WEB OF SCIENTIST: INTERNATIONAL SCIENTIFIC RESEARCH JOURNAL
ISSN: 2776-0979, Volume 3, Issue 6, June, 2022

DEVELOPMENT HISTORY OF MATERIALS SCIENCE BY THE SCIENTIFIC POINT OF VIEW

Riskulov A. A.
DSc, Prof. of the Materials Science and Mechanical Engineering Department, Tashkent State Transport University

Toirov O. T.
Ph.D. student of the Department of Materials Science and Mechanical Engineering, Tashkent State Transport University, Tashkent, The Republic of Uzbekistan
e-mail: tv574toirov@mail.ru

Tursunov N. K.
Ph.D., head of the Department of Materials Science and Mechanical Engineering, Tashkent State Transport University, Tashkent, The Republic of Uzbekistan,
e-mail: u_nadir@mail.ru

Alimukhamedov Sh. P.
Dr. Tech. sciences, professor
of the Department of Materials Science and Mechanical Engineering, Tashkent State Transport University, Tashkent, The Republic of Uzbekistan

Nurmetov Kh.I.
Senior Lecturer, of the Department of Materials Science and Mechanical Engineering, Tashkent State Transport University

Nafasov J. H.
Senior lecturer of the Department of Materials Science and Mechanical Engineering, Tashkent State Transport University
e-mail : nafasovz@mail.ru

Abstract

Materials science is conditionally divided into theoretical and applied one. The former one deals with general regularities of structure of materials and processes which occur in them under external effects. It is based on integration of achievements in physics, chemistry, physical chemistry, electrochemistry, physics of metals and other natural sciences development of which affects the amount of use of materials in technology and effectiveness of methods for processing them into articles. This connection, not so evident in the past, today shows effective ways of creation of materials and development of manufacturing methods which meet the increasing engineering and economic requirements. The objective of applied materials science is to seek for optimal structure and technology for processing materials when manufacturing parts of machines and other mechanical articles.

Keywords: development history, materials science, ages, historical stages, Copper Age, Bronze Age, Iron Age.

1. Introduction

History of material improvement is dialectically connected with the history of evolution of society. Seeking to discover new materials at all historical eras was caused by humans' will to make their life better. Naming of historical stages after the names of materials which "made the era" (Earlier, Middle, and Later Stone Ages, Copper, Bronze, and Iron Age) reflect their significance in human evolution.

Stone Age is divided into Earlier (Palaeolithic), Middle (Mesolithic), and Later (Neolithic). At Palaeolithic era, which began with the origination of human (over 2 million years ago) and lasted till the 10 millennium B.C., humans used tools made of stone, wood, and bone in a state of nature. They started to process them roughly by hits causing split and chip of a material at the time of Mesolithic (10–5 millennia B.C.). This is how the first material processing technique appeared. Neolithic (8–3 millennia B.C.) was manifested by humans' switch from foraging and hunting towards horticulture and pastoralism. Humans learned to drill and grind stones, burn clay. Spinning and weaving appeared, as well as technologies for wood and animal skin processing.

Copper Age (4–3 millennia B.C.) began at the end of Neolithic with the discovery of native copper smelting and casting. Also at that time appeared articles made of coloured ceramics – terra-cotta, majolica, and faience.

Bronze Age followed Copper Age and lasted up to the 1 millennium B.C. Since the discovery of tin bronze and spread of bronze articles and weapons stone lost its significance as the main material for instruments of production. Written language, slave-owning civilisation, and metallurgy emerged. It appeared when metal casting with modifying additives was mastered. In the course of time ore mining, processing it into semi-products, and metal melting became functions of specialists.

Iron Age (since the 1 millennium B.C.) started when copper reserves ran short and people switched to development of iron which since then dominates as the basis for materials. Iron Age substantially accelerated development of manufacturing. In China, Middle East, and the Mediterranean animal-geared mechanisms for materials processing appeared. Use of wood coal allowed increasing ore processing temperature up to 900°C. Drossy semi-product cleaning with torrefaction started and blacksmith iron was obtained. The steel made by Ancient Indian craftsmen became widely known.

The breakdown of the Roman Empire in the V century A.D. and the following centuries slowed down technological and social progress in Europe. A new era in material development started since the 2 millennium A.D. when energy of falling water started to be used to gear machines. The invention of air blasts made it possible to heat metal in chimneys to temperatures above iron melting temperature, process smelt and clean iron from impurities. These achievements determined the level of development of productive forces for several centuries.

2. Methods

An increase of metal article consumption and lack of wood coal as the energy source for ore melting led to a search for new technologies of metal smelting. In the mid XVIII century black coal started to be used instead of wood coal and puddling process was developed – to transform crude iron into low-carbon iron on a furnace hearth. Discovery of black coal coking accelerated development of metallurgy.

Russian metallurgy developed rapidly at the beginning of the XVIII century – at the time of Peter I. Ural became the leading ore mining and smelting region in Russia, Ural iron marked “Stary Sobol” (“Old Sable”) was considered the best in Europe. In the following years, extraction of minerals increased (first of all of metallic ores), manufacturing of metals and articles of them expanded, metal science developed. French scientist R.A. Réaumur, a famous biologist and physiologist who introduced Réaumur temperature scale, was the first to study metal grain structure and physical thermal processing of steel. M.V. Lomonosov (1711–1765) made a great contribution to development of theoretical basics of metallurgy by publishing the first textbook of mining. P.P. Anosov (1797–1851) developed theoretical basics of high quality cast steel making and unveiled the secret for Damascus steel making which was lost in the Middle Ages. English natural scientist H.C. Sorby (1826–1908) was the first to study structure of steel, minerals, and rocks with a microscope. The name of sorbitol – a component of iron-carbon alloys – originates from his name.

An increase of demand for machines, first of all textile ones, led to the emergence of mechanical engineering as a branch of industry in developed European countries in the mid XVIII century. The level of materials science at that time limited the opportunity for development of machines with a scarce group of materials covered by manufacturing system. Industrial Revolution of the XVIII–XIX centuries led to transformation of hand manufactures into a machine use factory system, drastically changed the level of material processes and technology. Iron melt in converter was processed into steel for the first time in the XIX century. The invention of three processes for steel making named after their inventors – Bessemer process (1856, English metallurgist H. Bessemer), Martin process (1864, Frenchman P. Martin), and Thomas process (1878, Englishman S. Thomas) – finished this prominent period in material history.

Establishment of materials science as an applied area of science took place at the turn of the XIX century when growth of material-intensive areas of industry reached such volumes that their further development became impossible without scientific generalisations. Specialisation of materials science as an engineering science related to mechanical engineering ended in the XIX century. Meanwhile it reached the theoretical level of natural sciences, interlacing with their applied areas – crystallography, physics of metals, optics etc.

Discovery of the periodic law by D.I. Mendeleev in 1869 was an important step for development of materials science. Discovery of critical points with a phase change by D.K. Chernov was a significant event for science. A prominent contribution to metal science was made by foreign scientists: German metallurgist A. Ledebur who studied structural condition of iron-carbon alloys, Englishman W.R. Austen who found out the nature of a solid solution in an iron-carbon system which was named austenite after him, English physicists F. Laves (Fritz Laves is a German – translator's note) – who discovered chemical compounds with ionic bonds – and W. Hume-Rothery – electron ones; German physicist M. Laue who was the first to use X-ray to study crystals; the founders of metallographic studies H. Sorby and A. Widmanstätten, German physicist and chemist G. Tammann who was famous for his pioneer studies in the area of vitreous state of substance, theory of crystallisation, heterogeneous equilibrium; English metallurgist R.A. Hadfield whose development of wear resistant manganese and silicon steels may be viewed as the start of wide use of alloy steel, and others [1].

An increase in volume of black coal coking in the XIX century led to accumulation of great amounts of coal tar. The problem of its use was solved in 1856 by English chemist W.H. Perkin (1838–1903) who developed the method for obtaining a dye – mauveine – from tar. After the discovery of benzene in 1865 development of chemistry of carbon and a new branch of industry, at first manufacturing dyes and medicines only, but since the early XX century also multiple synthetic materials for mechanical engineering, started.

3. Results and Discussion

The invention of the internal combustion engine at the end of the XIX century, development of automobile construction, railway transport, and aviation promoted research to improve materials and methods for their processing. A weighty contribution to development of metallurgy was made by Russian engineers: the founder of Russian blast furnace school M.K. Kurako (1872–1920) and the creator of physical and chemical basics of steelmaking process, theory of steel rolling and calibration V.Ye. Grum-Grzhimaylo (1864–1928). National school of physical and chemical analysis of alloys and solid solutions founded by N.S. Kurnakov (1860–1941) gained great authority. Fundamental works by A.A. Baykov (1870–1946) laid foundation of structural-change theory for metals. Works by N.I. Belyayev (1877–1920) were a substantial contribution to creation of alloy steel in Russia. Origination of electric welding technology is tied to inventions of Russian engineers N.N. Benardos, who proposed carbon rod electric arc metal welding, and N.G. Slavyanov, who developed metal rod welding with item pre-warming. The end of the XIX century was manifested by great discoveries which led to creation of breakthrough technologies, machines, and devices. A.N. Lodygin invented the light bulb in 1872, T. Edison discovered thermal ionisation in 1883, and A.G. Stoletov together with G. Hertz discovered the photoelectric effect. Vacuum-electron device manufacturing started which promoted progress of vacuum processes and technology. Meanwhile gas liquefaction technology emerged and developed which gave rise to cryogenic technology. These achievements became possible thanks to development of special hermetic seals.

In 1861 Russian chemist A.M. Butlerov developed and grounded the theory of chemical structure of substance. In 1909 S.V. Lebedev synthesised a polymer similar to natural rubber out of butadiene. At the early XX century, having studied reactions of phenol and formaldehyde, Belgian chemist L. Baekeland obtained a new material which was named Bakelite and became the first product of industry of plastics. “Iron Age” finally became a thing of the past. As the symbol of the role of iron in the development of society, the famous Eiffel Tower was erected to commemorate the opening of 1889 Paris World Fair.

In 1903 American engineers, brothers W. and O. Wright carried out the first successful flight on an airplane with an internal combustion engine. Following them A. Santos-Dumont, H. Farbe and others constructed airplanes in Europe. Ya.M. Gakkel, D.P. Grigorovich, I.I. Sikorsky and others created designs of airplanes in Russia in 1909–14. Since the mid 20-s duralumin, which laid foundation to a vast class of aircraftgrade metal alloys, started to be used in airplane construction instead of wood and fabric.

Scientific and technical revolution which began in the late 40-s of the previous century intensified further development of materials science. Rapid growth of scientific knowledge led to new viewpoints at substance structure. New types of materials were developed: superconductors electrical resistance of which at cooling below the critical point turns to zero; semiconductors electrical resistance of which at room temperature has an intermediate value between those of metals and dielectrics; synthetic diamonds obtained from graphite and other carbon-bearing substances, etc.

Thanks to works of Russian scientists the knowledge of structure, properties, and technologies for obtaining conventional materials of mechanical engineering was enriched. M. Pavlov (1863–1958) made a fundamental contribution into the theory of metal deformation combined with thermal treatment (thermomechanical treatment). Fundamentally new results were obtained by C.I. Gubkin (1898–1955) while studying metal flow. P.A. Rebinder (1898–1972) developed the concept of molecular mechanism of behaviour of surfactants, developed the basics of their use in technological processes. A great contribution into the study of martensitic transformation was made by G.V. Kurdyumov (1902–1996). The number of alloys with specific properties, such as corrosion resistant, special magnetic ones, "memory" of mechanical shape etc., increased rapidly. Ukrainian scientist A.A. Bochvar (1902–1984) discovered and studied the superplasticity phenomenon.

Research in the area of synthesis and recycling of polymers aimed at improvement of their mechanical properties, better strength under exposure of media and high temperatures was developed. Long the heat resistance upper limit of plastics did not exceed 100–120°C, which limited their use greatly. Basics of creation of heat resistant polymers were laid by K.A. Andrianov (1904–1978) who showed in 1937 that Si–O atom system may be used to build the main chain of supermolecules. Similar research by V.V. Korshak (1908–1988) led to synthesis of heat resistant phenol resins in the 40-s. The founder of national school of polymer physics and chemistry V.A. Kargin (1907–1969) studied the connection of their structure and properties, developed methods for polymer material structural modification. A substantial expansion of nomenclature of plastics and industrial technologies for their obtainment was reached thanks to concepts of hydrocarbon oxidation chain reaction and ionic polymerisation mechanisms developed by Russian scientists. A great contribution to development of various areas of polymer materials science was made by foreign scientists F. Jale, L. Mandelkern, J. Ferry, P. Flory, R.Houwink, T.Hayashi and others [1].

In 1954 the ex-USSR put into operation the first ever atomic power station developed under the command of I.V. Kurchatov (1902–1960). The Institute of Atomic Energy headed by him carried out research of thermonuclear reactions, a complex of research on plasma physics results of which made a great contribution to solving problems of atomic energy use. Materials resistant to nuclear radiation became one of such problems. For the first time high efficiency nuclear reactor coolants and fuel element materials which contain fissile substance and provide fuel–coolant heat transfer were developed. These types of materials formed a new knowledge-intensive group of materials resistant to nuclear exposure which is being actively developed.

In 1956 a discovery called wear-free transfer was registered in the USSR. Some years after that a group of scientists from Moscow discovered the phenomenon of ultra-low friction of materials, which allowed a significant machine wear costs decrease.

4. Conclusion

Achievements of materials science promoted space exploration to a great extent. Development of electromechanical containment system in the 50–60-s was a step of towards it. S.P. Korolev (1906–1966) and A.T. Tumanov (1909–1976) were the originators of technology for manufacturing materials in space. A new area of materials science called space materials science appeared the aims of which include design of technologies for materials forming and processing in specific zero-gravity conditions, forecast of properties of materials in space etc. One of the main directions in materials science of the last quarter of the XX century became obtainment of composite materials by combination of dissimilar components. Progress in technologies for material processing and modification allowed using conventional natural materials (basalts, diabases, wood) in severe operating conditions of modern machinery. Scientists face the challenge of development of a new generation materials with previously unknown combinations of properties, of materials which actively affect coupled environments and materials, of materials which change structure and properties in a directed manner according to operating conditions [4]. So at the current stage of development of materials science, in a negligibly small period of time comparing to human history technology has utilised the majority of materials known.

References:

1. Турсунов, Н. К., Семин, А. Е., & Котельников, Г. И. (2017). Кинетические особенности процесса десульфурации при выплавке стали в индукционной тигельной печи. Черные металлы, (5), 23-29.

2. Nurmetov, K., Riskulov, A., & Avliyokulov, J. (2021). Composite Tribotechnical Materials for Autotractor Units (No. 5039). EasyChair.
3. Рыскулов, А. А. (1990). Разработка машиностроительных материалов на основе смесей металлополимеров (Doctoral dissertation, Гомель).
4. Ryskulov, A. A., Liopo, V. A., Avdeichik, S. V., & Mikhailova, L. V. (2014). Features of the Physicochemical processes in a Metal–Polymer System. International Polymer science and technology, 41(8), 33-40.
5. Riskulov, A. A., Yuldasheva, G. B., Kh, N., & Toirov, O. T. (2022). DERIVATION PROCESSES OF FLUORINE-CONTAINING WEAR INHIBITORS OF METAL-POLYMER SYSTEMS. Web of Scientist: International Scientific Research Journal, 3(5), 1652-1660.
6. Riskulov, A. A., Yuldasheva, G. B., & Toirov, O. T. (2022). FEATURES OF FLUOROCOMPOSITES OBTAINING FOR WEARING PARTS OF MACHINE-BUILDING PURPOSE. Web of Scientist: International Scientific Research Journal, 3(5), 1670-1679.
7. Abdurazakov, A. A., Riskulov, A. A., Yuldasheva, G. B., & Avliyokulov, J. S. (2015). Technology of high-strength wear resistant fluorcomposites for mechanical engineering. Europaische Fachhochschule, (10), 43-47.
8. Nurmetov, K. I., & Riskulov, A. A. (2021). Some aspects of industrial polymer waste recycling system.
9. Akhmedov, D., Alimukhamedov, S., Tursunov, I., Narziev, S., & Riskaliev, D. (2021). Modeling the steering wheel influence by the driver on the vehicle's motion stability. In E3S Web of Conferences (Vol. 264, p. 05015). EDP Sciences.
10. Алимухамедов, Ш. П., Рахимов, Р. В., Инагамов, С. Г., Мамаев, Ш. И., & Кодиров, Н. С. (2022). Математическое моделирование передаточного механизма потележечной тормозной системы грузовых вагонов. Universum: технические науки, (2-3 (95)), 8-14.
11. Алимухамедов, Ш. П., & Гапиров, А. Д. (2018). Напряженно-деформированное состояние устройства для гашения динамических нагрузок в трансмиссии транспортных машин. Universum: технические науки, (12 (57)), 23-28.
12. Teleubaevich, U. T., Kayumjonovich, T. N., Pirmukhamedovich, A. S., & Muratovich, T. T. (2022). THERMODYNAMIC CALCULATION OF COMPLEX DEOXIDATION BY ALUMINUM AND SILICON OF MELTS OF STEEL 20GL FOR CAST PARTS OF ROLLING STOCK AUTOCOUPLE DEVICES. Web of Scientist: International Scientific Research Journal, 3(5), 1761-1771.

13. Kayumjonovich, T. N., Pirmukhamedovich, A. S., & Teleubaevich, U. T. (2022). INFLUENCE OF COATING FORMATION CONDITIONS IN CHLORINE-CONTAINING MEDIA ON THE CORROSION PROPERTIES OF TITANIUM. Web of Scientist: International Scientific Research Journal, 3(5), 1692-1701.
14. Kayumjonovich, T. N., Pirmukhamedovich, A. S., & Teleubaevich, U. T. (2022). JUSTIFICATION AND CHOICE OF RATIONAL OPERATING CURRENT FREQUENCY IN INDUCTION CRUCIBLE FURNACES. Innovative Technologica: Methodical Research Journal, 3(06), 40-47.
15. Мухитдинов, А. А., & Алимухаммедов, Ш. П. Методическое указание к выполнению диссертационной работы на соискание ученной степени кандидата технических наук.
16. Азимов, Ш. И. М. М., & Валиева, Д. Ш. (2021). АНАЛИЗ ПРОЧНОСТНЫХ ХАРАКТЕРИСТИК ЗУБЧАТЫХ ПЕРЕДАЧ ПРИВОДА ПОДАЧИ РАБОЧЕГО ОРГАНА ШТРИПСОВОГО СТАНКА. Scientific progress, 2(2), 1470-1472.
17. Файзибаев, Ш. С., Соболева, И. Ю., Нигай, Р. П., Мамаев, Ш. И., & Абдирахманов, Ж. А. У. (2022). Исследование влияния пластических деформаций на поверхности упрочняемого бандажа. Universum: технические науки, (1-1 (94)), 106-110.
18. Пьядичев, Э. В., Гапиров, А. Д., & Кузнецов, Д. Б. (1987). Исследование влияния физико-химических характеристик топлив на период задержки воспламенения в дизеле. Двигателестроение, (8), 35.
19. Shipilova, K., Radkevich, M., Tsoy, V., Shoergashova, S., Vildanova, L., & Gapirov, A. (2020, July). Land use by transport infrastructure in Tashkent City. In IOP Conference Series: Materials Science and Engineering (Vol. 883, No. 1, p. 012067). IOP Publishing.
20. Мухаммадиева, Д. А., Валиева, Д. Ш., Тоиров, О. Т., & Эркабаев, Ф. И. (2022). ПОЛУЧЕНИЕ ПИГМЕНТА НА ОСНОВЕ ОСАДКОВ ЭЛЕКТРОХИМИЧЕСКОЙ ОЧИСТКИ ХРОМАТСОДЕРЖАЩИХ СТОКОВ. Scientific progress, 3(1), 254-262.
21. RADKEVICH, M., SHIPILOVA, K., MYAGKOVA, N., ABDUKODIROVA, M., & GAPIROV, A. (2020, January). Assessment of some indices of environmental sustainability of transport in Tashkent. In Waste Forum (No. 1).

22. Гапиров, А. Д. (2015). Организация научной работы студентов по общеинженерным дисциплинам. Учёный XXI века, (12 (13)), 33-35.
23. Гапиров, А. Д. (2018). Современные тенденции защиты окружающей среды в автомобилестроении. Вопросы науки и образования, (3 (15)), 40-44.
24. Рисқулов, А. А., Юлдашева, Г. Б., Турсунов, Н. Қ., & Нурметов, Х. И. (2022). Таълимда замонавий инновацион технологияларни қўллаш–юксак малака эгаси бўлиш демакдир. Academic research in educational sciences, 3(TSTU Conference 1), 146-150.
25. Nurmetov, K. I., & Riskulov, A. A. (2021). Some aspects of industrial polymer waste recycling system.
26. Teleubaevich, U. T., Kayumjonovich, T. N., Pirmukhamedovich, A. S., & Muratovich, T. T. (2022). THERMODYNAMIC CALCULATION OF COMPLEX DEOXIDATION BY ALUMINUM AND SILICON OF MELTS OF STEEL 20GL FOR CAST PARTS OF ROLLING STOCK AUTOCOUPLE DEVICES. Web of Scientist: International Scientific Research Journal, 3(5), 1761-1771.
27. Kayumjonovich, T. N. (2022). DEVELOPMENT OF A METHOD FOR SELECTING THE COMPOSITIONS OF MOLDING SANDS FOR CRITICAL PARTS OF THE ROLLING STOCK. Web of Scientist: International Scientific Research Journal, 3(5), 1840-1847.
28. Toirov, B. T., Jumaev, T. S., & Toirov, O. T. (2021). Obyektlarni tanib olishda python dasturidan foydalanishning afzalliklari. Scientific progress, 2(7), 165-168.