubber, the greatest military nation in the world would be quickly rendered powerless. The development of synthetic rubber during World War II led in part to the great variety of the synthetic polymeric materials that surround us now almost invisibly. We are living in the midst of the Polymer Age, and few realize, or even know what this means. As Jeffrey L. Meikle argued in his book *American Plastic*, "most people ignored . . . that the United States entered the 'Plastics Age' in 1979 when the annual volume of plastic exceeded that of steel."[16] We can no longer ignore its presence in our lives, and its history requires telling.

A good starting point for understanding the historical development of polymers is Yasu Furukawa's *Inventing Polymer Science*, which traces the new chemistry created by the efforts of Hermann Staudinger and Wallace Carothers in the 1920s. Ironically, despite a long history, many chemistry textbooks and university programs have failed to address polymers. One observer noted that there was "academic apathy" regarding polymer science through the early 1970s.[17] In 1977, Paul Flory, often called the father of polymer science, said that he was never allowed to teach an undergraduate course in macromolecules at Stanford during the 1960s and 1970s. He argued that the result was that few students in the United States had any broad background in polymers. This remained the case as late as 1993 when Herman Mark, another polymer pioneer, said, "It is difficult to understand why, although half of professional chemists work with polymers, elementary textbooks on organic and physical chemistry hardly mention their existence."[18] Popular newspapers also frequently fail to report the latest polymer advances. Since April 1987, the word "polymer" has only appeared in *USA Today* 156 times. Likewise, since 1851 the *New York Times* has printed the term "polymer science" thirty-six times, and "polymer engineer" only five.

Compared to the number of scholarly studies on other scientific and technological developments like computers, automobiles, and electricity, historians have also been surprisingly quiet on the subject of polymers. The retrospective studies that do exist were largely written by former polymer practitioners. These "insider" stories include memoirs, review articles, and autobiographies. The American Chemical Society and the efforts of Raymond S. Seymour have also produced numerous works that contain much technical detail and scientific perspective. However, historians are beginning to take notice of the field, though biography still dominates their approach. Examples include Frank M. McMillan's *The Chain Straighteners* and Peter J.T. Morris's *Polymer Pioneers*.[19] Historical analysis of the development of rubber have received more attention than the broader topic of polymers. Among these, John Loadman's *Tears of the Tree* and Charles Slack's *Noble Obsession* are popular exceptions.[20]

There are many areas of polymer history that need attention. Furukawa noted, "there are few analytical histories that deal with both the intellectual and social setting of macromolecular chemistry in its formative period."[21] There are still fewer histories that deal with its institutional context. David A. Hounshell and John K. Smith, in their *Science and Corporate Strategy*, have presented an excellent account of the history of the DuPont company, including an important discussion of its significant contributions to polymer research.[22] Other histories of the rubber industry are starting to trace the important role they have played in the evolution of the Polymer Age. One of the best includes Mansel G. Blackford and K. Austin Kerr's *BFGoodrich*.[23] Journalists Steve Love and David Giffels have also told the memorable story of the symbiotic relationship between the city of Akron and the emergence of the rubber industry in their compelling *Wheels of Fortune*.[24] But for the most part, biographical treatments have far superseded the institutional perspective of the history of polymers.

There is no question that academic institutions have been essential to the emergence of the Polymer Age, and their historical neglect is an oversight that requires attention. An institutional perspective can help us understand the intellectual and social foundations from which polymer science and engineering developed. Much as an individual's biography yields important insights into a particular historical context, so, too, does an institutional focus reveal key perspectives. The Polymer Age arose through an international network of researchers working within large academic, industrial, and governmental organizations that developed the scientific and engineering skills to create and commercialize polymers. Among these institutions are academic programs (including the University of Akron, the University of Massachusetts-Amherst, Case Western Reserve University, California Institute of Technology, the University of Southern Mississippi, Virginia Tech, and Brooklyn Polytechnic), industrial organizations (e.g., IG Farben, DuPont, Dow Chemical, Goodyear, Bridgestone/Firestone, B.F. Goodrich, and General Tire), and various government agencies and scientific societies like the Rubber Division of the American Chemical Society.

It is beyond the scope of this book to present a sweeping account of the entire network of academic institutions responsible for the emergence of the Polymer Age over the past century. Instead, this book examines the story within the framework of one academic institution that has played the longest and arguably the most influential role in creating and shaping the Polymer Age—the University of Akron. This university has played a signal role in the emergence of the Polymer Age, starting in 1909 when Charles Knight offered the world's first course in rubber chemistry, marking the birth of a new academic discipline. This course has now evolved into an entire college—the College of Polymer Science and Polymer Engineering—which has been ranked for the last ten years as one of the top two academic institutions in the United States in the field. An examination of the near century in between the foundation of the course and the flourishing of the college demonstrates how long polymer chains became chains of opportunity for an academic discipline, an economic region, and a university.

1 THE BIRTH OF RUBBER CHEMISTRY

1909–1941

CENTURIES AGO, RUBBER—OR "CAOUTCHOUC" AS IT WAS then known—was simply a curious, sappy, milky-white substance that flowed from over three hundred different types of trees and other plants. The *Hevea brasiliensis* was the most well known, and Europeans discovered these sixty-foot-tall "weeping" trees in Central and South America in the fifteenth century. They experimented with the unusual elastic substance they produced, using it first as a bouncing ball. Then, in the 1760s, French researcher Francois Fresnau discovered that it was possible to dissolve natural rubber with turpentine, so that it could be spread upon clothing or other substances. In the 1770s, Joseph Priestley coined the term "rubber" after using it to rub out his pencil marks.[1] By the early nineteenth century, the thriving rubber industry emerged. It produced rubberized clothing and boots that were water-resistant. However, these early rubber products had critical flaws—they melted in the summer and cracked in the winter. In 1839, after Charles Goodyear in America, and Thomas Hancock in Britain, unlocked the vulcanization process through the use of sulfur and heat, the true potential of rubber was unleashed.[2]

In 1855, Charles Goodyear published a book on the vast number of applications and uses for this vulcanized "gum-elastic."[3] He envisioned a new rubberized world in which this miraculous substance would transform virtually every area of life. He foresaw mechanical, electrical, military, and medical uses. Homes would be filled with rubber products. Toys and other recreational items would be made with it. Transportation in stagecoaches and carriages would be more pleasant. Goodyear thought people would begin wearing all manner of rubberized goods, and he even imagined "fancy and ornamental uses." While commercial rubber products had existed before, vulcanization enabled rubber goods to become a viable, large-scale industry. Few other major commodities have experienced such a dramatic change in supply, demand, and cultural significance.[4]

Goodyear's prognostications came true, and the vulcanization of rubber is regarded today as one of the most important industrial developments of the nineteenth century. Rubber's properties were nothing short of revolutionary: it was elastic, waterproof, airtight, moldable, and spreadable. It became the "great shock absorber of the industrial age," with rubber springs cushioning carriages, rubber belts enabling machine gears to turn smoothly, and rubber seals preventing leaks and blocking air. Its resistance to electricity made it an enabling partner in the electrification of everyday life.[5] Rubber tires helped establish the bicycle craze of the 1890s and the corresponding association between freedom and personal transportation. At the turn of the twentieth century, the "automobile age" was also well under way, with some correctly predicting—in 1900—that there would soon be more cars than horses in American cities.[6] Without rubber tires, hoses, and gaskets, these automobiles would have been nothing more than immobile piles of metal and glass. But, despite the centrality of rubber to culture and

INDEX

ABOUT THE AUTHOR

Mark D. Bowles has authored or coauthored seven books on the history of space exploration, nuclear research, and medicine. His book, *Science in Flux*, won the American Institute of Aeronautics and Astronautics' 2005 History Manuscript Award, which is presented each year for the best historical manuscript dealing with the impact of aeronautics and astronautics on society. He received his B.A. in Psychology (1991) and M.A. in History (1993) from the University of Akron. He earned his Ph.D. in the History of Technology (1999) from Case Western Reserve University and his MBA in Technology Management from the University of Phoenix (2005). He founded Belle History in 2007. He is married to Nancy and they have a daughter, Isabelle. He can be reached at mark@bellehistory.com.