TMS

PROMOTING THE GLOBAL SCIENCE AND ENGINEERING PROFESSIONS CONCERNED WITH MINERALS, METALS, AND MATERIALS

Voting for *JOM's* Ten Greatest Materials Moments: Fact Sheet

WHAT IS A GREAT MATERIALS MOMENT?

A **Great Materials Moment** is defined as a pivotal or capstone event of human observation and/or intervention that led to a paradigm shift in humanity's understanding of materials behavior, that introduced a new era of materials utilization, and/or that yielded significant materials-enabled socio-economic changes.

WHO IS PRESENTING THE HONOR?

The top ten will be named by the journal *JOM* in celebration of The Minerals, Metals & Materials Society's 50th anniversary as a member society of the American Institute of Mining, Metallurgical and Petroleum Engineers.

JOM is the member journal of The Minerals, Metals & Materials Society.

WHAT IS THE METHODOLOGY?

An invitational group of *JOM* readers as well as other professional members of the greater materials science and engineering community were asked to submit nominations of great materials moments. This feedback was combined with research of the literature to build an inventory of more that 650 candidate moments. This raw inventory of moments was culled to a list of 100 nominees via an iterative process of the *JOM* staff working with esteemed members of the materials science and engineering community, especially individuals well versed in historical developments in the field.

For the final three months of 2006, the list of 100 nominee moments will be presented to the general public for on-line voting. The ten candidates receiving the greatest number of votes will be declared the greatest materials moments of all time.

HOW CAN SOMEONE VOTE?

All voting will be conducted at the following web site:

http://www.materialmoments.org/survey.html

Voting ends January 5, 2007.

WHEN AND WHERE WILL THE TOP TEN BE ANNOUNCED?

February 26, 2007, at the Walt Disney World Dolphin Hotel during an all-conference plenary session conducted at the 2007 TMS Annual Meeting.

The list will be counted down, from 10 to 1, by a panel of present and past TMS presidents.

FOR ADDITIONAL REFERENCE

- Nominees: Appear on following pages
- Greatest Materials Moments initiative: *http://www.materialmoments.org*
- The Minerals, Metals & Materials Society: *http://www.tms.org*
- *JOM*: *http://www.tms.org/jom.html*
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JOM's Greatest Materials Moments Nominees

GREAT MATERIALS MOMENT	DATE	SIGNIFICANCE
The earliest fired ceramics—in the form of animal and human figurines, slabs, and balls—(found at sites in the Pavlov Hills of Moravia) are manufactured starting about this time. .	28,000 BC (estimated)	Introduces materials processing.
The earliest form of metallurgy begins with the decorative hammering of copper by Old World Neolithic peoples.	8000 BC (estimated)	Leads to the replacement of stone tools with much more durable and versatile copper ones.
In and around modern Turkey, people discover that liquid copper can be extracted from malachite and azurite and that the molten metal can be cast into different shapes.	5000 BC (estimated)	Introduces extractive metallurgy—the means of unlocking the Earth's mineralogical treasures.
Egyptians smelt iron (perhaps as a by-product of copper refining) for the first time, using tiny amounts mostly for ornamental or ceremonial purposes.	3500 BC (estimated)	Unlocks the first processing secret of what will become the world's dominant metallurgical material.
Metal workers in the region of modern Syria and Turkey discover that addition of tin ore to copper ore before smelting produces bronze.	3000 BC (estimated)	Establishes the concept of metals alloying—blending two or more metals to create a substance that is greater than the sum of its parts.
The peoples of northwestern Iran invent glass.	2200 BC (estimated)	Introduces the second great nonmetallic engineering material (following ceramics).
Potters in China craft the first porcelain using kaolin.	1500 BC (estimated)	Begins a long tradition of exceptional craftsmanship and artistry with this class of ceramics.
Metal workers in the Near East develop the art of lost-wax casting.	1500 BC (estimated)	Establishes the ability to create and replicate intricate and complex metallurgical structures.
Metal workers in south India develop crucible steel making.	300 BC (estimated)	Produces "wootz" steel which becomes famous as "Damascus" sword steel hundreds of years later, inspiring artisans, blacksmiths, and metallurgists for many generations to come.
Chinese metal workers develop iron casting.	200 BC (estimated)	Introduces the primary approach to manufacturing iron objects for centuries in China.
Glass blowing is developed, probably somewhere in the region of modern Syria, Lebanon, Jordan, and Israel—most likely by Phoenicians.	100 BC (estimated)	Enables the quick manufacture of large, transparent, and leak-proof vessels.
Iron smiths forge and erect a seven meter high iron pillar in Delhi, India.	400 (estimated)	Defies deleterious environmental effects for more than one and a half millennia, creating an artifact of long-standing materials science and archaeological intrigue.
Johannes Gutenberg devises a lead-tin-antimony alloy to cast in copper alloy molds to produce large and precise quantities of the type required by his printing press.	1450	Establishes the fundamental enabling technology for mass communication.

Johanson Funcken develops a method for separating silver from lead and copper, ores of which are often mixed in deposits.	1451	Establishes that mining and metals processing operations can recover metals as a by-product of other operations.
Vannoccio Biringuccio publishes *De La Pirotechnia*.	1540	Provides the first written account of proper foundry practice.
Georgius Agricola publishes *De Re Metallica.*	1556	Provides a systematic and well-illustrated examination of mining and metallurgy as practiced in the sixteenth century.
Galileo publishes *Della Scienza Mechanica* ("on mechanical knowledge"), which he writes after he has been consulted regarding shipbuilding problems.	1593	Deals scientifically with the strength of materials.
Anton van Leeuwenhoek develops optical microscopy capable of magnifications of 200 times and greater.	1668 (estimated)	Enables study of the natural world and its structures that are invisible to the unaided eye.
Abraham Darby I discovers that coke can effectively replace charcoal in a blast furnace for iron smelting.	1709	Lowers dramatically the cost of ironmaking (enabling large-scale production) and saves regions from deforestation.
In Britain, the first glue patent is issued (for fish glue, an exceptionally clear adhesive).	1750	Initiates a rapid succession of adhesive developments with natural and then synthetic sources.
John Smeaton invents modern concrete (hydraulic cement).	1755	Introduces the dominant construction material of the modern age.
Luigi Brugnatelli invents electroplating.	1805	Originates the widely employed industrial process for functional and decorative applications.
Sir Humphry Davy develops the process of electrolysis to separate elemental metals from salts, including potassium, calcium, strontium, barium, and magnesium.	1807	Establishes the foundation for electrometallurgy and electrochemistry.
Auguste Taveau develops a dental amalgam from silver coins and mercury.	1816	Enables repeatable and low-cost dental filling material and establishes one of the earliest examples of metallic biomaterials.
Augustin Cauchy presents his theory of stress and strain to the French Academy of Sciences.	1822	Provides the first careful definition of stress as the load per unit area of the cross section of a material.
Friedrich Wöhler isolates elemental aluminum.	1827	Unlocks the most abundant metallic element in the Earth's crust.
Wilhelm Albert develops iron wire rope as hoisting cable for mining.	1827	Presents an exponential leap of large-scale construction and industrial opportunities over the limitations of hemp rope.
Charles Goodyear invents the vulcanization of rubber.	1844	Enables enormous progress in the transportation, electricity, manufacturing, and myriad other industries.

George Audemars patents "artificial silk" created using the fibrous inner bark of a mulberry tree.	1855	Leads to the manufacture of rayon and the era of synthetic fibers, creating sweeping effects on the textiles and materials industries.
Henry Bessemer patents a bottom-blown acid process for melting low-carbon iron.	1856	Ushers in the era of cheap, large-tonnage steel, thereby enabling massive progress in transportation, building construction, and general industrialization.
Emile and Pierre Martin develop the Siemens-Martin open-hearth furnace process.	1863	Produces large quantities of basic steel by heating a combination of steel scrap and iron ore with gas burners—helping to make steel the world's most recycled metal.
Henry Clifton Sorby uses light microscopy to reveal the microstructure of steel.	1863	Leads to the use of photomicrography with metals and the science of metallurgy.
Dmitri Mendeleev devises the Periodic Table of Elements.	1864	Introduces the ubiquitous reference tool of materials scientists and engineers.
Alfred Nobel patents dynamite.	1867	Proves of immeasurable assistance in conducting large-scale mining.
J. Willard Gibbs publishes the first part of the two-part paper "On the Equilibrium of Heterogeneous Substances."	1876	Provides a basis for understanding modern thermodynamics and physical chemistry.
William Siemens patents the arc-type electric furnace.	1878	Leads to the modern electric arc furnace, which is the principle furnace type for the modern electric production of steel.
Pierre Manhès constructs the first working converter for copper matte.	1880	Initiates the modern period of copper making.
Charles Martin Hall and Paul Héroult independently and simultaneously discover the electrolytic reduction of alumina into aluminum.	1886	Provides the processing foundation for the proliferation of aluminum for commercial applications
Adolf Martens examines the microstructure of a hard steel alloy and finds that, unlike many inferior steels that show little coherent patterning, this steel had many varieties of patterns, especially banded regions of differently oriented microcrystals.	1890	Initiates the use of microscopy to identify the crystal structures in metals and correlate these observations to the physical properties of the material.
Pierre and Marie Curie discover radioactivity.	1896	Marks the beginning of modernera studies on spontaneous radiation and applications of radioactivity for civilian and military applications.
William Roberts-Austen develops the phase diagram for iron and carbon.	1898	Initiates work on the most significant phase diagram in metallurgy, providing the foundation for the indispensable tool for other material systems.
Johann August Brinell develops a test to estimate the hardness of metals that involves pressing a steel ball or diamond cone against the specimen.	1900	Establishes a reliable (and still commonly used) method to determine the hardness properties of virtually all materials.
Charles Vincent Potter develops the flotation process to separate metallic sulfide minerals from otherwise unusable minerals.	1901	Opens the opportunity for the large-scale recovery of metals from increasingly difficult-to-treat low-grade ores from mining operations.

Leon Guillet develops the alloying compositions of the first stainless steels.	1904	Expands the versatility of steel for use in corrosive environments.
Alfred Wilm discovers the precipitation hardening of aluminum alloys.	1906	Yields the "hard aluminum" duraluminum, the first high-strength aluminum alloy.
Leo Baekeland synthesizes the thermosetting hard plastic Bakelite.	1909	Marks the beginning of the "plastic age" and the modern plastics industry.
William D. Coolidge devises ductile tungsten wire, using a powder metallurgical approach, for use as an energy-efficient, high-lumen lighting filament.	1909	Spurs the rapid expansion of electric lamps and initiates the science of modern powder metallurgy.
Kammerlingh Omnes discovers superconductivity while studying pure metals at very low temperatures.	1911	Forms the basis for modern discoveries in low- and high-temperature superconductors and resulting high-performance applications.
Max von Laue discovers the diffraction of x-rays by crystals.	1912	Creates means to characterize crystal structures and inspires W.H. Bragg and W.L Bragg in developing the theory of diffraction by crystals, providing insight into the effects of crystal structure on material properties.
Albert Sauveur publishes *Metallography and Heat Treatment of Iron and Steel.*	1912	Promulgates the "processing-structure-properties" paradigm that guides the materials science and engineering field.
Niels Bohr publishes his model of atomic structure.	1913	Introduces the theory that electrons travel in discrete orbits around the atom's nucleus, with the chemical properties of the element being largely determined by the number of electrons in each of the outer orbits.
Jan Czochralski publishes the paper "Ein Neues Verfahren zur Messung des Kristallisationsgeschwindigkeit der Metalle" ("A New Method for the Measurement of the Crystallization Rate of Metals"), in which he describes a method of growing metallic monocrystals.	1918	Becomes the method of choice for growing high-performance materials, such as the silicon crystals used in the semiconductor computer chip industry.
A.A. Griffith publishes "The Phenomenon of Rupture and Flow in Solids," which casts the problem of fracture in terms of energy balance.	1920	Gives rise to the field of fracture mechanics.
Hermann Staudinger publishes work that states that polymers are long chains of short repeating molecular units linked by covalent bonds.	1920	Paves the way for the birth of the field of polymer chemistry.
John B. Tytus invents the continuous hot-strip rolling of steel.	1923	Provides the basis for the inexpensive, large-scale manufacturing of sheet and plate products.
Karl Schroter invents cemented carbides as a class of materials.	1923	Provides the basis for the workhorse materials of the tool and metal-cutting industries.
Cornelius H. Keller patents alkyl xanthates sulfide collectors.	1925	Begins a revolution in sulfide mineral flotation, turning worthless mineral deposits into bonanzas.
Werner Heisenberg develops matrix mechanics and Erwin Schrödinger invents wave mechanics and the non-relativistic Schrödinger equation for atoms.	1925	Forms the basis of quantum mechanics.

Waldo Lonsbury Semon invents plasticized polyvinyl chloride (PVC).	1926	Becomes one of the world's most versatile and widely used construction materials.
Paul Merica patents the addition of small amounts of aluminum to Ni-Cr alloy to create the first "superalloy."	1926	Leads to the commercialization of the jet engine, along with increased efficiency for modern power turbine machinery.
Clinton Davisson and Lester Germer experimentally confirm the wave nature of the electron.	1927	Provides fundamental work necessary for much of today's solid-state electronics.
Siegfried Junghans perfects a process for the continuous casting of nonferrous metal.	1927	Provides the basis for commercial exploitation of high-volume continuous casting.
Arnold Sommerfeld applies quantum statistics to the Drude model of electrons in metals and develops the free-electron theory of metals.	1927	Supplies a simple model for the behavior of electrons in a crystal structure of a metallic solid and contributes to the foundation of solid-state theory.
Fritz Pfleumer patents magnetic tape.	1928	Establishes the technology and leads to many subsequent innovations for data storage.
Arne Olander discovers the shape-memory effect in an alloy of gold and cadmium.	1932	Leads to the development of the commercial shape-memory alloys that are employed in medical and other applications.
Max Knoll and Ernst Ruska build the first transmission electron microscope.	1933	Accesses new length scales and enables improved understanding of material structure.
Egon Orowan, Michael Polyani, and G.I. Taylor, in three independent papers, propose that the plastic deformation of ductile materials could be explained in terms of the theory of dislocations.	1934	Provides critical insight toward developing the modern science of solid mechanics.
Wallace Hume Carothers, Julian Hill, and other researchers patent the polymer nylon.	1935	Greatly reduces the demand for silk and serves as the impetus for the rapid development of polymers.
Erich Schmid and Walter Boas publish *Kristallplastizitaet,* which details 15 years of research on plastic deformation of metallic single crystals.	1935	Leads to a much better understanding of plastic deformation, a critical property of metals.
Norman de Bruyne develops the composite plastic Gordon-Aerolite, which consists of high-grade flax fiber bonded together with phenolic resin.	1937	Paves the way for the development of fiberglass.
André Guinier and G.D. Preston independently report the observation of diffuse streaking in age-hardened aluminum-copper alloys.	1937	Leads to the improved understanding of precipitation-hardening mechanisms.
Otto Hahn and Fritz Strassmann find that they can split the nucleus of a uranium atom by bombarding it with neutrons	1939	Establishes nuclear fission and leads to applications in energy and atomic weapons.
Russell Ohl, George Southworth, Jack Scaff, and Henry Theuerer discover the existence of p- and n-type regions in silicon.	1939	Provides a necessary precursor to the invention of the transistor eight years later.

Wilhelm Kroll develops an economical process for titanium extraction.	1940	Establishes the primary means of producing the high-purity titanium needed for products ranging from high-performance aircraft to corrosion-resistant reactors.
Frank Spedding develops an efficient process for obtaining high-purity uranium from uranium halides.	1942	Enables the development of the atomic bomb in the Manhattan Project.
John Bardeen, Walter H. Brattain, and William Shockley invent the transistor.	1948	Becomes the building block for all modern electronics and the foundation for microchip and computer technology.
Bill Pfann invents zone refining.	1951	Enables the preparation of high-purity materials, such as the improved semiconductors critical for electronic applications.
Nick Holonyak, Jr., develops the first practical visible-spectrum light-emitting diode (LED).	1952	Marks the beginning of the use of III-V alloys in semiconductor devices, including heterojunctions and quantum well heterostructures.
S. Donald Stookey discovers a heat-treatment process for transforming glass objects into fine-grained ceramics.	1952	Leads to the introduction of Pyroceram and CorningWare.
A team in Sweden produces the first artificial diamonds by using high heat and pressure.	1953	Gives rise to the industrial diamond industry, with applications in machining, electronics, and a variety of other areas.
Gerald Pearson, Daryl Chapin, and Calvin Fuller unveiled the Bell Solar Battery—the world's first device to successfully convert useful amounts of sunlight directly into electricity.	1954	Serves as the very foundation for solar energy production as well as photo-detector technology.
Peter Hirsch and coworkers provide experimental verification by transmission electron microscopy of dislocations in materials.	1956	Not only is dislocation theory verified unequivocally, but the power of transmission electron microscopy in materials research is demonstrated.
Jack Kilby integrates capacitors, resistors, diodes, and transistors into a single germanium monolithic integrated circuit or "microchip."	1958	Makes possible microprocessors and, thereby, high-speed, efficient, convenient, affordable, and ubiquitous, computing and communications systems.
Frank VerSnyder develops the directionally solidified columnar-grained turbine blade	1958	Enables performance enhancements for jet engines, saving airlines millions of dollars per year in fuel costs alone.
Pol Duwez uses rapid cooling to make a gold-silicon alloy that remains amorphous at room temperature.	1959	Represents the first true metallic glass, which has been applied in transformer cores and offers significant potential.
Richard Feynman presents "There's Plenty of Room at the Bottom" at a meeting of the American Physical Society	1959	Introduces the concept of nanotechnology (while not naming it as such).
Arthur Robert von Hippel publishes *Molecular Science and Molecular Engineering.*	1959	Creates an emerging discipline aimed at designing new materials on the basis of molecular understanding.
Stephanie Kwolek invents the high-strength, low-weight plastic Kevlar.	1964	Improves the performance of tires, boat shells, body armor, components for the aerospace industry, and more.

Cambridge Instruments introduces a commercial scanning electron microscope.	1965	Provides an improved method for the high-resolution imaging of surfaces at greater magnifications and with much greater depth of field than possible with light microscopy.
Karl J. Strnat and coworkers discover magneto-crystalline anisotropy in rare-earth cobalt intermetallic compounds.	1966	Leads to the fabrication of high-performance permanent magnets of samarium-cobalt and, later, neodymium-iron-boron for use in electronic devices and other areas.
Larry Hench and colleagues develop bioactive glass for orthopedic use.	1969	Changes the paradigm in biomaterials to include interfacial bonding of the implant with host tissues.
James Fergason, utilizing the twisted nematic field effect, makes first operating liquid crystal displays.	1970	Completely redefines many products and applications, including computer displays, medical and industrial devices, and the vast array of consumer electronics.
Bob Maurer, Peter Schultz and Donald Keck invent low-loss optical fiber.	1970	Provides the basis for the increased bandwidth that revolutionized telecommunications.
Hideki Shirakawa, Alan MacDiarmid, and Alan Heeger announce the discovery of electrically conducting organic polymers.	1977	Leads to the development of flat panel displays using organic light-emitting diodes, solar panels, and optical amplifiers.
Heinrich Rohrer and Gerd Karl Binnig invent the scanning tunneling microscope.	1981	Provides three-dimensional atomic-scale images of metal surfaces and quickly becomes widely used in research to characterize surface roughness and observe surface defects.
Robert Curl, Jr., Richard Smalley, and Harold Walter Kroto discover that some carbon arranges itself in the form of soccer-ball-shaped molecules with 60 atoms called buckminsterfullerenes or "buckyballs."	1985	Opens the possibility that carbon can assume an almost infinite number of different structures.
Paul Chu creates a superconducting yttrium-barium-copper oxide ceramic.	1987	Opens the possibility of large-scale application of superconducting materials
Don Eigler spells out "IBM" with individual xenon atoms using a scanning tunneling electron microscope	1989	Demonstrates that atoms can be manipulated one by one, the basis for "bottoms-up" production of nanostructures.
Sumio Iijima discovers nanotubes, carbon atoms arranged in tubular structures.	1991	Creates expectations of important structural and nonstructural applications as nanotubes are about 100 times stronger than steel at just a sixth of the weight while also possessing unusual heat and conductivity characteristics.
Eli Yablonovich produces "photonic crystals" by drilling holes in a crystalline material so that light of a certain wavelength cannot propagate in the material.	1991	Forms a basis for the development of "photonic transistors."