APPENDIX A

TIMELINE OF MATERIALS AND TECHNOLOGICAL DISCOVERIES

>50,000 B.C.	Brushes are developed to apply pigment to cave walls
30,000 B.C.	Clothing materials are fabricated from animal skins
24,000 B.C.	Ceramic materials are made from animal fat and bone, mixed with bone ash and clay
20,000 B.C.	Ivory and bone are used to make sewing needles
20,000 B.C.	A nonwoven fabric, later termed felt, is made from compressed wool/hair
10,000 B.C.	Gourds, seapods, bones, and clay are used to make ocarinas or vessel flutes
4,000 B.C.	Stones are first used to construct roads in Ur (modern-day Iraq)
3,500 B.C.	Copper metallurgy is invented and used to fabricate a variety of materials
3,500 B.C.	The first reported use of glass in Egypt and Mesopotamia
3,400 B.C.	Linen cloth synthesized from flax is used to wrap mummies in Egypt
3,200 B.C.	Bronze is used for weapons and armor
3,000 B.C.	Egyptians wear clothing comprised of cotton fibers
3,000 B.C.	The Egyptians construct the first stringed musical instrument
3,000 B.C.	Soap is first synthesized in Egypt using wood ash and animal fat
2,600 B.C.	Silk fibers are used for clothing in China
2,000 B.C.	Pewter beginning to be used in China and Egypt
1,600 B.C.	The Hittites develop iron metallurgy
1,600 B.C.	Conceptual designs are invented for bathing suits, fabricated/named bikini in 1946
1,300 B.C.	Invention of steel when iron and charcoal are combined properly
1,000 B.C.	The abacus is created by the Babylonians
1,000 B.C.	Glass production begins in Greece and Syria
900s B.C.	Assyrians develop pontoon rafts for armies to cross rivers
800s B.C.	Spoked wheels are fabricated and used throughout Europe
700 B.C.	Italians invent false teeth
105 B.C.	Paper is first fabricated from bamboo fiber in ancient China
50 B.C.	Glassblowing techniques are developed in Syria
Birth of Christ	
590	Chinese scientists discover explosive mixtures consisting of sulfur, charcoal, and saltpeter (potassium nitrate)
618	Paper money is first put into use during the Tang dynasty of China (618–906)
700s	Porcelain is invented in China

1156	First reported synthesis of perfume by Henchum Seiken
1182	The magnetic compass is developed and widely used in China[1]
1249	Gunpowder is designed/synthesized by Rodger Bacon
1280	The cannon is invented in China
1286	Eyeglasses are first used in Venice
1400	The first use of grenades in France, designed by an unknown inventor
1450	Crystallo, a clear soda-based glass, is invented by Angelo Barovier
1570	The pinhole camera is invented
1590	Glass lenses are developed in Netherlands and used for the first time in microscopes and telescopes
1593	Galileo invents a water thermometer
1608	The Dutch scientist Hans Lippershey invents the telescope
1612	The Flintlock firearm is developed in France
1621	John Napier invents the slide rule
1643	Torricelli makes the first barometer using mercury in a sealed glass tube
1651	The Dutch scientist Anton van Leeuwenhoek develops a microscope
1668	Isaac Newton invents a reflecting telescope
1709	Gabriel Fahrenheit invents an alcohol thermometer (mercury thermometer developed in 1714)
1710	Bathroom bidet is invented in France
1712	The steam engine is first invented in England
1714	The first patent for a typewriter is awarded in England to Henry Mill
1718	The machine gun is developed in England
1738	William Champion patents a process for the production of metallic zinc by distillation from calamine and charcoal
1770	First reported use of porcelain false teeth in France
1774	The electric telegraph is developed by Georges Louis Lesage
1779	Bry Higgins issued a patent for hydraulic cement (stucco) for use as an exterior plaster
1789	Chlorine bleach is developed by Claude Louis Berthollet in France
1800	Alessandro Volta makes a Copper/Zinc acid battery
1815	Humphry Davy invents a safety lamp that is used in coal mines without triggering an explosion
1820	Thomas Hancock develops the first elastic fabrics
1821	Thomas Johann Seebeck invents the thermocouple
1823	Charles Macintosh patents a method for making waterproof garments
1824	Patent issued to Joseph Aspdin for the invention of cement
1825	Hans Christian Orsted produces metallic aluminum
1825	William Sturgeon invents the electromagnet
1837	Wheatstone and Cooke invent the telegraph
1838	Regnault polymerizes vinylidene chloride via sunlight
1839	Goodyear (US), MacIntosh, and Hancock (England) vulcanize natural rubber
1839	Sir William Robert Grove experimented with the first fuel cell, using hydrogen and oxygen gases in the presence of an electrolyte
1842	The facsimile machine is invented by Alexander Bain
1849	Ferroconcrete, concrete reinforced with steel, is invented by Monier
1855	Bessemer process for mass production of steel patented
1856	Invention of the first synthetic dye, mauveine, by William Henry Perkin
1857	Toilet paper is designed and marketed for the first time
1860	Fredrick Walton invents linoleum, comprised of linseed oil, pigments, pine rosin, and pine flour
1861	James Clerk Maxwell demonstrates color photography
1864	Development of flash photography by Henry Roscoe in England

1872	Asphalt is first developed by Edward de Smedt at Columbia University
1872	Polyvinyl chloride (PVC) is first created by Eugen Baumann
1873	Levi Strauss & Co. begin producing blue-jeans out of durable canvas
1876	Nicolaus Otto invents a gas motor engine
1877	Thomas Edison completes the first phonograph
1881	Alexander Graham Bell builds the first metal detector
1883	Charles Fritts makes the first solar cells using selenium wafers
1885	Sunglasses are invented
1885	Karl Benz designs and builds the first gasoline-fueled automobile
1885	The first gasoline pump is manufactured by Sylvanus Bowser
1887	Contact lenses are invented by Eugen Frick in Switzerland
1888	George Eastman introduces a Kodak camera
1890	The zipper is invented by Whitcomb Judson in Chicago, IL
1891	The first commercially produced artificial fiber, Rayon, is invented
1892	Calcium carbide is synthesized, as well as acetylene gas that is generated from the carbide
1893	Edward Goodrich Acheson patents a method for making carborundum (SiC), an abrasive compound
1896	Henry Ford constructs the first horseless carriage
1901	The first mercury arc lamp is developed by Peter Hewitt
1902	August Verneuil develops a process for making synthetic rubies
1902	The neon light is invented in France
1903	Ductile tungsten wire is synthesized by Coolidge
1907	Leo Hendrik Baekeland invents Bakelite (phenol- formaldehyde resins), used in electronic insulation
1908	Cellophane is invented by Brandenberger, a Swiss textile engineer
1909	Leo Baekeland presents the Bakelite hard thermosetting plastic
1916	Jan Czochralski invents a method for growing single crystals of metals
1916	Kotaro Honda discovers a strongly magnetic Co/W alloy
1920	Herman Staudinger (Germany) advances the macromolecular hypothesis – the birth of polymer science
1923	Mercedes introduces the first supercharged automobile, the 6/25/40 hp
1924	Corning scientists invent Pyrex, a glass with a very low thermal expansion coefficient
1924	Celanese Corporation commercially produces acetate fibers
1924	The first mobile, two-way voice-based telephone is invented at Bell Labs
1926	Waldo Semon at B.F. Goodrich invents plasticized PVC known as *vinyl*
1929	Polysulfide (Thiokol) rubber is synthesized
1929	Carothers (du Pont) synthesizes the first aliphatic polyesters, establishes the principles of step-growth polymerization, and develops nylon 6,6
1931	Julius Nieuwland develops the synthetic rubber called *neoprene*
1931	Poly(methylmethacrylate) (PMMA) is synthesized
1932	Hans von Ohain and Sir Frank Whittle file patents for the jet engine
1932	Cathode ray tubes (CRTs) are invented by Allen B. Du Mont
1933	Ernest Ruska discovers the electron microscope; magnification of 12,000×
1933	Fawcett and Gibson develop polyethylene (LDPE)
1936	The first programmable computer, the Z1, is developed by Konrad Zuse
1937	Polystyrene is developed
1937	Chester Carlson invents a dry printing process commonly called *Xerox*
1938	Roy Plunkett discovers the process for making poly-tetrafluoroethylene, better known as *Teflon*™
1940	Thomas and Sparka synthesize isobutylene–isoprene rubber
1940	Butyl rubber is synthesized in the US

1941	Canadian John Hopps invents the first cardiac pacemaker
1942	The synthetic fabric, polyester, is invented
1943	The first kidney dialysis machine is developed
1943	Polyurethanes are synthesized by Otto Baeyer
1944	The first plastic artificial eye is developed in the US
1945	Percy Spencer creates the first microwave oven
1946	Mauchly and Eckert develop the first electronic computer ENIAC (Electronic Numerical Integrator and Computer)
1947	The first transistor is invented by Bardeen, Brattain, and Shockley at Bell Labs
1947	The first commercial application of a piezoelectric ceramic (barium titanate) used as a phonograph needle
1947	Invention of magnetic tape for recording applications
1947	Schlack develops epoxy polymeric systems
1951	Individual atoms seen for the first time using the field ion microscope
1950	The first commercial production of acrylic fibers by du Pont
1951	The computer UNIVAC 1 is developed
1951	Polypropylene is developed by Paul Hogan & Robert Banks of Phillips
1952	The first application of antiperspirant deodorant with a roll-on applicator
1953	Karl Ziegler discovers metallic catalysts which greatly improve the strength of polyethylene polymers
1954	Six percent efficiency silicon solar cells made at Bell Labs
1954	Charles Townes and Arthur Schawlow invent the MASER (microwave amplification by stimulated emission or radiation)
1955	Optical fibers are produced
1956	Liquid Paper™ is formulated by Bette Nesmith Graham
1957	Keller first characterizes a single crystal of polyethylene
1958	Bifocal contact lenses are produced
1959	Pilkington Brothers patent the float glass process
1959	The first commercial production of Spandex fibers by du Pont
1960s	Polymers are first characterized by GPC, NMR, and DSC
1960	The first working laser (pulsed ruby) is developed by Maimam of Hughes Aircraft Corporation. Javan, Bennet, and Herriot make the first He:Ne gas laser
1960	Spandex fibers are synthesized
1962	The first SQUID superconducting quantum interference device is invented
1962	Polyimide resins are synthesized
1963	The first balloon embolectomy catheter is invented by Thomas Fogarty
1963	Ziegler and Natta are awarded the Nobel Prize for 1950's polymerization studies
1964	Bill Lear (of "Lear Jet" fame!) designs the first eight-track player
1965	A bulletproof nylon fabric, Kevlar, is invented at DuPont
1965	James Russell invents the compact disk
1965	Styrene–butadiene block copolymers are synthesized
1966	Fuel-injection systems for automobiles are developed in the UK
1966	Faria and Wright of Monsanto synthesize and test Astroturf
1967	Keyboards are first used for data entry, replacing punch cards
1968	Liquid crystal display is developed by RCA
1968	Allen Breed invents the first automotive air bag system
1969	The scanning electron microscope (SEM) is first used in laboratories to view cells in 3D
1969	George Smith and Willard Boyle invent charge-coupled devices (CCD) at Bell Labs
1970	The floppy disk (8 in.) is invented by Alan Shugart at IBM

1970	The first microfiber (polyester) is invented by Toray Industries in Japan. The first fabric comprised of microfibers, Ultrasuede, is also introduced
1971	The liquid crystal display (LCD) is invented by James Fergason
1971	The first single chip microprocessor, Intel 4004, is introduced
1971	The video cassette recorder (VCR) is invented by Charles Ginsburg
1971	Hydrogels are synthesized
1972	Motorola demonstrates the use of the first portable cellular phone[2]
1973	The disposable lighter is invented by Bic
1973	Magnetic resonance imaging (MRI) is invented by Lauterbur and Damadian[3]
1974	Post-it® notes featuring a low-residue adhesive is invented by 3M
1975	The laser printer is invented
1975	Robert S. Ledley is issued the patent for "diagnostic X-ray systems" (CAT scans)
1976	The inkjet printer is developed by IBM
1977	The Cray-1® supercomputer is introduced by Seymour Cray
1977	Electrically conducting organic polymers are synthesized by Heeger, MacDiarmid, and Shirakawa (Nobel Prize awarded in 2000)
1978	An artificial heart, Jarvik-7, is invented by Robert Jarvik
1978	The first analog video optical disk player is introduced by MCA Discovision
1979	The first cassette Walkman TPS-L2 is invented by Masaru Ibuka of Sony
1980	Compact disk players are introduced by Philips
1981	The world's largest solar-power generating station goes into operation (10 MW capacity)
1981	The scanning tunneling microscope (STM) is invented
1982	The first "personal computer" (PC) is introduced by IBM[4]
1982	Robert Denkwalter *et al.* from Allied Corporation are granted the first patent for dendrimers
1983	US phone companies begin to offer cellular phone service
1983	Steve Jobs of Apple introduces a new computer featuring the first graphical user interface (GUI), named *The Lisa*
1984	The CD-ROM is invented for computers
1984	The first clumping kitty litter is invented by biochemist Thomas Nelson
1985	Donald Tomalia and coworkers at Dow Chemical report the discovery of hyperbranched polymers, named *dendrimers*
1986	Synthetic skin is invented by Gregory Gallico, III
1987	Bednorz and Muller develop a material that is superconducting at $-183°C$
1987	Conducting polymers are developed by BASF
1988	A patent is issued for the Indiglo™ nightlight, consisting of electroluminescent phosphor particles
1989	High-definition television is invented
1989	NEC releases the first "notebook" computer, the NEC Ultralite
1989	A breathable, water- or wind-proof fabric, GORE-TEX®, is introduced
1989	The Intel 486 microprocessor is developed, featuring 1,000,000 transistors
1990	Biotextiles are invented in the US
1991	Iijima of NEC Corporation discovers carbon nanotubes
1992	MiniDiscs (MDs) are introduced by Sony Electronics, Inc.
1992	Prof. Jerome Schentag invents a computer-controlled "smart pill," for drug-delivery applications
1993	The Pentium processor is invented by Intel
1994	The first search engine for the World Wide Web is created by Filo and Yang[5]

1994	Lyocell is introduced by Courtaulds Fibers, consisting of a material derived from wood pulp
1995	Digital Versatile Disk or Digital Video Disk (DVD) is invented
1996	The Nobel Prize in Chemistry is awarded to Richard Smalley, Robert Curl, and Harry Kroto for their 1985 discovery of the third form of carbon, known as *buckminsterfullerene* ("bucky balls")[6]
1996	WebTV is invented by Phillips
1996	The Palm Pilot is debuted by 3Com
1997	The gas-powered fuel cell is invented
1997	A fire-resistant building material, Geobond, is patented
1997	Nokia introduces the Nokia 9000i Communicator. This combines a digital cell phone, hand-held PC, and fax
1998	Motorola introduces Iridium service, the first global satellite-based wireless telephone service[7]
1998	Adam Cohen (19 years old!) develops an "electrochemical paint brush" circuit that uses an STM probe to manipulate copper atoms on a silicon surface
1998	Apple computer introduces the iMac
1998	Geoffrey Ozin at the University of Toronto develops synthetic seashells from SiO_2
1998	Toyota Motor Corporation releases the Prius – the first mass-produced hybrid low-emission vehicle (LEV)
1998	Television stations in the US began to transition from analog to digital signals
1999	Danish physicist Hau is able to control the speed of light, useful for potential applications in communications systems and optical computers
1999	Safeco Field in Seattle opens, featuring a retractable roof, and extensive drainage lines and heating coils to maintain ideal turf conditions[8]
1999	The chemical ingredient used by mussels to anchor themselves to rocks is discovered, and used to synthesize a waterproof adhesive
1999	Molecular-based logic gates are demonstrated to work better than silicon-based gates – an important precedent in the development of a molecular computer
2000	Intel releases the Pentium IV microprocessor, consisting of 42 million transistors
2000	Motorola releases the i1000 Plus – the first cell phone capable of connecting to the internet
2000	Robotic pets (*e.g.*, Poo-Chi, Tekno) are first introduced
2000	The first generation of "digital jukeboxes," the AudioReQuest ARQ1, retails for $800 and is the first device capable of storing thousands of MP3 songs
2001	The AbioCor self-contained artificial heart is implanted into Robert Tools
2001	SmartShirt sensors, to record and report body diagnostics, are designed by SensaTex, Inc. and Georgia Tech Research Corporation
2001	The bioartificial liver is invented by Kenneth Matsumura
2001	A fuel-cell bicycle is developed by Aprilia
2001	Digital satellite radio is developed by XM and Sirius
2001	SunClean self-cleaning glass is introduced by PPG Industries
2001	A wrinkle-free shirt is developed by Corpo Nove (Italy), consisting of Ti-alloy fibers interwoven with nylon
2002	Clothing comprised of nanowhiskers is invented by Nano-tex, LLC to aid in stain resistance
2002	The lightest substance on Earth, known as *Aerogels*, is developed by NASA

2002	Scientists at SUNY, Buffalo, develop a new type of semiconducting material, GaSb/Mn, that will be used for future spintronics-based devices[10]
2003	Scientists discover a method used to commercially produce spider-web silk[9]
2003	Nanoparticles are used for the first time for clearcoat paint finishes (PPG – Ceramiclear^{TM})
2003	Nanofilters are used to purity groundwater in Manitoba, Canada
2003	Digital videodisk recorders (DVRs) are introduced
2003	IBM develops the smallest light-emitting transmitter, comprised of carbon nanotubes (CNTs)
2003	Apple computer releases laptops featuring 17- and 12-in. LCD screens
2003	Bandages are made from fibrinogen, a soluble protein found in blood
2004	The Blue Gene/L produced by IBM is able to perform 70.7 trillion calculations per second, making it the fastest computer in the world, to date
2004	Apple releases the iPod mini – the size of a business card, but able to hold 1,000 songs
2004	Scientists are able to control polymorphism through crystallization within nanopores
2004	A compound in the shape of a Borromean knot is discovered, based on earlier theoretical simulations
2004	Nintendo releases the hand-held gaming system, Nintendo DS
2005	Carbon nanotubes are synthesized in bulk, and spun into a yarn
2005	iPod Nano and a video-capable iPod are introduced by Apple
2005	Motorola releases the ROKR E1 phone, capable of music downloading
2006	High-definition DVD players become commercially available
2006	Apple computer introduces MacBook Pro, MacBook, and iMac product lines that contain Intel dual-core chips – the first to contain over one billion transistors
2006	Flat-panel display technologies employing carbon nanotubes are demonstrated
2006	LG designs cellular phone that has a built-in breathalyzer for sobriety testing; this application is also tested as standard equipment for future automobiles
2007	Apple releases the iPhone, which combines cellular phone, internet, and iPod functionalities
2007	LG releases the first dual HD-DVD/Blu-ray high-definition player

References and Notes

1 The magnetic compass may have been first used during the Qin dynasty in China (*ca.* 200 B.C.).

2 The first call that was made with a portable cellular phone was made by Dr. Martin Cooper, who called his rival, Joel Engel, at Bell Labs!.

3 The Nobel Prize for Medicine was awarded to Paul C. Lauterbur and Sir Peter Mansfield "for their discoveries concerning magnetic resonance imaging." This announcement failed to acknowledge Raymond V. Damadian who was the first person to propose MRI for medical diagnostics. In an effort to become properly acknowledged, Damadian placed full-page ads in major newspapers such as the *Washington Post*, the *New York Times*, and the *Los Angeles Times*. His fight for proper recognition is not unwarranted; the US National Medal of Technology was awarded to Damadian and Lauterbur in 1988, which recognized both scientists as co-inventors. Unfortunately, in an attempt to "make them [the Stockholm Nobel Prize committee] accountable to world opinion," Damadian may only be remembered for his unprecedented fight for personal recognition, rather than his co-discovery.

[4] The first PC (IBM 5150) retailed for $2,880, and was powered by the Intel 8088 microprocessor comprised of a 3-μm circuit, containing 29,000 transistors. This system was capable of performing 4.8 million cycles per second (4.8 MHz). The first microprocessor, the Intel 4004 developed in 1971, consisted of 2,300 transistors in a 3.5-mm circuit. Amazingly, modern computers costing $2,000 are now capable of performing 2+ billion instructions per second (2 GHz), and feature 100s of millions of transistors contained within a circuit size of 130 nm! Computational devices have decreased steadily at about five linear dimensions per decade, but are rapidly approaching a barrier. Chapter 6 on nanotechnology will discuss the future of electronic devices.

[5] This was simply a list of other sites called "Jerry's Guide to the World Wide Web." Within 8 months, more than 100,000 people were using this sit as an index to the Web, and it was eventually renamed Yahoo!.

[6] This award is considered to have generated a new field known as "nanotechnology," as worldwide exposure was instantly aware of these nanoscale molecules, and other developments in this size regime were found shortly thereafter. It should be noted that the discovery of dendrimers by Denkwalter and coworkers from Allied Corporation was disclosed in 1981, 4 years before bucky balls were discovered. It may be expected that these nanopolymeric materials will be extremely influential toward the nanotechnology revolution (see Chapter 5 for more information on dendritic materials).

[7] This service quickly filed for bankruptcy; satellite-based wireless service is not yet widely available.

[8] The price tag was $500M, making Safeco Field the most expensive field built to date in the US.

[9] Spider-web silk is *ca.* five times stronger than steel by weight, and almost as elastic as nylon. Fibers comprised of the synthetic silk were demonstrated to be stronger than Kevlar, and may be useful for biomedical applications such as artificial tendons and ligaments and surgery sutures, as well as lightweight body armor for military applications.

[10] Rather than using electronics to turn switches on/off, spintronic devices use electronic spins to represent information. This will allow these devices to process billions of pieces of information simultaneously, greatly increasing the speed and power of electronic devices. For more information on the future of spintronics, see: http://www.spintronics-info.com/.