MATERIALS RESEARCH CHRONOLOGY, 1917–1957

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Science and Technology Division, Library of Congress

YEARS OF MATERIALS PROGRESS
SAPPHIRE ANNIVERSARY

Directorate of Materials and Processes
Aeronautical Systems Division
Wright-Patterson Air Force Base
Dayton, 1962

Contents

Foreword

This book is one of three prepared by the staff of the Science and Technology Division of the Library of Congress, at the request and with the financial support of the Directorate of Materials and Processes (Materials Central), Wright-Patterson Air Force Base, Ohio. These three books have been compiled and published as a part of the activities of Materials Central in connection with the celebration of its 45th year as the center of materials research and development for the U.S. Air Force. Three activities of Materials Central are highlighted in these publications. One is a compilation of annual award-winning technical papers prepared by Materials Central personnel, the second is a collection of abstracts of scientific and technical papers and reports prepared by Materials Central and its scientific and industrial contractors during the past decade and a half, and the third is a chronology of significant materials events beginning 45 years ago and ending in the present. It is believed these three books will provide a valuable permanent set of references to anyone interested in the materials sciences.

Preface

Forty-five years ago Air Force materials research was started on a very modest scale. Funds were limited, and the range of materials used in World War I airplanes was small. From the time of the heavier-than-air flights of the Wright brothers, the need for high strength coupled with light weight had raised problems in aeronautics usually absent from conventional materials uses. The margin of error was narrow, necessitating careful specification of materials used in components and thorough inspection and testing. As the performance of airplanes improved, the demands on materials increased. Older materials required modifications, and new materials came under consideration.

Up to World War II the Air Force effort in materials was limited more by lack of funds than by the inadequacy of existing knowledge. During that conflict the situation changed drastically. Extensive research programs were launched in government laboratories, universities, non-profit institutions, and industry. By the end of the war the performance requirements, especially at high temperatures, had consumed a great proportion of the existing stock of scientific and technological knowledge of materials. With the advent of jets, missiles, and rockets, it became apparent that future aerospace progress necessitated a broad research and development program in the materials field.

The story of the past forty-five years of research in the many materials fields of interest to the Air Force is not yet committed to the pages of formal histories. The events are still too new and too complex for a full retrospective analysis. What follows is a chronology of selected incidents taken from the world literature on the subject. Included are significant discoveries, items representative of the research at particular times in specific fields, and references indicative of future trends. By and large, the chronology is limited to materials used in the construction of the bodies of airplanes and missiles and of their propulsion units. No attempt has been made to bring the chronology down past 1957, because work in the most recent years is often too new for successful inclusion in a work of this nature.

The entries in the chronology and in the bibliography of sources are identically numbered. The name and subject indexes are keyed to the entry numbers.

Chronology

1917

February 20, 1917: L. Lilienfeld describes the preparation of films from cellulose ethyl ether or other cellulose ethers by dissolving in alcohol or benzene, filtering, and then pouring or spreading the solution. The process may also be used to produce an artificial silk. 1

May 24, 1917: W. Guertler and W. Sander receive a patent disclosing the high strength obtainable by the heat treatment of wrought aluminum-zinc-magnesium alloys. 2

July 10, 1917: H. Dreyfus develops a transparent fabric for use in the construction of aircraft, etc., comprising cellulose acetate reinforced with a metallic fabric of some kind, preferably a mesh. 3

August 1, 1917: A composition consisting of cork fragments and a solution of casein in water with borax, lime silicate or waterglass, castor oil, and tannic acid is patented by N. A. T. N. Feary. 4

August 28, 1917: S. E. Graves and T. W. H. Ward devise a varnish for airplanes consisting of a solution of cellulose ester in acetone. 5

November 27, 1917: Hydrolyzed starch mixed with alum and sodium hydroxide to form sodium aluminate in the starch is used to join woodwork or veneering, according to a patent issued to R. W. Tunnell. 6

1918

February 5, 1918: J. E. Southcombe and H. M. Wells receive a patent for the addition of oleic acid to mineral oils. 7

July 16, 1918: A. Flatters' dope for fabrics for balloons and other aircraft purposes is made of the following: casein, borax, soap, glycerol and water. When dry, a coating composed of a solution of commercial animé gum is applied as a fireproof finish. 8

1919

1919: P. D. Merica, R. G. Waltenberg, and H. Scott, National Bureau of Standards, explain the heat-treatment phenomena exhibited by duralumin age-hardening caused by the formation of sub-microscopic particles of an intermetallic compound from the supersaturated solid solution. 9

April 8, 1919: J. R. McLain impregnates thin cloth or paper with phenol-formaldehyde resins, using pressure to consolidate it. 10

May 15, 1919: N. A. T. N. Feary develops an airplane non-conducting flexible fabric provided with an electrically deposited metallic coating for fireproofing and strengthening. The fabric is saturated in boiling linseed oil under pressure, dried, coated with plumbago, and passed in contact with conductors through a copper sulphate solution. 11

July 16, 1919: J. A. Newton and T. R. C. Wilson report the findings of the Forest Products Laboratory on the nature of the relations between the specific gravity or density of a wood and its strength properties. 12

December 1919: A. W. Hull shows the lattice of alpha iron to be body-centered cubic. 13

1920

1920: R. O. Herzog and W. Jancke conduct X-ray spectroscopic investigations of cellulose. 14

June 1920: Irving Langmuir demonstrates that a monolayer of oleic acid is sufficient to lower the coefficient of friction of rubbing solids to only 0.1. 15

July 1920: J. W. Marden and M. N. Rich, Bureau of Mines, produce a zirconium powder of high purity by reducing potassium fluozirconate with aluminum and then distilling out (in vacuo) the resulting low-aluminum alloy. 16

August 1920: B. Strauss and E. Maurer, Krupp, announce the commercial possibilities of austenitic chromium-nickel steels. 17

October 28, 1920: D. M. Sutherland forms a varnish for airplane fabrics of 6–12 parts acetylcellulose, 36–44 parts acetone, 24 parts benzene, 24–25 parts "borated benzen," and 2–3 parts benzyl alcohol. 18

1921

1921: W. Rosenhain, S. L. Archbutt, and D. Hanson investigate the Y-alloy of aluminum, which contains 4 per cent copper, 2 per cent nickel, and 1.5 per cent magnesium. 19

1921: W. P. Sykes demonstrates that the ductility of molybdenum is very temperature-sensitive, an abrupt transition from ductile to brittle taking place near room temperature, depending markedly on the thermal and mechanical history of the sample. 20

March 1921: A. A. Griffith postulates that solid materials contain small, often invisible cracks which are extremely efficient levers in prying atoms apart. 21

April 19, 1921: A. W. Clement discloses the composition of two acid-resisting alloys, one having 10 per cent molybdenum, 80 per cent cobalt or nickel, and 0.1–4.0 per cent manganese, with or without 10 per cent iron, the second lacking manganese. 22

June 15, 1921: Z. Jeffries and R. S. Archer propose slip interference theory of hardening. 23

August 13, 1921: R. Walter is apparently the first to recognize that only a very small percentage of boron is required to produce an appreciable hardening effect. 24

August 16, 1921: A. Pacz describes an alloy series from which machinable castings having a specific gravity of less than 2.7 can be formed, consisting of 8–20 per cent silicon and 92–80 per cent aluminum. 25

October 19, 1921: Formaldehyde condensation products with carbamide or its derivatives, prepared by H. John, are described as good, transparent adhesives, usable for joining glass, metals, and other materials or as a lacquer for coating airplane wings or other fabrics. 26

December 1921: E. Rassow and L. Velde present a recrystallization diagram of aluminum. 27

1922

1922: H. W. Gillet and E. L. Mack combine aluminum and ferroboron in order to introduce boron into steel. 28

April 1, 1922: L. Lilienfeld patents a method for the preparation of cellulose ethers and notes their possible use as adhesives. 29

May 30, 1922: F. Pollak reports the use of salts of strong acids, *i.e.* ammonium chloride or nitrate, as catalysts to harden urea-resin adhesives. 30

June 8, 1922: L. Lilienfeld prepares ethyl derivatives of cellulose soluble in water below 16° and insoluble above by treating derivatives soluble in water above 16° with caustic alkali. 31

July 1922: S. Dushman and I. Langmuir, General Electric, show that the variation of the diffusion coefficient in alloy systems is the result of an activation process. 32

August 1922: A. Westgren and G. Phragmen demonstrate that alpha, beta, and delta iron are all body-centered cubic, while gamma iron is face-centered cubic, and that solid-solution austenite is an interstitial solid solution. 33

September 5, 1922: A. Stock and H. Goldschmidt produce beryllium metal by electrolysis of a fused bath of sodium and beryllium fluorides. 34

September 20, 1922: H. Goldschmidt and O. Neuss produce a condensation product from formaldehyde and urea in the presence of acids and acid salts. 35

October 25, 1922: H. Gault develops a coating, formed of cellulose acetate in combination with other compounds, to be used on airplane wings covered with cloth fabrics. 36

1923

1923: While studying alloys, particularly solid solutions, by means of X-ray diffraction, E. C. Bain discovers superlattices, demonstrating the maintenance of the solvent-lattice type in primary solid solutions and the variation of the lattice spacing with variation in solute concentrations. 37

February 13, 1923: Vinyl chloride is formed by the reaction of hydrochloric acid on nascent acetylene in a process developed by H. Plauson. 38

March 1923: G. I. Taylor and C. F. Elam prove that observed plastic strains can be resolved into simple shears along crystal planes marked by slip lines. 39

April 1923: S. Albert Reed reports results of tests with his one-piece, solid duralumin propeller. 40

July 3, 1923: K. Ripper obtains a condensation product of urea and formaldehyde by the use of salts giving an alkaline reaction on hydrolysis. These are added to retard gelatinization of the initial condensation products soluble in water. 41

August 20, 1923: Artificial resins obtained by the polymerization of aldehydes are used as adhesives or cements, either alone, in solution, or mixed with other filling material. 42

October 1923: A. Fry, Krupp, describes the process of nitriding for surface hardening. 43

October 30, 1923: R. S. Archer and Z. Jeffries, Alcoa, describe an aluminum alloy (51S) containing one per cent magnesium and one per cent silicon, which is hard and of high strength. 44

October 30, 1923: R. S. Archer and Z. Jeffries, Alcoa, disclose an aluminum alloy (25S) with approximately 4.4 per cent copper, 0.8 per cent silicon and 0.75 per cent manganese, improvable as to strength and hardness by heating to about 500° C, quenching, and aging at 120–160° C. 45

November 1923: H. J. Gough and D. Hanson suggest that local deformation strain hardens metal locally and initiates fracture when some limiting value is reached. 46

1924

March 28, 1924: A. Joffe *et al.* show that normally brittle alkali halides can be made to behave in a ductile manner by immersion of the crystals in warm water while they are being loaded. 47

May 7, 1924: The Naugatuck Chemical Co. receives a patent for polymerized styrene and its homologs. 48

July 12, 1924: I. Ostromislensky describes ways of polymerizing styrene to produce three series of compounds. 49

August 1924: F. W. Caldwell and O. Clay describe the design, materials, and method of construction of "Micarta" propellers. 50

October 1924: A. E. Van Arkel describes a process whereby carbides and nitrides can be prepared by deposition from the vapor phase. 51

1925

February 9, 1925: Cyclization of rubber, which later proves to be the basis of a number of industrially important adhesives, is developed by W. C. Geer. 52

April 14: R. C. Stanley, International Nickel, obtains nickel-copper alloys (of the Monel type) by roasting a nickel-copper material, the product being subjected to a melting temperature with a sulpher-removing slag in a basic-lined electric furnace. 53

April 21: William Hoopes, Alcoa, devises a method of obtaining aluminum at least 99.8 per cent pure by electrolytic refining. 54

May 5: P. Rosband and E. Schmid demonstrate that plastic flow is determined by the shear stress acting on glide planes. 55

August 11: K. Schröter adds cobalt metal to tungsten carbide to form a tougher material than the cast carbide. 56

October 29: A. E. Van Arkel and J. H. de Boer describe the preparation of pure titanium, zirconium, hafnium, and thorium metals. 57

November 2: I. Ostromislensky prepares a polymer of vinyl chloride by effecting the polymerization in two stages. In the first stage a polymer is produced which is soluble in acetone and in the second stage further polymerization is effected by the action of light or heat or both. 58

November 13: H. J. Tapsell and J. Bradley find the creep resistance of 80–20 nickel-chromium alloy to be superior to other materials available at this time. 59

December 30: T. F. Tesse secures a patent on a process whereby the fabric of airplane wings is provided with at least three successive coatings—the intermediate coating being formed from a cellulose acetate solution and possessing greater flexibility and elasticity than the other two. 60

1926

1926: R. W. Bailey states that, during time of minimum creep rate, the strain hardening produced by creep is continuously overcome by the annealing effect of high temperature. 61

1926: W. Hume-Rothery shows that structurally analogous alloy phases are characterized by a fixed ratio of the number of valence electrons present. 62

February 9: R. L. Johnston, R. G. Archer, and Z. Jeffries, Alcoa, develop an aluminum alloy, adapted for chill-casting, which consists of 3–10 per cent silicon, 2–5 per cent copper, and 15 per cent or less zinc. 63

February 9: P. D. Merica, International Nickel, obtains a patent for a nickel-copper-aluminum alloy (the last up to 17 per cent) suitable for steam-turbine blades. 64

February 9: A. Pacz develops an aluminum (70 per cent), copper (15–27.5 per cent), and silicon (2.5–15 per cent) alloy. 65

April 27: A. E. Van Arkel and J. H. de Boer describe a process for separating hafnium and zirconium halogenides by adding a halogenide of an element of the fifth and sixth group to the mixture and then performing a fractional distillation. 66

May: W. Fink and E. D. Campbell, using X-ray measurements, show that martensite is body-centered tetragonal. 67

June: D. J. McAdam Jr. discusses the results of studies on the stress-strain cycle and corrosion-fatigue in metals. 68

June 6: W. Sander and K. L. Meissner describe the use of zinc and magnesium as hardening elements in heat-treated aluminum alloys. 69

June 16: J. Frenkel calculates that the shear stress required to cause one plane of atoms to slip over an adjacent one should be about one-sixth of the shear modulus. 70

August: G. D. Bengough and H. Sutton develop a corrosion-resistant oxide coating for aluminum. 71

September 29: W. Kroll prepares metallic beryllium by the decomposition of molten beryllium-alkali double fluorides by an alkaline earth-metal (magnesium or lithium) at temperatures above 1000° C. 72

October 20: J. Baer produces a rubber-like product ("Perduren") by means of the reaction between alkali sulphides and chlorohydrocarbons. 73

November 1: F. Pollak obtains condensation products from formaldehyde and urea by reacting urea, etc., with formaldehyde (or a polymer of it) in the presence of a base such as ammonia, pyridine, or urea itself. 74

December 28: W. A. Mudge, International Nickel, produces an aluminum-nickel-copper alloy by adding an aluminum alloy such as 35–85 per cent aluminum, 45–10 per cent nickel, 20–5 per cent copper to a molten bath consisting mainly of copper and nickel. 75

1927

1927: E. H. Dix, Jr. of Alcoa makes the first public announcement of Alclad, a new corrosion-resistant aluminum product. 76

January 19: R. L. Aston reports measurements of stressed tensile samples of aluminum showing that the strain indicated by relative changes in lattice orientation is less near grain boundaries than within the grain. 77

January 21: Porous masses of aniline-formaldehyde resin condensation products are densified by the use of heat and pressure. (Soc. Anon. pour l'Ind. chim. à Bâle). 78

January 29: Aniline-formaldehyde condensation products, formed in presence of acid, are treated with a base to eliminate acid. The result is a homogeneous, easily-worked product which can be dried and compressed in molds. (Soc. Anon. pour l'Ind. chim. à Bâle). 79

March 25: U. R. Evans observes that, speaking generally, the junction of dissimilar metals often constitutes the seat of severe corrosion, and that, on the whole, heterogeneous materials are more liable to attack than homogeneous materials. 80

June: D. J. McAdam Jr. discusses results of studies on corrosion-fatigue limits and the relationship between fatigue and corrosion-fatigue in nonferrous metals, especially nickel-copper alloys and alloys of aluminum. 81

July: J. W. Marden and M. N. Rich, Westinghouse, obtain practically pure vanadium by the reduction of vanadium pentoxide with metallic calcium in the presence of calcium chloride. 82

August 18: Polymerization of ethylene is effected by C. Epner through the action of dark or silent electric discharge at ordinary or raised temperatures to produce a product containing both saturated and unsaturated hydrocarbons. 83

October: P. A. Levene and A. Walti achieve the first preparation of the higher polypropylene glycols. 84

November 8: W. A. Wirz, British Celanese, Ltd., develops a process whereby perforated sheet-metal plates are placed between sheets of a cellulose acetate compound which penetrates the perforations of the metal after heat and pressure are applied to produce an airplane panel material. 85

December: C. Davisson and L. H. Germer, Bell Telephone Laboratory, demonstrate that a lattice will diffract an electron beam, a discovery which greatly augments diffraction methods for the determination of lattice structure. Davisson later receives Nobel Prize for this work. 86

December 27: F. S. Malm describes an adhesive, consisting of rubber, rosin, rosin oil, and a fibrous filler including asbestos, which is suitable for use on metals. 87

1928

1928: C. J. Smithels, S. V. Williams, and J. W. Avery report that although oxidation resistance increased in nickel-chromium compounds as the chromium content increased from 20 per cent to 30 per cent, the strength at temperatures above 750° C decreased with increasing chromium content. 88

February: In investigating the nature of cohesion, J. E. Lennard-Jones and B. M. Dent quantitatively analyze the electrostatic forces of attraction between particles. 89

March 23: J. F. Walsh and A. F. Caprio, Celluloid Corporation, place unpolymerized or partially polymerized vinyl compounds between two surfaces and produce adhesion by polymerizing with suitable catalysts. 90

April: L. Prandtl differentiates between true hysteresis and elastic after-effect, and also postulates the existence of what is now known as an edge or line dislocation. 91

April: Duralumin sheet quenched in hot water has greater susceptibility to intercrystalline attack than when quenched in cold water, according to research done by H. S. Rawdon. 92

May 22: E. H. Dix, Jr., Alcoa, patents a process for protecting alloys of the duralumin type against corrosion by coating the strong alloy sheet on each side with a layer of aluminum of high purity. 93

July 3: R. Franks and B. E. Field, Haynes Stellite Company, receive a patent for a nickel alloy containing 3–5 per cent aluminum, 3.5–6 per cent silicon, 5–12 per cent tungsten, 6–12 per cent zirconium, and one per cent or less boron, described as suitable for high-speed tools. 94

July 19: I. G. Farben receives a patent for modifying phenol-formaldehyde condensation products with cellulose ethers to control hardening, as in the preparation of experimental laminated structures. 95

July 27: W. E. Lawson, Imperial Chemical Industries, patents a synthetic resin containing ethers similar to the "glyptal" type prepared by heating polybasic carboxylic acids or anhydrides with ether alcohols to 175–250° C to obtain complete estrification. 96

September 11: R. Franks and B. E. Field, Haynes Stellite Company, receive a patent for a nickel alloy suitable for high speed tools and containing 3–5 per cent aluminum, 3.5–6 per cent silicon, 5–12 per cent tungsten, 6–12 per cent titanium, and up to one per cent boron. 97

September 22: I. G. Farben patents a process whereby water-insoluble or poorly soluble binders such as ethyl cellulose are formed into an aqueous dispersion which is sprayed, kneaded, etc., and may then be dried and treated with substances capable of dissolving or swelling the binding agent. 98

November 2: A process is developed by British Celanese, Ltd., in which phenol or creosol-formaldehyde resins are modified with cellulose esters, acetate, and nitrate, as well as a plasticizer. The process is useful in the preparation of adhesives for safety glass manufactures. 99

December: A. B. Kinzel, Union Carbide, introduces a high-strength, low-alloy silicon-manganese steel with improved susceptibility to heat treatment due to the addition of one per cent carbon. 100

1929

1929: B. E. Field, Union Carbide, describes new developments in nickel-molybdenum-iron, nickel-silicon, and nickel-aluminum alloys of high corrosion resistance, the first two showing good high-temperature properties. 101

1929: M. L. V. Gaylor and G. D. Preston ascribe age-hardening of duralumin to the distortion of the space lattice caused by precipitation of highly dispersed particles. The precipitation involves the resection of the atoms of the dissolved metal from the lattice of the solid solution (possibly with formation of molecules) and the coagulation of the rejected atoms or molecules. 102

February 11: Synthetic gummy and resinous products are produced from vinyl esters and aldehydes by H. W. Mathesan and F. W. Skirrow, Canadian Electro Products Company. 103

April 23: F. M. Becket assigns a patent to the Electro Metallurgical Company for an acid-resistant alloy of at least 40 per cent nickel, 15–40 per cent molybdenum, and iron not less than 10 per cent nor more than 5 times the amount by which the molybdenum per cent exceeds 10. 104

July 16: I. Ostromislensky prepares a polymerized vinyl chloride (soluble in chlorobenzene) which is purified from the acetone-soluble polymer to produce films of durable flexibility from its chlorobenzene solutions. 105

August: W. H. Carothers, DuPont, discusses the structure of polymers and the difference between addition and condensation polymers. 106

August: W. H. Carothers and J. A. Arvin list some nonmonomeric esters (polymers) prepared by heating the acid and 5 per cent excess of the glycol for about 3 hours at 795°–185° C and then at 200°–250° C and 0.2 mm. for 3 hours. 107

October 17: A patent is issued to I. G. Farben on the use of phosphoric acid as an oxidation retardant in carbon and graphite materials. 108

November: P. Chevenard shows that small additions of aluminum or titanium make nickel-chromium alloys responsive to thermal treatment. 109

1930

January 28, 1930: Styrene yields polymerization product by treatment in aqueous emulsion with oxygen or reagents such as hydrogen peroxide, according to an I. G. Farben patent. 110

February 4: Ethylene, vinyl chloride, vinyl acetate or other polymerizable compounds are subjected to the resonance radiation of a metal such as mercury to form rubber-like products in a process developed by Hugh S. Taylor. 111

March: R. N. Pease reports that the first product of the reaction of the polymerization of ethylene at 450°–600° is butene of the chain type. 112

April 22: W. A. Mudge, International Nickel, produces the first age-hardening wrought nickel alloy ("K-Monel"). 113

May 9: Rubber-resisting abrasives are prepared by H. Mark and H. Hopff, I. G. Farben, by introducing hydrocarbon compounds, oxygenated organic compounds, and organic or inorganic substances having a hardening effect into rubber solutions. 114

May 24: J. C. Patrick obtains rubber-like product ("Thiokol") by condensing ethylene dihalide and sodium polysulphide in the presence of a liquid which raises the solubility of the former. 115

May 27: J. W. Marden and M. N. Rich, Westinghouse, produce malleable chromium by compacting substantially pure chromium powder and heating in an inert environment, the ingot being consolidated by heating to slightly below the melting point. 116

June 29: H. Mark and C. Wulff, I. G. Farben, develop a method for obtaining pure styrene by preparing it from ethylbenzene and cooling it to a low temperature (−30° to −60° C). 117

August 28: G. Kurdjumow and G. Sachs show the orientation relationships and the sets of shearing processes by which the austenite lattice may be converted into the martensite lattice. 118

September 2: W. A. Wissler, Haynes Stellite Company, patents an alloy for metal-cutting tools containing 15–40 per cent chromium, 15–35 per cent tungsten, 0.5–2.5 per cent boron and 0.75–2.5 per cent carbon and the remainder nickel (not over 50 per cent of the total). 119

October: H. Mark uses X-ray technique to investigate colloid solutions of cellulose and cellulose ester solutions. 120

November: E. F. Bachmetew determines for severely rolled duralumin the change in the orientation of the crystallographic axes from two axes [112 and 111], toward one axis [111]. 121

December: C. Wagner and W. Schottky present a theory of lattice defects involving deviation from ideal composition. 122

June 30: J. A. Nieuwland, Notre Dame University, describes a method of preparing vinyl derivatives of acetylene by the reaction of acetylene and an ammonia salt or a cyclic nitrogen base pyridine in the presence of a nonalkaline catalyst such as cuprous chloride. 127

June 30: J. A. Nieuwland, Notre Dame University, describes a process for obtaining resinous products from acetylene polymers. 128

July 15: R. Schafmeister, Krupp, receives patent for addition of cobalt, zirconium, uranium, hafnium, and various rare earth-metals to austenitic chromium-nickel steels to prevent intergranular attacks. 129

November: After investigating polymerization of chloroprene, W. H. Carothers and co-workers announce the discovery of polychloroprene, "Neoprene," production beginning this year. 130

1931

1931: F. Wever and W. Jellinghous report on their investigation of the constitution of the iron-nickel-chromium series of alloys. 123

January 20: Celluloid sheets, the surfaces of which have been partially dissolved, are used for uniting a metal surface layer such as aluminum with an underlying layer of composite wood construction in a process developed by F. H. Auld. 124

February 23: C. Agte *et al.* state that rhenium made by deposition on a hot wire is about as ductile as copper and rollable without difficulty. 125

June 23: F. Hofmann and M. Otto, I. G. Farben, polymerize ethylene by the action of boron fluoride under pressure. 126

1932

1932: C. R. Austin and G. P. Halliwell describe the development of heat-treated "Konel" alloys (nickel-cobalt-iron base with titanium) and their high-temperature properties. 131

1932: H. Mark studies cellulose chains, noting that they are of finite length and that breaking takes place through slipping due to the rupture of the oxygen linkage binding them together. 132

October: W. H. Zachariasen presents a theory of the atomic arrangement in glass which envisages the forces linking the atoms as essentially the same as those in crystals and suggests that the principal difference between a crystal network and a glass network is the presence of symmetry and periodicity in the former and their absence in the latter. 133

December 15: R. Franks receives a patent for a corrosion-resistant alloy formed of 15–25 per cent molybdenum, 10–20 per cent chromium, 5–15 per cent iron, about 5 per cent tungsten, not over 0.2 per cent carbon, and the rest nickel, at least 40 per cent. 134

1933

January 25: O. Ruff and O. Bretschneider describe the preparation of tetrafluoroethylene from carbon tetrafluoride. 135

March: J. B. Johnson and T. Oberg, Army Air Force, report on the mechanical properties of aircraft metals at −40° C. 136

March: O. Klingohr compares the oxidation in air at 700° C of a hard metal consisting of 42.5 per cent titanium carbide, 42.5 per cent molybdenum carbide, 14 per cent nickel, and one per cent chromium with that of a 94–6 tungsten carbide-cobalt alloy and demonstrates the former's beneficial oxidation resistance at elevated temperatures. 137

April: L. Prandtl presents a mechanical model of a molecular system for properties of matter in an amorphous state. 138

April: C. Wagner shows that only the migration of charged species contributes to the oxidation reaction. 139

June 13: To produce homogeneous plastic masses, ethylcellulose with an ethoxy content of 42–48 per cent is dissolved at a temperature of 80° C in an organic solvent which dissolves it only when hot and which has a boiling point of at least 80° C. The ethylcellulose is precipitated by cooling the solution to at least 30°, and the precipitate is filtered and washed up while containing some of the solvent, according to E. Dörr and O. Leuchs, I. G. Farben. 140

August 8: F. Webel, I. G. Farben, produces polymerization products from alkylene oxides by having the vapors of the oxides in contact with a catalyst (potassium hydroxide, or sodium bisulphate and sodium sulphate) at 40–200° C. 141

August 15: F. Winkler *et al.*, I. G. Farben, produce liquid aromatic hydrocarbons by heating a gas, essentially methane, to 700–1200° C in the presence of a silicon catalyst. 142

August 29: L. J. Weber, Alcoa, develops an experimental aluminum alloy which, in artificially aged temper, had a yield strength in excess of 80,000 psi. 143

October: W. Schmidt *et al.* observe that pressing at a high temperature gives strong directional properties, as recrystallization occurs between successive stages, producing new basal planes with a perpetual tendency to become parallel to one another throughout the mass. 144

October 10: W. L. Simon, B. F. Goodrich Company, shows how the polymerized vinyl chloride product can be plasticized to a rubber-like material. 145

November: W. H. Carothers, and F. J. Van Natta report the preparation of polyesters from ω-hydroxy-decanoic acid with molecular weights from 780–25,200. 146

November 7: G. A. Perkins, Carbide and Carbon Chemical Corporation, uses cuprous chloride catalysts for the production of vinyl chloride. 147

December 20: A. Nathansohn polymerizes cellulose acetate by treating it with an organic solvent such as acetone (inert with respect to a halogen-phosphorous compound) and pyridine. 148

1934

1934: F. M. Becket and R. Franks report on the corrosion-resistance properties of nickel-chromium steels, proposing the use of columbium to secure immunity from intergranular attack. 149

1934: H. Mark quantitatively studies the behavior of chain polymers during plastic deformation. 150

1934: W. A. Mudge and Paul D. Merica, International Nickel, describe a new series of aluminum-copper-nickel alloys of high strength, a typical example being K-Monel where 4 per cent aluminum is added to "Monel" metal. 151

January 30: Polymerization products of esters of ethylenedicarboxylic acids prepared by H. B. Dykstra, Du Pont, are coating compounds with clear films and may be used with conjointly polymerized vinyl esters or styrene. 152

February: H. Schlechtweg develops the concept of nonlinear elastic materials, in which strain is uniquely determined by stress (whereas in plastic materials strain is also a function of time). 153

February 5: The Gadeau low-temperature, three-layer process for producing superpurity aluminum was patented by Cie. Alais, Forges et Camargue. 154

April: Some fifty organic reactions in the liquid phase were studied at pressures up to 3000 atm. and at temperatures up to 180° C, and it was found that all the reactions which proceeded slowly at atmospheric pressure were accelerated at the same temperature under high pressure, while those which did not proceed at atmospheric pressure (in the absence of catalysts) did not proceed at pressures up to 3000 atm. 155

April 17: F. W. Sullivan and V. Voorhees, Standard Oil of Indiana, patent a polymerization process for the preparation of saturated aliphatic hydrocarbons from olefins, using aluminum chloride as the catalyst. The process was independently discovered by H. Zorn of I. G. Farben. 156

May 15: C. H. Prange, Austenal Laboratories, patents a cast metallic denture of an alloy with more than 50 per cent cobalt, 10–40 per cent chromium, which is later (1941) developed for gas turbine blading and known as "Vitallium." 157

June 8: A small proportion, *e.g.*, 5–10 per cent, of a chlorobiphenyl is added to unpolymerized or partly polymerized styrene, whereby harder, less flammable, and more easily molded polymerization products are obtained in a process developed by Robert Müller. 158

June 28: H. Sukohl and G. Schwarz devise an apparatus and method for coating air propellers with cellulose material which is initially in a softened or plastic state and is then subjected to uniform pressure. 159

July: G. I. Taylor proposes the theory that yield strength of metals is determined by internal stresses opposing the motion of distortions, these stresses becoming larger as deformation proceeds. 160

August 21: E. F. Lowry, Westinghouse, patents a filament base made of a nickel-cobalt-iron-titanium alloy ("Konel"). 161

September 11: Fibrous sheet material, such as paper, is used together with a heat-hardened phenolic condensation product and a layer of vulcanized rubber bonded to the material to minimize sound transmission and give desired flexibility for airplane cabin construction. Developed by H. Swan and S. Higgins. 162

October: M. J. Buerger, M.I.T., proposes a model for a mosaic structure of crystals in which subboundaries are formed (if inhomogeneous warping occurs between neighboring regions of a crystal) where crystal orientation changes discontinuously, persisting and propagating with newly formed portions of the crystal. 163

October: W. Hume-Rothery *et al.* discover that solid solutions cannot be formed to any appreciable extent if the atomic diameter of the added metal differs from that of the solvent metal by more than 14 percent. 164

October 3: To produce rubber with good resistance to attraction, it is treated, in the presence of an inert solvent such as benzene, with an organic-inorganic oxonium compound, according to a patent issued to H. Mark and H. Hopff, I. G. Farben. 165

December 17: A resin for making lacquers, coverings, etc., is obtained by condensing aminobenzene with wood oil, treating product with a solution of anhydrous aminobenzene and formaldehyde, and treating resulting mass with formaldehyde. 166

December 29: R. F. Mehl, E. L. McCandless, and F. N. Rhines show that oxide layers bear a fixed orientation relationship to the metal crystal on which they form. 167

1935

1935: E. Schmid explains the origin of strain-hardening in single crystals as mainly derived from slip interference due to intersecting slip planes. 168

April 12: H. Staudinger and F. Staiger prepare para-linked ethers containing three to six benzene rings and compare their viscosities. 169

July: The flight-testing is reported of a small, low-wing monoplane conceived and built under the direction of Harry N. Atwood and constructed from a material called "Duply," which is produced by impregnating thin strips of wood with a thermoplastic under heat, weaving them around wooden forms, and welding the veneer and plastic together by steam cooking 170

July 22: O. Röhm polymerizes acrylic esters, regulating the process by the addition of small amounts of essential oils containing unsaturated cyclic bonds of the terpene series. 171

September 30: Vinyl polymerization products are made by supporting absorbent material, *e. g.*, fabric, paper, plywood, in a chamber, and introducing one or more unpolymerized or partially polymerized unsaturated organic compounds capable of forming hard polymerized products. The product may be used in parts of airplanes, according to the inventor, O. Röhm. 172

November 16: Polystyrene is made resistant to heat by submitting it to the prolonged action of temperatures in the range 80–130° C, but below the depolymerization temperature, until its softening point, determined by the Martens method, is above 66° C. 173

December 17: Cellulose esters of the heterogeneously linked dicarboxylic acids, such as cellulose acetate glycolate, have good adhesive properties according to C. J. Malm and C. R. Fordyce, Eastman Kodak. 174

December 19: W. O. Herrmann and W. Haehnel describe adhesives made of polymerized vinyl compounds and nitrocellulose. 175

1936

1936: W. Hume-Rothery discovers that atoms whose diameters differ by less than 15 per cent usually form substitutional alloy systems, while those whose diameters differ by more than 15 per cent do not form such alloy systems. 176

January: H. Mark and R. Raff discuss the relation between rate of formation of nuclei and rate of growth of styrene polymers. 177

January: H. Staudinger reports that the addition of divinylbenzen to polystyrene will cause the latter to gel or insolubilize by effecting cross-linking. 178

January: G. Walter reports the results of research on the mechanism of urea-formaldehyde resinification, which has revealed the nature of the urea-resin polymer formed through condensation of methylol ureas and the existence of chemical groupings contributing to the adhesive properties. 179

January 14: In making polymerization products of organic esters, an I. G. Farben process uses vinyl peroxides of fatty acids containing at least 4 carbon atoms in the molecule as catalysts. 180

January 31: O. Röhm polymerizes methacrylic esters, vinyl acetate, and styrolene and combines them with a porous or absorbent material such as filter paper. 181

February: R. Roscoe discovers that thin films on crystals have a strengthening effect. 182

April 9: To produce formed articles methacrylic acid esters are polymerized in narrow chambers and subjected to a temperature-regulating medium, according to a patent issued to O. Röhm. 183

July 21: N. B. Pilling and P. D. Merica, International Nickel, patent a series of iron-nickel-titanium alloys age-hardened at elevated temperatures, then quenched and reheated to effect hardening. 184

October: W. Kroll discusses the preparation of alloys of ductile chromium by sintering chromium powder with other powdered metals. 185

October 22: G. P. Halliwell, Westinghouse, patents high-strength alloys (20–70 per cent nickel, 60–10 per cent cobalt, 5–50 per cent iron, and 0.5–10 per cent titanium), quenched from a temperature of 900° C or higher and aged at 500°–800° C for at least a half hour. These alloys are suitable for engine valves and seats. 186

October 29: Sheets of glass are united by a film containing a polymer of a vinylethinyl carbinol in a process developed by W. H. Carothers *et al.*, Du Pont. 187

December 4: P. Spitaler reports that the shrinkage of magnesium alloys in mold is nearly the same as that of commercial coating alloys of aluminum. 188

1937

1937: J. L. Haughton and W. E. Prytherch demonstrate the beneficial effects of cerium on magnesium alloys for high-temperature use. 189

June: W. Kroll describes the preparation of ductile titanium alloys by obtaining titanium metal through reduction of the oxide and then sintering and hot-rolling the alloys. 190

July 23: H. Hurter receives a patent for low-temperature all-fluoride electrolyte for the production of super-pure aluminum. 191

August 3: A composite material comprising a substance capable of being hardened or set, and reinforced with a nonmetallic fibrous material, is developed by N. A. De Bruyne and the De Havilland Aircraft Company. 192

September 1: Solid polymers of ethylene are produced by subjecting the latter to a temperature of 100–300° C at 1200 atm. pressure or by subjecting it to a small amount of oxygen at 500 atm., according to a process developed by E. W. Fawcett *et al.*, Imperial Chemical Industries. 193

September 22: W. Kroll reports the preparation of high-titanium and high-zirconium alloys from the metal powders reduced from their oxides by calcium. 194

October: B. E. Warren's X-ray studies confirm Zachariasen's deductions about the structures of silicate and borate glasses. 195

November 5: E. N. da C. Andrade devises a method for growing single crystals of molybdenum. 196

November 6: I. Langmuir, and V. J. Schaefer find that during the modification of a stearic acid monolayer by the presence of salts in the substrate, in some cases adsorbed atoms or molecules take positions between the molecules of the original monolayer, a phenomenon known as "penetration." 197

November 9: G. F. Comstock and V. V. Efimoff devise a method of incorporating nitrogen in alloy steels whereby a cyanonitride of titanium or zirconium is added as an alloy to the other ingredients. 198

November 9: H. Pulfrich, Berlin-Wilmersdorf, patents a sintered ceramic material which is substantially impenetrable by gases and is adapted to be fusion-welded to glass and to form a vacuum-tight seal therewith. 199

November 11: W. W. Triggs prepares polyamides by the heat treatment of a previously formed and isolated salt of diamine and dicarboxylic acid. 200

December 20: P. Brenner and H. Kostuen suggest that an elevated temperature-aging treatment of 24S–RT sheet will raise the compressive yield strength. 201

1938

1938: G. H. S. Price *et al.* discuss the factors which influence the preparation of alloys, particularly of the copper-nickel-tungsten system, made by mixing, pressing, and sintering metal powders in an atmosphere of hydrogen at temperatures sufficiently high to ensure the presence of a liquid phase during the formation of the alloy. 202

February 16: W. H. Carothers, Du Pont, describes a process for the synthesis of polyamides to produce linear condensation superpolymers suitable for the production of pliable strong elastic fibers. 203

April 5: P. M. McKenna develops a method of producing titanium carbide-tungsten carbide solid solutions whereby the components, usually in the ratio 1 : 1, are made to react in a superheated nickel melt, and the resulting solid solution is isolated by treating the comminuted melt with aqua regia. 204

April 7: I. G. Farben condenses acrylic acid amide with formaldehyde in the presence of sodium hydroxide, then polymerizing it to produce nitrogeneous synthetic amides used as adhesives and in other manners. 205

May 10: In bonding metal to wood, G. R. Ensminger, Du Pont, coats the metal with an alkyd resin to secure good adhesion. 206

May 24: H. D. Newell and M. Fleischmann patent an iron-chromium-nickel-molybdenum alloy (16 per cent chromium, 25 per cent nickel, 6 per cent molybdenum), which would be modified in 1940 to a 16–25–6 composition for high temperature use. 207

June 20: G. Gauthier notes the grain refinement produced by zirconium in magnesium alloys as useful in overcoming the coarsening caused by beryllium additions. 208

July: P. P. Alexander points out that very pure titanium boride can be prepared from titanium hydride and boron powders by sintering in the atmosphere of the liberated hydrogen. 209

July: W. Hume-Rothery and G. V. Raynor show that the extent of terminal solid solubility is related to the relative atom sizes, to chemical affinity effects between the unlike atoms, and to the atom-valence electron ratios, and extend this. 210

July 5: A monomeric ester is dispersed in an aqueous vehicle containing a granulating agent such as polymethacrylic acid, subjected to polymerizing conditions, and the granular polymer filtered off in a process devised by B. M. Marks, Du Pont, for the polymerization of acrylic and homologous acids. 211

September 20: Diamine dicarboxylic acid salts suitable for forming spun fibers are prepared by W. H. Carothers, Du Pont. 212

September 20: A process for making synthetic fibers from polyamides derived from diamines and dibasic carboxylic acids, etc., is described by W. H. Carothers, Du Pont. 213

September 20: Linear polyamides suitable for spinning into strong pliable fibers are prepared by W. H. Carothers, Du Pont. 214

October 9: F. Bollenrath, H. Cornelius, and W. Bungardt publish an extensive study of the suitability of materials for use in exhaust turbines and combustion engines. 215

October 26: Monomeric esters of α-methylene monocarboxylic acids are subjected to polymerizing conditions in the presence of a sulphur dioxide catalyst, according to a process developed by D. E. Strain, Du Pont. 216

1939

January: R. W. Powell and F. H. Schofield measure the thermal conductivities of carbon and graphite grades at temperatures up to 2500° C and find the conductivity of the latter to decrease with increasing temperature and that of the former either to change very little or to increase slightly with increasing temperature until the temperature to which the grade was baked in the manufacturing process has been exceeded. 217

February 3: J. D. Fast describes the preparation, mechanical properties, and applications of zirconium. 218

February 7: G. F. Comstock, Titanium Alloy Manufacturing Co., discloses high aluminum alloys with titanium which require no heat treatment or quenching to attain high strength. 219

February 22: Monomeric vinylidene chloride is polymerized by being subjected to a temperature of 25°–125° C in the presence of a polymerization catalyst, according to a process developed by Dow Chemical. 220

March 7: Anhydro-formaldehyde-aniline is treated by K. Frey and A. Gams with an aniline salt-forming acid such as hydrochloric and with a formaldehyde-yielding compound. The effect of the acid is eliminated by sodium hydroxide. 221

April: J. M. Burgers points out that a low-angle grain boundary is equivalent to an array of appropriately arranged dislocations, thus introducing the concept of screw dislocations. 222

April 11: E. W. Fawcett, R. O. Gibson, and M. W. Perrin, Imperial Chemical Industries, polymerize ethylene by heating to 100°–400° C under a pressure of 500–3000 atm. 223

May: E. Orowan points out that the concept of nonhomogeneous deformation implies that the metal must develop some islands in which the strain is mostly plastic and other islands in which it is mostly elastic. 224

May 31: A. F. Bidaud and J. I. G. Fabre form adhesives by combining aqueous cellulose ether solutions and aqueous emulsions of polyvinyl esters. 225

June 6: J. H. Reilly and R. M. Wiley, Dow Chemical Co., obtain a moldable product by polymerizing monomeric vinylidene chloride by prolonged heating in presence of 0.1 per cent of benzoyl peroxide. 226

July 18: Charles B. Sawyer, Brush Beryllium, patents a series of copper-nickel-beryllium alloys with good heat-hardening qualities. 227

August: P. M. McKenna reports the production of tantalum carbide, said to be especially suitable as a supplementary carbide for sintered hard-metal tool materials, by reacting tantalum with carbon in an aluminum metal bath heated to 2000° C in a graphite crucible. 228

August: J. A. Thompson and M. W. Mallett show that magnesia, which cannot be cast very satisfactorily from aqueous slips because of the damaging effects of hydration, can be slipcast in absolute alcohol. 229

August 3: W. A. Wood, National Physical Laboratory, Great Britain, studies the changes in the crystalline structure of metals during cold-working and shows that the metal accommodates itself to external deformation by the dispersion into and relative movements of the crystallites, accompanied by measurable internal strains in the lattice. 230

August 18: W. O. Herrmann develops a safety glass in which sheets of glass are glued together with polyvinyl acetates. 231

October 19: Kurt Riechers, DVL, describes an air-tight airplane covering made of a web of wire impregnated with synthetic resin. 232

1940

1940: W. Kroll describes how ductile titanium could be produced in quantity by the reduction of titanium tetrachloride by magnesium. 233

January 9: T. W. Dike develops for use in making plywood, an adhesive formed of dissolved phenolic resin, which is capable of being polymerized by heat pressure. 234

March 19: B. J. Dennison develops a process for making laminated safety glass in which two sheets of glass are bonded by a layer of synthetic plastic material. 235

March 28: B. Chalmers concludes that grain boundary material has a slightly lower melting point than bulk material. 236

April 19: R. Franks, Haynes Stellite Co., receives a patent for corrosion-resistant nickel alloys (nickel over 45 per cent, with at least one per cent of chromium, 10–45 per cent molybdenum and tungsten, 0.8–6 per cent antimony, 25 per cent or less iron, 3 per cent or less manganese, 2 per cent or less silicon, 3 per cent or less vanadium, and one percent or less carbon). 237

May 7: A. Renfrew and W. E. F. Gates, Imperial Chemical Industries, Ltd., develop a laminated sheet material in which sheets of paper or textile are united by means of resins of acrylic polymers under heat and pressure. 238

June 25: W. Kroll describes apparatus and process for producing cold-malleable titanium by reducing the titanium halide with magnesium at about 800° in an oxygen-free atmosphere. 239

September 10: F. L. Bishop and C. S. Shoemaker, American Window Glass Co., develop a process for the manufacture of laminated glass with acrylic polymer resins as the strengthening bond. 240

October 24: B. R. F. Kjellgren and Charles B. Sawyer, Brush Beryllium, patent an arc process for the preparation of beryllium-copper alloys. 241

October 29: E. W. Fawcett, R. O. Gibson, and M. W. Perrin, Imperial Chemical Industries, Ltd., make laminated glass sheets in which two sheets of glass are united with a film of solid polymer of ethylene. 242

December: E. R. Parker finds that ferrous niobide, when in the proper state of dispersion, is very stable at elevated temperatures and that carbon-free iron-columbium alloys with such precipitates possess high resistance to creep. 243

December: S. J. Rosenberg determines the effect of subzero temperatures down to $-78°$ C upon tensile properties, hardness, and impact resistance of metals commonly used in aircraft construction. 244

1941

February 4: R. J. Plunkett, Kinetic Chemicals, Inc., obtains tetrafluorethylene polymers which are resistant to corrosive reagents and vapors and useful in manufacturing heat-resistant clothing by using a zinc chloride or silver nitrate catalyst at superatmospheric pressures. 245

February 25: James V. Nevin patents a method of making hot-pressed plywood panels using phenolic resins. 246

March: E. G. Rochow and W. F. Gilliam, General Electric, report on two methods for preparing polymeric methysilicon oxides (the action of Me-Mg-Br on silicon tetrachloride followed by hydrolysis; the hydrolysis of mixtures of trichloromethylsilane and dichloromethylsilane) and the resulting products. 247

March 11: H. T. Neher and C. F. Woodward develop a shatterproof glass using at least one layer of glass with a strengthening layer of copolymer of vinyl alcohol and at least one acrylic or methacrylic ester, according to a patent issued to Röhm and Haas Co. 248

March 18: C. G. Bieber and M. P. Buck, International Nickel, modify "K-Monel" by substituting titanium for part of the aluminum and produce a series of agehardened nickel alloys. 249

May 6: J. A. Nock, Jr., Alcoa, patents wrought, heat-treated, artificially-aged aluminum alloys with 4–6 per cent zirconium, 0.75–2.50 per cent magnesium, 0.1–2.0 per cent copper, and a grain-refining element. 250

May 16: C. A. A. Rayner develops an adhesive compound comprising an aqueous urea-formaldehyde condensation product containing an unusually large amount of formic acid. 251

September 2: S. G. Saunders and H. Morrison, Chrysler Corp., develop an adhesive, made of rubber, rosin, and asphalt, which is suitable for use on rubber, wood, and metals ("Cycleweld"). 252

October 16: Component parts of fully cured synthetic resin materials (phenol-formaldehyde, cresol-formaldehyde, urea-formaldehyde, melamine-formaldehyde) are cemented by means of uncured phenol-formaldehyde followed by heat and pressure in a process developed by N. A. De Bruyne and C. A. A. Rayner, Aero Research, Ltd., and the De Havilland Aircraft Co. 253

October 17: N. A. De Bruyne and C. A. A. Rayner, Aero Research, Ltd., and the De Havilland Aircraft Co., develop an adhesive or cementing compound comprising an intimate mixture of an aromatic amine-formaldehyde condensation product and a fusible heat-hardenable phenol-formaldehyde condensation product. 254

November: H. J. Wallbaum succeeds in preparing pure silicides by sintering powder mixtures of the pure components in aluminum oxide crucibles under argon or in a vacuum at relatively low temperatures. 255

1942

1942: M. A. Grossmann proposes a method for calculating the hardenability of steel whereby a base hardenability, reckoned according to the carbon content alone, is multiplied by a factor for each chemical element present. 256

January: F. Keller and R. A. Bossert, Alcoa, show that 24S alloy is of a different composition than duralumin because it contains the effective phase (aluminum-copper-magnesium) which is absent in the latter. 257

March 3: J. F. Dreyer develops a luminous material suitable for use in instrument boards of automobiles, airplanes, etc., made by adding fluorescent dye to a urea-formaldehyde varnish and impregnating the fabric body sheet with it. 258

April: G. E. Clausen and J. W. Skehan, Machlett Laboratories, obtain malleable beryllium by adding 0.5 per cent titanium or zirconium as reducing agents and then hot rolling in nickel envelopes. 259

April 9: P. Schwarzkopf and I. Hirschl propose a method for the production of solid solutions of carbides whereby the individually formed carbides are heated together to a temperature at which a solid solution is formed. 260

April 30: N. A. De Bruyne develops laminated structures which comprise a base of a nonmetallic material, *e.g.*, a fabric impregnated with phenol-formaldehyde resins, to which a metal skin covering is attached by mechanical bonding. 261

May 26: Aero Research, Ltd., patents urea-formaldehyde adhesives in which formaldehyde and urea are refluxed together in an acid solution. 262

June 6: E. Orowan, Cambridge University, observes kinking in metals. 263

September 24: J. H. Frye, Jr., and W. Hume-Rothery find that the increase in hardness for a given atom per cent of solute is linearly related to the square of the lattice distortion for elements in the same row of the periodic table. 264

September 25: R. Canter and H. D. Geyer prepare a coating to prevent ice from sticking to material by mixing a high-melting wax, an alkyd resin, an urea-formaldehyde resin, and a special solvent. 265

October 7: E. G. Rochow, General Electric, receives patents for various polymeric silicons, their production, and possible uses, including use with glass fibers in insulating electrical conductors. 266

October 13: W. P. Erichs, American Cyanamid Co., develops a resinous product for use in coating compounds and adhesives and formed through the condensation of polyalkylal guanidine salts with polycarboxylic acids and their anhydrides. 267

November 3: R. V. Heuser and W. P. Erichs, American Cyanamid Co., develop organic nitrogen resins used in preparing coating compounds and as initial material for the synthesis of laminated materials, resins, or adhesives. 268

November 24: N. A. De Bruyne and D. A. Hubbard, Aero Research, Ltd., develop an adhesive for uniting two surfaces of wood made up of melamine, urea- or thiourea-formaldehyde resin, and a foam hardener. 269

December 29: W. Zeriveck, E. Heinrich, and P. Pinten, General Aniline and Film Corp., develop a hard infusible furane resinous condensation product suitable for use as an adhesive. 270

1943

1943: G. D. Cremer and J. J. Cordiano discover that aluminum can be used to manufacture powder-metallurgical products with high strength properties. 271

1943: P. G. McVetty shows that creep occurs in three stages and gives a mathematical formulation of creep curves. 272

January 12: G. Natta synthesizes styrene. 273

January 12: M. A. Pollack, I. E. Mushat, and F. Strain, Pittsburgh Plate Glass Co., develop a process for the polymerization of polyhydric alcohol esters of monocarboxylic acids whereby the polymerization is interrupted before the polymer is converted into an insoluble gel, the unpolymerized monomer is separated, and the process continues until the polymer has been converted into an infusible state. 274

March 30: E. T. Lissig and I. Gazdik, B. F. Goodrich Co., develop phenolic resins of resorcinol-formaldehyde which aid in improving the adhesion of rubber to cotton, as in tires. 275

April 27: N. A. De Bruyne and C. A. A. Rayner, Aero Research, Ltd., develop a process for joining surfaces in aircraft production whereby one surface is coated with an adhesive mixture of a phenol-formaldehyde condensation product and an initial phenol-formaldehyde condensation product. 276

July 6: Urea-formaldehyde resin adhesives are applied as foam to prevent swelling and warping of the veneer in a process developed by A. Menger and E. Bock. 277

October: Olefins form compounds with salegenin, the precursor of phenol-formaldehyde resin, to form wood and metal adhesives, according to J. I. Cunneen, E. H. Farmer, and H. P. Koch. 278

1944

January 25: G. F. D'Alelio and J. W. Underwood, General Electric, form compounds comprising an acid-curing thermosetting-resin such as melamine-formaldehyde resin. 279

April 8: A glycerol-phthalate resin forms undercoating in a comparatively new method of preventing ice accretion developed by G. S. Edlineton. 280

May: G. B. Rheinfrank, Jr., and W. A. Norman, Materiel Command, USAAF, report on the first glass fiber laminate fuselage which was built at Wright Field and flight tested on March 24, 1944. 281

July 4: E. G. Rochow, General Electric, prepares polymeric organosilicon compounds for electric insulation and other uses by reacting silicon tetrachloride with the magnesium derivative of a dihalogenated aromatic hydrocarbon. 282

August 22: R. M. Thomas and W. J. Sparks, Jasco, Inc., patent a lubricant composed of a mineral hydrocarbon lubricating oil with butadiene. 283

August 22: W. J. Sparks and R. M. Thomas, Jasco, Inc., patent the first successful process for the copolymerization of dienes with isobutylene. 284

August 29: D. B. Grossman, Roxalin Flexible Finishes, Inc., develops a synthetic fabric covering for the framework of aircraft parts comprising a shrunk-taut nylon secured to and covering the framework and impregnated with "cellulosic dope." 285

October 5: A process for mildew-proofing textile aircraft fabrics with an agent such as copper naphthenate after placement on the aircraft framework is developed by L. Room, Roxalin Flexible Finishes, Inc. 286

October 26: A. J. Daly, P. R. Harotin, and B. Shaw, Celanese Corporation of America, devise a method of building on the surface of glass plate a multilayer protective sheet of cellulose acetate and a plasticizer. 287

November: G. G. Havens, Consolidated-Vultee, develops a two-piece (rubber and plastic) adhesive for aircraft metal ("Metlbond") that can be cured under low pressure in inexpensive jigs. 288

November 14: N. A. De Bruyne and E. L. R. Morvat obtain a heat-hardenable adhesive, used in plywood, by incorporating phenyl-guanazale with the condensation product. 289

1945

1945: C. W. Balke and C. C. Balke produce columbium metal by heating a mixture of columbium carbide and oxide in a vacuum, liberating carbon monoxide. 290

1945: J. H. Hollomon and L. D. Jaffe discuss the effects of carbon content, temperature, and time in the secondary hardening of chromium steel. 291

March 6: J. F. Hyde, Corning Glass, receives a patent for the preparation of organosilicon polymers by treating silicon tetrachloride or ethyl orthosilicate with a Grignard reagent. Subsequent mixing and condensation forms heterocyclic trimers and further polymerization occurs by oxidation or hydrolysis to yield silicon-oxygen linkages between trimers. 292

March 20: Depolymerized rubber and phenolic resin are dissolved in a mutual solvent to form a useful adhesive, according to C. F. Brown and G. E. Hulse, U.S. Rubber Co. 293

May 22: S. G. Saunders and H. Morrison add a synthetic resin like urea-formaldehyde to "Neoprene" to obtain an adhesive suitable for metals, plastics, and other materials. 294

July: Work at the National Bureau of Standards and elsewhere shows that a cubic solid solution rich in zirconia can be formed by fixing the oxide with certain other refractory oxides, and that in some cases this cubic form is stable at high temperatures. 295

August 7: A. W. Merrick, Austenal Laboratories, patents the use of "Vitallium" in turbine buckets for exhaust turbine superchargers. 296

August 7: E. G. Rochow, General Electric Company, receives a patent for a process of synthesizing silicones by the reaction of methyl and phenol chlorides with silicon metal at 300° C in the presence of copper powder. 297

September: M. A. Miner, Douglas Aircraft, proposes the theory that cumulative fatigue damage is identical with the summation of the cycle ratios of overstress applied. 298

September 19: H. Dreyfus develops coating compositions for aircraft fabric made of cellulose ester containing the radicals of acetic acid, a monocarboxylic acid ester, and a metallic powder. 299

October 9: J. F. Hyde, Corning Glass Works, devises a method of polymerizing organosilicon polymers by partial oxidation induced by passing a stream of air through silicone. 300

1946

1946: R. S. Dean, J. R. Long, F. S. Wartmen, and E. L. Anderson show the engineering possibilities of titanium. 301

1946: W. Kroll, A. W. Schlechten, and L. A. Yerkes, Bureau of Mines, describes a process for obtaining ductile zirconium by preparing carbides from zircon sand, obtaining chlorides, reducing with magnesium, distilling in a vacuum, and arc-melting. 302

1946: R. M. Parke and F. B. Bens, Climax Molybdenum, publish first systematic study of chromium-base alloys for high-temperature applications. 303

1946: R. M. Parke and J. L. Ham describe methods for melting and casting molybdenum, with particular attention to the special process needed to make molybdenum castings ductile. 304

1946: F. N. Rhines proposes that the bonds between individual powder particles in sintering are essentially the same as those holding the internal atoms of the crystal together. 305

1946: C. Zener, Watertown Arsenal, points out that many aspects of the inelastic behavior of metals may be explained on the assumption that, whatever the exact structure of the boundary, the resistance to slipping of one grain over another obeys the laws commonly associated with amorphous rather than crystalline materials. 306

June 14: J. R. Whinfield and J. T. Dickson patent a process for obtaining fibers from glycol terephthalate polymers. 307

June 21: N. A. De Bruyne makes hard expanded or cellular resin masses by mixing urea-formaldehyde sirup with an aniline-formaldehyde condensation product and heating. 308

July: D. G. Moore, L. H. Bolz, J. W. Pitts, and W. N. Harrison, NBS, report on use of ceramic coatings to protect molybdenum. 309

August: A. R. Troiano and A. B. Greninger point out that hardening reaction in steel has much in common with the shear-like diffusionless transformations in other alloy systems. 310

August 20: D. J. Sullivan develops a self-sealing fuel container in which the inner layer is a polyamide, which resists softening and swelling when under machine-gun fire. 311

October: E. A. Gulbransen and J. W. Hickman perform an electron diffraction study of the oxide films formed on high nickel alloys at temperatures from 300° to 700° C. 312

December: A. J. Barry establishes the relationship between the viscosity and the average molecular weight for the dimethyl silicone polymers. 313

1947

1947: R. Kiessling, University of Uppsala, obtains pure specimens of molybdenum and tungsten borides by sintering very pure boron and metal powders in vacuo and then studies their crystal structures. 314

1947: A. D. Smigelskas and E. O. Kirkendall demonstrate that the separate rates of diffusion in alloy systems are not necessarily equal. 315

March: W. N. Harrison, D. G. Moore, and J. C. Richmond apply coatings of specially developed frits with additions of aluminum oxide, chromium oxide, or cobalt oxide to typical superalloys and attain a greatly increased oxidation resistance, some of the coated specimens withstanding 500 hours of exposure in air at 820° C without visible changes. 316

August: C. A. Crawford describes two nickel-base alloys developed with properties useful for gas-turbine applications at temperatures up to at least 1500° F. One is "Inconel-X," a wrought material with high rupture strength at all temperatures up to 1500° F and higher, the other is a cast material primarily suited for extended service applications requiring high creep resistance in the neighborhood of 1500° F. 317

August 19: F. H. Roberts and H. R. Fife, Carbide and Carbons Chemical Corp., produce mixtures of polyoxyalkylene monohydroxy compounds by treating alkylene oxide mixtures with monohydroxy-aliphatic alcohols in the presence of 0.75 per cent sodium hydroxide. 318

1948

1948: R. Kiessling, University of Uppsala, prepares boron of high purity by the reduction of boron tribromide vapor with hydrogen. 319

1948: C. Zener proposes the hypothesis that intergranular cracks may be initiated when shear-stress relaxation occurs along grain boundaries. 320

January: R. L. Machlin presents a dislocation theory of fatigue failure for annealed solid solutions and an equation giving the dependence of a number of cycles for failure on stress, temperature, material parameters, and frequency for uniformly stressed specimens. 321

March 23: H. L. Leland, Standard Oil Development Co., patents oils for lubricants and hydraulic fluids based on mixtures of chlorinated aromatic compounds, a polystyrene viscosity index improver, and inhibitors. 322

June 15: W. Kroll and F. E. Bacon patent a process for the reduction of a zirconium-silicon-iron alloy by mixing with ferrous chloride, heated to a temperature above 220° and below the melting point of ferrous chloride, the resulting zirconium chloride being usable for production of zirconium. 323

June 16: R. Irmann, Aluminum-Industrie, A.G., describes a process for the manufacture of sintered aluminum products of high-temperature strength. 324

July: D. G. Moore, L. H. Bolz and W. N. Harrison find frits containing zirconium oxide will protect molybdenum for short periods (10–45 minutes) in oxidizing atmospheres up to 1930° C. 325

August 3: W. Kroll produces chromium powder by converting the chloride to the nitride by ammonia treatment, the nitride yielding the powder at 1100°–1600° in vacuo. 326

December 28: H. R. Fife and Walter J. Toussaint, Carbide and Carbon Chemicals Corp., prepare polyoxyalkylene diol esters suitable as lubricants where fluidity at low temperatures is required. 327

1949

1949: A. G. Guy, General Electric, reports on a series of nickel base alloys for high-temperature use containing 20 per cent chromium, 6 per cent aluminum, 6 per cent molybdenum, 2 per cent columbium, 0.5 per cent boron. 328

1949: J. L. Zambrow and M. G. Fontana report results of tests on mechanical properties, including fatigue, of aircraft alloys at very low temperatures. 329

January: A. H. Cottrell and B. A. Bilby, University of Birmingham, propose that the temperature dependence of the yield strength of bcc metals results from the interaction of dislocations with impurity atoms which segregate in the vicinity of dislocations and anchor them. 330

January 18: H. P. Bradley and J. L. Dum develop a process for bonding metal by means of chlorinated rubber adhesives containing a polyalkylene polyamine. 331

February: J. T. Norton and A. L. Mowry, M.I.T., produce solid solutions of fourth and fifth group carbides by mixing the preformed carbides with one per cent of cobalt powder in stainless ball mills, adding organic solvents, pressing the dried and screened mixture into compacts and sintering in the high-frequency vacuum furnace for three hours at 2100° C. 332

March: A. R. Blackburn, T. S. Shevlin, and H. R. Lowers, Ohio State University, conclude after studying the wetting of alumina by various metals that chromium-alumina compositions offer the most desirable combinations. 333

March 12: W. K. Burton, N. Cabrera, and F. C. Frank, in discussing the role of dislocations in crystal growth, postulate that the shape of the critical nucleus is not square but a figure with rounded corners inscribable in the previously postulated square nucleus. 334

April: M. D. Burdick, R. E. Moreland, and R. F. Geller report test results on a series of various combinations of metallic oxides which indicate that materials high in beryllium oxide exhibit promising heat-shock resistance. 335

July: P. Ehrlich obtains first pure specimen of titanium boride by sintering very pure boron and titanium powders in vacuo. 336

July 5: A. J. Berry, D. E. Hook, and L. De Pree, Dow Corning, patent a process for obtaining a hydrochlorosilyl addition product with rubber. 337

July 23: C. C. Laughlin and E. Wainer, National Lead, discover that 0.6–1.0 per cent of chromium oxide added to the titanium oxide-carbon black mixture produces a carbide which contains less than 0.2 per cent of free carbon and is harder than titanium carbide produced in the usual manner. 338

August 30: H. R. Fife and F. H. Roberts, Carbide and Carbon Chemicals Corp., prepare esters of aliphatic monoethers of polyoxyalkylene suitable as metal lubricants. 339

September: In studying metallographically the bonding between boron carbide and metals, H. J. Hamjian and W. G. Lidman, NACA, find that iron as well as nickel and cobalt forms bonding zones and that chromium exhibits good wetting properties. 340

September 6: S. A. Ballard, R. C. Morris, and J. L. Van Winkle, Shell Development Corp., prepare polyoxyalkylene compounds for use as lubricants. 341

November: I. E. Campbell *et al.* describe the carburization of molybdenum, tungsten, niobium, tantalum, and chromium wires with methane and other hydrocarbons in a hydrogen or hydrogen-nitrogen atmosphere. 342

December: A. Cibula and R. W. Ruddle propose that the tensile properties of high-strength cast aluminum alloys increase markedly with decrease in grain size, owing primarily to changes in the form of the intergranular shrinkage cavities. 343

1950

March: W. G. Lidman and M. J. Hamjian report that iron-bonded boron carbides were exceptionally strong at elevated temperatures near the melting point of the metal additive. 344

March 7: A. J. Berry, Dow Corning Corp., produces aromatic halosilanes by reacting an aromatic chlorohydrocarbon having a nuclearly substituted chlorine with a monoorganodichlorosilane in the presence of boron and aluminum chlorides. 345

March 14: T. W. Evans, D. E. Adelson, L. N. Whitehill, Shell Development Co., produce copolymers of diallyl phthalate with allyl vinyl phthalate suitable for aircraft windows. 346

April: R. Kieffer obtains zirconium carbide on a semitechnical scale by precarburizing very pure zirconium oxide in a high-frequency-heated graphite crucible at 1800° C and finishing the operation in a carbon-tube vacuum furnace at 1700° C after grinding and adding more carbon. 347

April: P. J. Maddex and L. W. Eastwood describe a continuous method of producing titanium in which magnesium and titanium tetrachloride are used as raw materials. 348

May 13: G. F. Hüttig *et al.* describe a method of producing zirconium carbide by adding chlorine-evolving substances to the carburizing gas, a process which should be advantageous if it is desired to obtain products of a theoretical carbon content. 349

June 27: C. E. Bixler patents a bonding or cementing mixture composed of low-melting polyexoxide. 350

August: E. M. Trent *et al.* report that chromium carbide added to titanium carbide-nickel and titanium carbide-cobalt cermets improved their oxidation resistance until it compared favorably with that of many heat-resistant steels at about 900° C. 351

August 8: A. Dreyling and C. W. Johnson, Du Pont, patent an airplane fabric which is predoped with an aqueous emulsion of a cellulose derivative, dried, and then mounted on the airframe and doped again. 352

August 15: F. C. Frank and W. T. Read propose that certain geometrical arrangements of dislocation lines are able to create from themselves large numbers of new dislocations not involving kinetic energy. 353

August 22: H. Scott, R. B. Gordon, and F. C. Hull, Westinghouse, disclose a wrought austenitic precipitation-hardened alloy of nickel, chromium, molybdenum (or tungsten), and titanium carbide ("Discalloy") for the rotors of jet engines. 354

October: L. Brewer, A. W. Searcy, D. H. Templeton, and C. H. Dauben report the existence of a number of stable high-melting phases in the tantalum-silicon, molybdenum-silicon, and tungsten-silicon systems. 355

October 31: G. H. Denison, Jr., N. W. Farby, and R. O. Bolt, California Research Corp., disclose a nonflammable aircraft hydraulic fluid made by blending a liquid chlorinated olefin, an alkaline earth-metal phenate, a chlorinated benzene, and other components. 356

November 14: P. M. McKenna patents a process for preparing tungsten monocarbide from tungsten-containing material. 357

1951

1951: E. N. da C. Andrade and C. Henderson conclude that in metals without notable impurities glide is due to two distinct processes: first the initiation of glide planes, which temperature agitation tends to check, and second to glide proceeding on already initiated planes which temperature agitation tends to promote. 358

1951: W. J. Childs, J. E. Cline, W. M. Kisner, and J. Wulff pass a stream of purified hydrogen mixed with very pure molybdenum pentachloride vapor through a glass chamber containing an object to be coated and obtain molybdenum deposition by reduction. 359

January: E. A. Beidler, C. F. Powell, and I. E. Campbell report a method of protecting molybdenum by using a molybdenum disilicide coating. 360

January 23: Lubricating die surfaces of glass are devised by J. Sejournet and L. Labataille for the extrusion of high-melting metals and alloys such as those of molybdenum. 361

March: D. G. Moore, S. G. Benner, and W. N. Harrison, National Bureau of Standards, report the development of a coating containing 80 per cent by weight chromium and 20 per cent by weight of an alkali-free frit (glass) which markedly reduces oxidation in air at 980° C and exhibits the same thermal-shock resistance as the base material. 362

March 6: Patent was issued to C. R. Ameberg and S. F. Walton on a plating of a refractory metal, or a coating with a glaze of a refractory hard metal, oxide, silicide, etc., for raising threshold oxidation temperatures in carbon and graphite materials. 363

April 17: A patent claiming hydraulic fluids useful at low temperature and of low flammability consisting of trialkyl phosphates, tricresyl phosphate, a linear polymer of methacrylate esters, and a glycidyl ether is granted to F. J. Watson, Shell Development Co. 364

May: L. Brewer, D. L. Sawyer, D. H. Templeton, and C. H. Dauben determine the phases of the binary systems of boron with cerium, titanium, zirconium, niobium, tantalum, molybdenum, tungsten, thorium, and uranium. 365

May: C. Malmstrom *et al.*, North American Aviation, measure short-time tensile breaking strength for various grades of graphite from room temperature to the sublimation point and determine the variation in density of carbons and graphites as a function of position in molded and extruded forms. 366

May 27: Temperature-resistant adhesives for laminated metal substances are made of a polyfunctional phenol and a vinyl resin, according to a patent issued to F. J. Nagel, Westinghouse Electric Corp. 367

June: H. B. Goodwin and C. T. Greenidge, Battelle, demonstrate the arc-melting of tungsten to form a small forgeable ingot. 368

June 5: J. H. Ramage, Westinghouse, devises a method of coating refractory oxidizable metals (tantalum and zirconium) by electroplating with chromium followed by heating in a hydrogen atmosphere. 369

June 26: A. J. Berry patents a process for producing phenylene-linked organopolysilanes. 370

June 26: W. A. Zisman, D. R. Spessard, and J. G. O'Rear, Naval Research Laboratory, develop nonflammable hydraulic fluids and lubricants for military aircraft using water-glycol fluids. 371

July: D. G. Moore, L. H. Bolz, J. W. Pitts, and W. N. Harrison, NBS, report that a coating for molybdenum consisting of a chromium frit provided good oxidation protection but markedly reduced specimen life. 372

July 31: W. O. Binder improves the high-temperature strength of austenitic steels by the addition of 0.005–0.1 per cent boron to retain the improved strength imparted by cold-working and then "hot cold-worked" at above 1000° F but below recrystallization temperature. 373

October: J. E. Cline and J. Wulff describe a method of producing composite metal-ceramic bodies, starting from powders consisting of ceramic particles which have been coated with metal by vapor deposition. 374

October: L. D. Hower, Jr., J. W. Londree, Jr., and H. F. G. Ueltz investigate a three-phase approach to cermet compacts (oxide, interstitial compound, and metal). 375

November: A. R. Blackburn and T. S. Shevlin, Ohio State, develop a method of producing a 30 per cent chromium-70 per cent alumina cermet by sintering compacts of the constituents at 1700° C in a slightly oxidizing atmosphere of hydrogen with induced water vapor in a sealed furnace heated with molybdenum elements. 376

December: F. B. Litton reports he was able to roll hafnium metal cold to a 65 per cent reduction, but it could not subsequently be bent without fracture, and he suggests that 30 percent might be a more suitable reduction. 377

December: J. F. Wygant describes the formation of bodies of magnesium oxide having only 2 per cent porosity by hydrostatic pressing of material having a crystal size of about 200 Å. 378

1952

January: F. Seitz, University of Illinois, introduces the idea that the intersection of screw dislocations may produce point defects. 379

March 15: C. Herring and J. K. Galt, Bell Telephone Laboratory, report that tin whiskers (about 10^{-4} cm. diam.) display elastic and plastic behavior not far from that of a perfect crystal of about 1000 times greater strength than ordinary tin crystals. 380

April: F. W. Glaser and W. Ivanick succeed in preparing compacts of solid binder-free titanium carbide specimens of remarkably high strength by hot pressing powder containing 79.1 per cent titanium, 19.3 per cent combined carbon, and 0.6 per cent free graphitic carbon at about 1.3 tsi at temperatures ranging from 2600° to 3000° C. 381

May: P. Chiotti describes a procedure for the preparation of the nitrides and carbides of several metals and for the preparation of refractory bodies from them. 382

June 10: S. A. Ballard, R. C. Morris, and J. L. Van Winkle, Shell, note that liquid carboxylic acid diesters of polyalkylene glycols have high viscosity indices, low pour points, good thermal stability, and considerable resistance to oxidation 383

July: F. R. Larson and J. Miller adapt to the rupture and creep behavior of several widely different alloys a relation which evaluates the relative effects of time and temperature on the tempering of steels. 384

July: W. G. Pfann discusses the phenomenon of zone-melting and examines the consequences of the subsequent manner of freezing with respect to solute distribution in the ingot and with particular reference to purification and to prevention of segregation. 385

August: A nickel-bound (cobalt-free) chromium carbide is developed by General Electric with good resistance to abrasion, erosion, and corrosion and particularly high resistance to oxidation at high temperatures. 386

September: N. Dudzinski shows the possibility of manufacturing aluminum alloys of high Young's modulus by the addition of intermetallic compounds and high-melting-point metals, which themselves have a high value of Young's modulus. 387

October: J. Washburn and E. R. Parker provide the first experimental verification of the existence of edge dislocations, finding their behavior under stress to be in accord with theory. 388

1953

1953: H. Staudinger is awarded Nobel Prize for Chemistry for showing that small molecules polymerize by chemical intersection, not by physical aggregation, and that linear molecules can be built synthetically. He also established the relationship between the molecular weight of a high polymer and its viscosity in solution. 389

January 13: R. J. Nebesar develops a synthetic fabric (glass fiber, nylon, orlon), impregnated with resin and then covered with a thin sheet of surfacing resin, which is useful in making radar domes. 390

February: E. Ryschkewitch reports that an increase in porosity of about 10 per cent lowers the compressive strength of sintered alumina or zirconia by about 50 per cent. 391

April 28: Substantially fire-resistant hydraulic fluids consisting of mixtures of a trialkyl phosphate and a triaryl phosphate which may also contain viscosity index improvers, corrosion inhibitors, and antioxidants are claimed by F. J. Watson, Shell, in two patents. 392

June 16: L. A. Mikeska and P. V. Smith, Standard Oil Development Co., develop a synthetic lubricant of branched-chain trialkyl esters of phosphoric acid. 393

July: G. B. Wachtman, Jr., and L. H. Maxwell, A.R.D.C., show that the plastic deformation of ceramic oxide single crystals approximates one-half the melting temperatures on the absolute scale. 394

November: W. D. Kingery, M.I.T., reviews the metal-ceramic reactions, surface and interfacial energies, constituent properties, and effect of the dispersed state on the fabrication and properties of cermets. 395

November 17: Hydraulic fluids of low density which are substantially fire resistant are prepared from trialkyl phosphates and polyhydric alcohols by M. F. George, Jr., and P. M. Reedy, Jr., Lockheed Aircraft Co. 396

December 19: A. R. G. Brown, A. R. Hall, and W. Watt, Royal Aircraft Establishment, obtain flat specimens of pyrolytic graphite by cracking hydrocarbons on to flat graphite rods, the density approaching the theoretical density as the temperature of deposition is raised. 397

1954

1954: J. F. Lynch, J. A. Slyh, and W. H. Duckworth impart significant oxidation resistance to graphite by coating it with molybdenum disilicide powder suspended in a phenolic resin and then baking at 2150°–2210° C. 398

March: L. J. Trostel, Jr., E. T. Montgomery, and T. S. Shevlin, A.R.D.C., describe the vibrational forming of cermets of ceramic oxide fibers and powdered metal mixtures, such as fibrous aluminum silicate bonded by 71.4–91.0 weight per cent of stainless steel. 399

June 8: Polyvinyl acetals are stabilized with two-thiazoline-two-thiol for safety-glass interlayers by C. H. Jarboe, Du Pont, the high thermal stability of the adhesive making it especially valuable for use in aircraft. 400

August: E. M. H. Lips and H. Van Zuilen, N. V. Phillips, report a method of obtaining exceedingly high strength in alloy steels by cooling from the austenitizing temperature to a subcritical temperature where they are deformed and then quenching and tempering at a low temperature. 401

September: P. G. Cotter and J. A. Kohn prepare hafnium carbide from a melt at slightly above 2800° C. 402

September 21: R. A. Kempe and R. R. Ruppender, Thompson Products, coat molybdenum and tungsten articles at 1600°–2300° F with aluminum, silicon, or zirconium obtained by the decomposition of the halides in a stream of hydrogen. 403

September 28: E. Wainer, Thompson Products, develops a binary coating for refractory metals using silicon or zirconium as the primary element and various elements as the secondary. 404

October 19: R. F. Baker, Westinghouse, receives patents for ductile molybdenum and molybdenum alloys (less than 20 per cent tungsten plus a total of 0.50 per cent nickel, cobalt, and iron) and for forging molybdenum alloyed with 0.1 per cent cobalt. 405

December: C. L. Kolbe, General Electric Research Laboratory, shows the feasibility of hot-working molybdenum in an inert atmosphere. 406

1955

1955: E. S. Blake, W. C. Hamann, and J. W. Richards show that esters containing no beta hydrogen atoms are more stable thermally and can withstand temperatures at least 90° F higher than other esters. 407

1955: General Electric Research Laboratory produces synthetic diamond. 408

1955: C. T. Sims, C. M. Craighead, and R. I. Jaffee, Battelle, report on the fabrication of rhenium metal by powder metallurgy and on its various physical and mechanical properties. 409

January: J. E. Dorn shows that elevated temperature creep of metals occurs by a process of dislocation climb which requires activation and diffusion of atoms. 410

January: R. E. Wilson, L. B. Coffin, and J. R. Tinklepaugh, A.R.D.C., report that the modulus of rupture strength of self-bonded silicon carbide increased with temperature, achieving 69,000 psi at 2500° F. 411

April: M. L. Kronberg reports on the plastic deformation of single crystals of synthetic sapphire. 412

April: G. Natta, Milan Polytechnic, describes a new class of polymers which have exceptional structural regularity and are made from α-olefins. 413

April 19: Charles B. Criver, Alcoa, describes the properties and preparation of aluminum-base alloys suitable for use at elevated temperatures (copper 5–9 per cent, manganese 0.15–1.2 per cent, vanadium 0.05–0.15 per cent, and zirconium 0.05–0.25 per cent), plus minor constituents. 414

May 3: W. M. Wheildon, Jr., Norton Company, files application for a patent for a process of atomizing directly from solid bodies to produce a ceramic coating. 415

June: D. J. Maykuth *et al.* determine the effect of small quantities of various elements on the ductility of chromium and report the fabrication of an iodide chromium sheet having an average ductile-to-brittle bend-transition temperature below 0° C. 416

June: G. Natta and P. Corradini, Milan Polytechnic, analyze the X-ray diagrams of isotactic polystyrene, which show that the chain has a helical shape, each turn consisting of three monomeric units. 417

July: C. D. Bopp and O. Sisman report that benzene rings in polymers improve resistance to nuclear radiation, a phenomenon probably due to their high resonance energy. 418

August 2: R. M. Poorman, Linde Air Products Company, devises method of flame-spraying ceramic coatings using detonation waves. 419

September 13: Silicone fluids usable as hydraulic fluids can be stabilized and given resistance to gelation at elevated temperatures by the addition of an organic phosphite (tritolyl and triphenyl phosphite), according to A. R. Gilbert, General Electric. 420

November: E. M. Sherwood *et al.* determine the vapor pressure of rhenium over a temperature range of 2220°–2725° C, finding it to be approximately one and one half times that of tantalum, and estimate its boiling point as 5630° C. 421

December: K. M. Taylor, Carborundum Corporation, describes a self-bonded boron nitride (I) made by hot-pressing, whose crystal structure and machining and lubricating properties resemble those of graphite. 422

December 27: Cellular plastics used as internal material or fillers or as layers in sandwich assemblies are strengthened with use of a fibrous glass fabric secured to the inner surface of the metal, according to a patent issued to E. Simon, F. W. Thomas, and L. A. Dixon, Jr., Lockheed Aircraft Corp. 423

1956

1956: Work conducted by W. R. D. Jones and G. V. Hogg, Cardiff University, on magnesium-lithium alloys indicated silver to be most effective in increasing alloy stability. 424

January: F. E. Block *et al.* obtain high-purity chromium by electrolysis of purified aqueous solutions at elevated temperatures. 425

January: R. C. Gifkins proposes that round or r-type cracks can be initiated along grain boundaries by the action of grain boundary shearing. 426

January: J. A. Hedvall reports that inactive gases dissolved or adsorbed in oxides in some cases affect the surface activity of the solid. 427

April 17: F. W. Diggles develops a transparent plastic material made of cellulose acetate butyrate ester and methyl methacrylate and suitable for attachment to aircraft canopies. 428

June: M. C. Carosella and J. D. Mettler, Electro Metallurgical Co., describe a new process for producing high-purity chromium from high-carbon ferrochromium (obtained from an electric furnace) and 99.8 per cent chromium electrodeposited in diaphragm cells from a chromium-alum solution. 429

June 9: C. T. Sims, Battelle Development Corp., receives a patent for rhenium fabrication processes. 430

June 26: John P. Swentzel, Carborundum Co., develops a new dense silicon-nitride-bonded silicon carbide refractory. 431

July 21: I. Mikheeva *et al.* report a method for preparing a high-purity aluminum-lithium alloy by the thermal decomposition of lithium aluminum hydride. 432

September: H. H. Uhlig describes the dependence of the oxidation rate of metals on the work function of the metal and on the properties of semiconducting oxides in contact with the metal. 433

November: R. A. Alliegro, L. B. Coffin, and J. R. Tinklepaugh, Alfred University, produce pressure-sintered silicon carbide with a modulus of rupture of 70,000 psi at 2500° F. 434

November: C. W. Chen and E. S. Machlin postulate that, since intercrystalline v-type cracks occur in bicrystal in the absence of plastic deformation, jogs already exist in grain boundaries. 435

December 25: A method for flame-spraying a coating of refractory cermets on metal surface is discovered by E.T. Montgomery, A. P. Welch, and J. L. Bitonte, Ohio State University. 436

1957

January 29: H. P. Hood and S. D. Stookey, Corning Glass, develop a crystalline glass with properties within the range of heavy structural materials by adding a nucleating agent like titanium oxide to the pure mixture, which when heated, cooled, and slowly baked yields a dense mass of interlocking crystals. 437

March: J. E. Burke claims that in sintering with alumina the grain boundaries act either as sinks or as diffusion paths for lattice vacancies. 438

May 21: While investigating the low-temperature unstable plastic deformation of aluminum alloys, Z. S. Basinski discovers that discontinuities in the stress-strain curve are caused by a localized temperature rise produced during the deformation. 439

July: N. W. Furby, R. L. Peeler, and R. I. Stirton report that Oronite Fluid 8515, a silicate ester fluid, is used in hydraulic systems of the B–58 supersonic bomber and the X–15 research vehicle built by North American. 440

August: C. A. Arenberg *et al.* report that the addition of calcium fluoride to vanadium pentoxide in the sintering of thoria was beneficial in the development of high density bodies. 441

August: E. P. Hyatt, C. J. Christensen, and I. B. Cutler report that ferric oxide aided in lowering the sintering temperatures of both zircon and zirconia bodies to give sintered bodies of high density. 442

August 6: N. W. Furby, J. M. Stokely, and E. G. Foehr develop alkyl ethers derived from polyalkylene glycols for use as jet-turbine lubricants. 443

September: M. L. Huggins and T. Abe postulate that in glasses containing, in addition to boric oxide, small relative amounts of an alkali or alkaline earth oxide, some of the boron atoms are surrounded by four oxygen atoms, all the oxygen atoms bridging between two boron atoms, while at concentrations beyond that of the thermal expansion minimum, some oxygens are assumed to have only one boron neighbor. 444

September: A. E. R. Westman and P. A. Gartaganis study the chain-length distributions in solutions of sodium phosphate glasses and discover cyclic phosphates to exist in solutions of glasses having or approaching the metaphosphate composition despite prolonged heating of the glasses in the molten condition. 445

December: E. Ryshkewitch, National Beryllia Corp., observes that coiled chips formed when a diamond tool (at room temperature) cuts the surface of highly polished materials (ruby, quartz glass, etc.) display plasticity. 446

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