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Editorial Note on Materials Science and Engineering

Natarajan K

Department of Chemistry, Bharathiar University, Coimbatore, Tamil Nadu, India

Editorial

The interdisciplinary field of materials science, also commonly termed materials science and engineering, covers the design and discovery of new materials, particularly solids. The intellectual origins of materials science stem from the Enlightenment, when researchers began to use analytical thinking from chemistry, physics, and engineering to understand ancient, phenomenological observations in metallurgy and mineralogy. Materials science still incorporates elements of physics, chemistry, and engineering. As such, the field was long considered by academic institutions as a sub-field of these related fields. Beginning in the 1940s, materials science began to be more widely recognized as a specific and distinct field of science and engineering, and major technical universities around the world created dedicated schools for its study.

Materials scientists emphasize understanding, how the history of a material (processing) influences its structure, and thus the material's properties and performance. The understanding of processing-structure-properties relationships is called the materials paradigm. This paradigm is used to advance understanding in a variety of research areas, including nanotechnology, biomaterials, and metallurgy. Materials science is also an important part of forensic engineering and failure analysis – investigating materials, products, structures or components, which fail or do not function as intended, causing personal injury or damage to property. Such investigations are key to understanding, for example, the causes of various aviation accidents and incidents.

The material of choice of a given era is often a defining point. Phrases such as Stone Age, Bronze Age, Iron Age, and Steel Age are historic, if arbitrary examples. Originally deriving from the manufacture of ceramics and its putative derivative metallurgy, materials science is one of the oldest forms of engineering and applied science. Modern materials science evolved directly from metallurgy, which itself evolved from mining and (likely) ceramics and earlier from the use of fire. A major breakthrough in the understanding of materials occurred in the late 19th century, when the American scientist Josiah Willard Gibbs demonstrated that the thermodynamic properties related to atomic structure in various phases are related to the physical properties of a material. Important elements of modern materials science were products of the Space Race; the understanding and engineering of the metallic alloys, and silica and carbon materials, used in building space vehicles enabling the exploration of space. Materials science has driven, and been driven by, the development of revolutionary technologies such as rubbers, plastics, semiconductors, and biomaterials.

A material is defined as a substance (most often a solid, but other condensed phases can be included) that is intended to be used for certain applications. There are a myriad of materials around us; they can be found in anything from buildings and cars to spacecraft. The main classes of materials are metals, semiconductors, ceramics and polymers. New and advanced materials that are being developed include nanomaterials, biomaterials, and energy materials to name a few.

The basis of materials science is studying the interplay between the structure of materials, the processing methods to make that material, and the resulting material properties. The complex combinations of these produce the performance of a material in a specific application. Many features across many length scales impact material performance, from the constituent chemical elements, its microstructure, and macroscopic features from processing. Together with the laws of thermodynamics and kinetics materials scientists aim to understand and improve materials.

Structure is one of the most important components of the field of materials science. Materials science examines the structure of materials from the atomic scale, all the way up to the macro scale. Characterization is the way materials scientists examine the structure of a material. This involves methods such as diffraction with X-rays, electrons or neutrons, and various forms of spectroscopy and chemical analysis such as Raman spectroscopy, energy-dispersive spectroscopy, chromatography, thermal analysis, electron microscope analysis, etc.

Materials science evolved, starting from the 1950s, because it was recognized that to create, discover and design new materials, one had to approach it in a unified manner. Thus, materials science and engineering emerged in many ways: renaming and/or combining existing metallurgy and ceramics engineering departments; splitting from existing solid state physics research (itself growing into condensed matter physics); pulling in relatively new polymer engineering and polymer science; recombining from the previous, as well as chemistry, chemical engineering, mechanical engineering, and electrical engineering; and more.

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Address for Correspondence: *Dr. Natarajan K, Department of Chemistry, Bharathiar University, Coimbatore, Tamil Nadu, India, E-mail: natarajank267@gmail.com*

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