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# The Role of Material Science in Modern Engineering

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**ABSTRACT:** The paper emphasises the very significant role of materials selection for design and manufacturing processes of new needed products, having the highest attainable quality and performance at the optimum and possibly the lowest cost level. The engineering design processes cannot be set apart either from the material design, being more and more often computer aided, or the technological design of the most suitable manufacturing processes. The review of the multi-millennia long history of human civilisation indicates that the significant increase of the level of living and production is connected more often with the launching of new material groups with the properties better and better adjusted to real requirements of customers getting more sophisticated nearly each day, and also the launching of the technological processes which are relevant to them. The given reasons enable to forecast that the future of the market and products with the required properties, which appear on the market, are inseparably connected with the development of materials science and engineering.

**KEYWORDS:** Development of human civilisation; Engineering design; Materials design; Manufacturing; Materials science and engineering

## I. INTRODUCTION

Most materials scientists and engineers recognize the tremendous opportunities available at this time in history for advances in biotechnology or biomedicine and, closer to home, the intersection of materials and biology. Materials science and engineering is expected to play a highly significant role in the foreseeable future of bio medicine. Conversely, noting that materials science finds its roots in solid state physics and chemistry, biology is logically the next great frontier for materials science and engineering. However, researchers and educators working to integrate biology or biomedicine into materials science and engineering, and vice versa, have invariably encountered several challenges. These challenges may be grouped into two aspects of "bio complexity." First, biomaterials replace or interface with biological substances, especially tissues and cells. Biological tissues, or biological materials, are living, adapt to chemical and physical stimuli, perform multiple functions, and exhibit hierarchical structure with precise organization over multiple length scales. Therefore, biological materials exhibit complex processing-structure-property relationships, unmatched in engineering materials, which are only beginning to be established.

In contrast, the vast majority of biomaterials used in biomedical devices have historically included common engineering materials (e.g., stainless steel, titanium, alumina, porcelain, polyethylene, polymethylmethacrylate, etc.) that exhibited desirable properties that were borrowed for biomedical applications. These biomaterials enhanced the quality of life for countless individuals through passive interaction with biological systems. In other words, "do no harm." Thus, metallurgical or materials engineers were well-positioned to contribute to the design and manufacturing of a conventional stainless steel implant, for example, through traditional education in physical metallurgy or materials structure-property relationships, with little consideration of biology.

A second generation of biomaterials began to introduce materials that are favourably reactive to biology, including bioactive ceramics and glasses and biodegradable polymers. In the present age, so-called third generation biomaterials are intended for proactive interaction with biology. Examples include: tissue engineering scaffolds able to guide cell differentiation and tissue growth via signal transduction vehicles for controlled and/or targeted delivery of pharmaceuticals, proteins, and nucleic acids and multifunctional diagnostics and sensors among others. Materials scientists and engineers who wish to contribute to these and other exciting applications of biomaterials must become increasingly knowledgeable, or at least conversant, in biology and biomedicine.

## II. LITERATURE REVIEW

**Florin Tudorache et al (2016)** Humidity sensor characteristics and electrical properties of Ni–Zn ferrite material doped with Dy were studied after synthesis via sol–gel self-combustion method. In order to obtain different micro configurations of the material reflected in different porosities, four different fuel agents were involved: citric acid, tartaric acid, cellulose and urea. XRD and XPS techniques were used to certify the composition. The influence of fuel agent and structural features on the electrical properties of ferrite sintered pellets was investigated at room temperature as a function of frequency and humidity. Because the electrical characteristics of a porous material can significantly affect by the humidity, the electrical measurements were carried out in controlled humidity environments.

**T Kyu, Jainagesh Sekhar (2014)** Materials Science is interdisciplinary, being grounded in the fundamentals of chemistry, physics and, more recently, biology', explains Rama Rao [1] in one of the most succinctly written articles that comprehensively encompasses almost all aspects of Materials Science and Processes; in particular for 'crafting multi-component compositions, ensuring fine-scale microstructure, and employing extreme temperature and pressure.

**Paulo S. Batista et al (2013)** In this study, we investigate the generation of hydroxyl radicals mediated by a composite containing TiO<sub>2</sub> and 1.6% m/m of zinc phthalocyanine (TiO<sub>2</sub>/ZnPc) in aqueous suspensions containing methanol as oxidisable substrate. The composite features a specific surface 20% less than the value estimated for TiO<sub>2</sub> P25, probably due to the covering of the surface of the oxide by ZnPc and the pH of the isoelectric point of this composite equal of 5.5, about two units of pH lower than the value estimated for TiO<sub>2</sub> P25, are probably related to the difference in photocatalytic activity found for these materials. To assess the influence of different spectral bands of electromagnetic radiation on the production of hydroxyl radicals, we used different sources of radiation in experiments conducted to estimate the quantum efficiency of hydroxyl radical formation (HO•), via photocatalytic oxidation of methanol.

**B. S. Kademani et al (2013)** This study attempts to highlight quantitatively and qualitatively the growth and development of world literature on materials science in terms of publication output and citations as per Web of Science (2006–2010). The objective of the study was to perform a scientometric analysis of all materials science research publications in the world. The parameters studied include growth of publications and citations, continent-wise distribution of publications and citations, country-wise distribution of publications, domain-wise distribution of publications and citations, publication efficiency index, distribution of publications and citations according to number of collaborating countries, variation of mean impact factor in materials science domains, identification of highly cited publications and highly preferred journals, quality of research output and application of Bradford's law.

### Materials Science and Engineering

Sometimes the discipline of Materials Science and Engineering can be sub-divided into materials science and materials engineering sub disciplines. Strictly speaking, materials science involves investigating the relationships that exist between the structures and properties of materials. Conversely, materials engineering is based on the application of this structure-property correlations, in designing or engineering the structure of a material to produce a pre-determined set of properties. From a functional perspective, the role of a materials scientist is to develop or synthesise new materials, whereas a materials engineer is called upon to create new products or systems using existing materials and/or to develop techniques for processing materials. Most graduates in materials programmes are trained to be both materials scientists and materials engineers.

### Materials science and engineering and their historical evolution

The aim of materials science is to investigate the effect of the structure in various scales on materials properties. The numerous grades of the actually available materials yield new innovative potential in implementation of products. Determining the relationships among structure, technological process, and functional properties, and also the selection of materials and technological processes forming their structure and properties for a use in complex manufacturing systems, feature the main focus of materials engineering. Therefore, the development of materials engineering features an important determinant of the quality of life of the contemporary societies. Materials science appeared as an independent branch of science at the end of the 1950s, continuing mainly the physical metallurgy traditions, which was created at the beginning of industrial revolution, converted next smoothly to materials technology and in consequence to the materials science. Links were developed simultaneously between materials technology and materials engineering, and applied sciences.



### Modern Materials Needs And Challenges

In spite of the tremendous progress that has been made in the field of materials science within the past few years, there still remain technological challenges, including the development of more sophisticated and specialized materials, as well as the impact of materials production on environment. Nuclear (fission as well as fusion) energy holds some promise, but the solutions to the many key problems that remain will, necessarily, involve materials from fuels to containment structures to facilities for the disposal of radioactive waste. Fusion is the process that powers the sun and stars, has the potential to provide large-scale, safe energy production, without adding to the global warming and without the long term radioactive waste associated with conventional fission power stations. Progress in fusion research has been incredibly rapid in recent years. There has been major progress in fusion materials and technology, with prototypes of the key components of a fusion power plant built and successfully tested.

### Materials science and engineering and their historical evolution

The aim of materials science is to investigate the effect of the structure in various scales (electron, crystalline, micro, and macro) on materials properties. The numerous grades of the actually available materials yield new innovative potential in implementation of products. Determining the relationships among structure, technological process, and functional properties, and also the selection of materials and technological processes forming their structure and properties for a use in complex manufacturing systems, feature the main focus of materials engineering. Therefore, the development of materials engineering features an important determinant of the quality of life of the contemporary societies.

### Importance of Engineering Materials

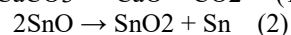
Development of new materials has followed a number of different pathways, depending on both the nature of the problem being pursued and the means of investigation. Breakthroughs in the discovery of new materials have ranged from pure serendipity, to trial-and-error approaches, to design by analogy to existing systems. These methodologies will remain important in the development of materials but as the challenges and requirements for new materials become more complex, the need to design and develop new materials from the molecular scale through the macroscopic final product will become increasingly important. The use of molecular modeling and the engineering of new materials into useable forms or devices are of particular importance.

## III. METHODOLOGY

The population used in this research is working in a modern engineering organization a total of companies and engineers who as registered license, using the population database from the Council of Engineers. The sample group used in this research is those working in the engineering organization that are modern engineers and non-engineers by calculating the sample size according to the formula of Taro Yamane, the sample size choose to collect 400 people to refer all employees, that is suitable and namely the distribution. This is a one-sample t-test that matches the single population of the research.

## IV. RESULTS

XRD studies of the phase composition showed that, in the material of pure CaZrO<sub>3</sub> after firing at 1200°C, there are present three phases: orthorhombic calcium zirconate, ZrO<sub>2</sub> stabilized with calcium oxide Ca<sub>0.15</sub>Zr<sub>0.85</sub>O<sub>1.85</sub> and free calcium oxide CaO, which originates from the thermal decomposition of CaCO<sub>3</sub> according to equation 1. In a mixture of SnO and CaZrO<sub>3</sub> after the first stage of heat treatment existence of several phases: orthorhombic CaZrO<sub>3</sub>, regular and monoclinic ZrO<sub>2</sub>, SnO<sub>2</sub>, Ca<sub>2</sub>SnO<sub>4</sub> and CaSnO<sub>3</sub>. At temperatures over 270°C, SnO is unstable and undergoes decompose for SnO<sub>2</sub> and metallic tin according to equation 2.



The measured diffraction patterns of fired samples at 1700°C are presented in Figures 1 and 2. It is clear from XRD patterns that single phase CaZrO<sub>3</sub> is obtained after annealing at a temperature of 1700°C for 10 hours. As shown in Figure 4 only the single phase orthorhombic CaZrO<sub>3</sub> peaks were obtained. No second-phase zirconia was observed. The phase composition revealed that the synthesis of calcium zirconate at a temperature of 1700°C has already begun. These results are cited in the review of literary data on the synthesis of calcium zirconate in the sintering process. XRD analysis (Fig. 1) Indicated that the compound obtained after annealing the second mixture at 1700°C for 10 hours is a mixture of two crystalline phases: orthorhombic CaZrO<sub>3</sub> and regular ZrO<sub>2</sub>.

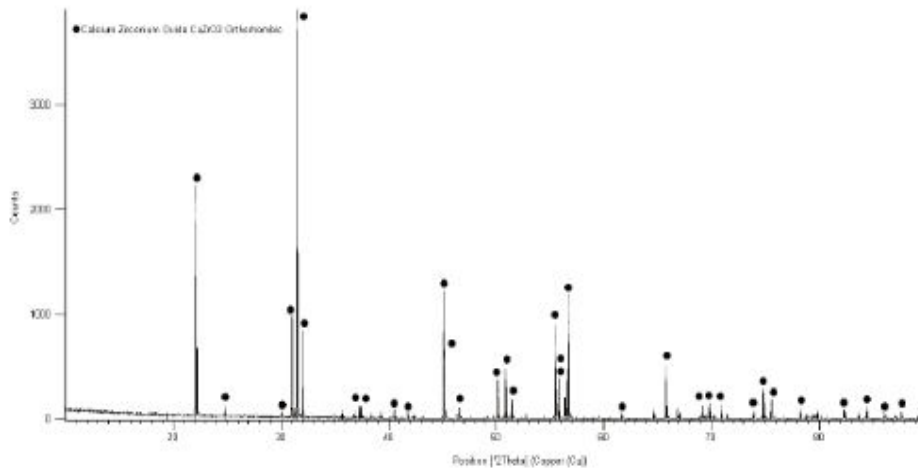


figure :1 XRD patterns of the CaZrO3 materials after firing at 1700°C.

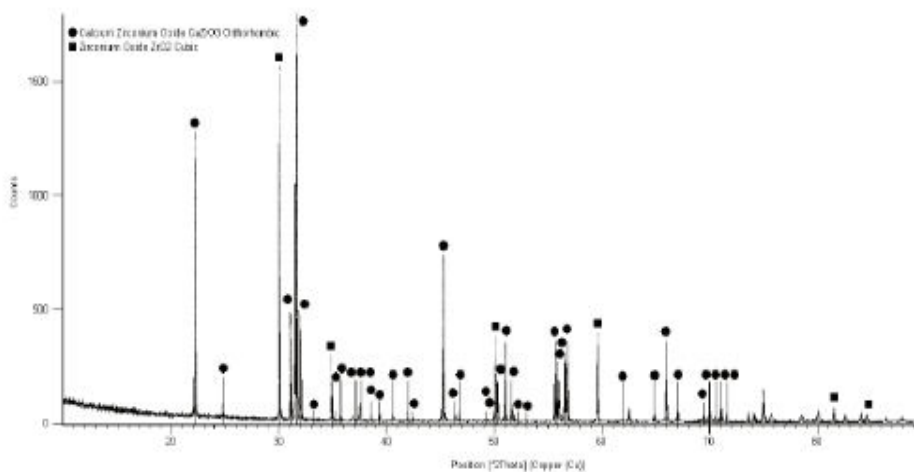


Figure 2: XRD patterns of the CaZrO3 modified SnO material after firing at 1700°C

The scanning electron microscopy (SEM) micrographs of the samples after firing at 1700°C are presented in Figures 3 and 4. Chemical compositions of the samples were confirmed by the EDS measurements (Tables 1 and 2). In both figure the materials showed high porosity which is in good agreement with the mercury porosimetry research. The grains are irregular in shape and size, and individual grains contact with different numbers of neighbors. Figure 2 presents the scanning electron microscopy micrograph of CaZrO3 material. Besides CaZrO3 grains, there is also present a small amount of calcium oxide stabilized ZrO2 (Point 1). By analyzing the microstructure in the SEM image, and EDS study of the CaZrO3 modified SnO, it outcomes that Sn ions (both Sn<sup>2+</sup> and Sn<sup>4+</sup>) incorporate in the calcium zirconate structure replacing Zr in different amounts.

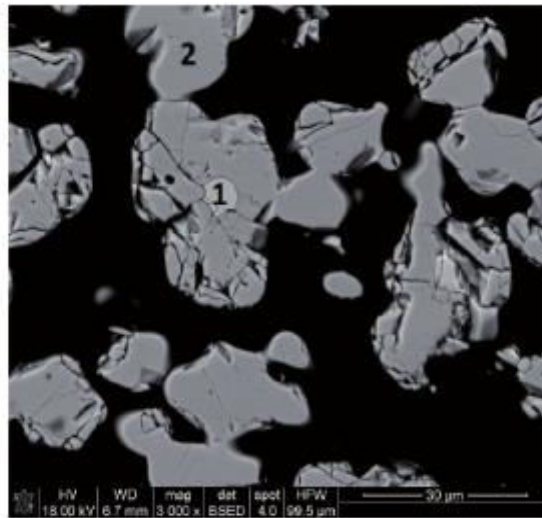


Figure 3 : SEM image of the CaZrO<sub>3</sub> material microstructure after firing at 1700°C; dark gray grains – calcium zirconate, light gray grains – ZrO<sub>2</sub> stabilized with calcium oxide

Table 2 The results of EDS analysis of the CaZrO<sub>3</sub> material in the point 1 and 2

Element	Point 1 [wt. %]	Point 2 [wt. %]	Theoretical stab. ZrO <sub>2</sub> [wt. %]	Theoretical ZrO <sub>2</sub> [wt. %]	Theoretical CaZrO <sub>3</sub> [wt. %]
O	27.9	27.5	26.2	26.0	26.8
Zr	64.9	50.9	68.5	74.0	50.9
Ca	7.22	21.6	5.31	–	22.3

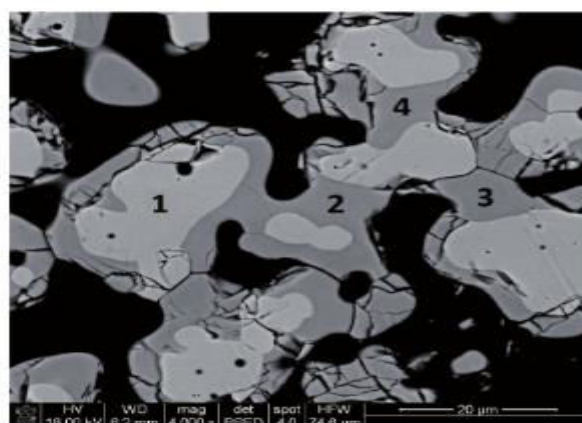


figure 4 SEM image of the CaZrO<sub>3</sub> modified SnO material microstructure after firing at 1700°C; dark gray grains – calcium zirconate doped with different amount SnO, light gray grains – ZrO<sub>2</sub> stabilized with calcium and tin oxide

Table 4 The results of EDS analysis of the CaZrO<sub>3</sub> modified SnO material in the point 1, 2, 3 and 4

Element	Point 1 [wt. %]	Point 2 [wt. %]	Point 3 [wt. %]	Point 4 [wt. %]	Theoretical CaZrO <sub>3</sub> [wt. %]	Theoretical CaZrO <sub>3</sub> modified SnO [wt. %]
O	27.9	26.5	28.0	27.8	26.8	24.6
Zr	62.2	40.2	42.1	39.7	50.9	46.8
Sn	2.7	11.5	8.3	11.2	–	12.7
Ca	7.2	21.8	21.6	21.3	22.3	16.4

## V. CONCLUSION

Man has used different kinds of Materials for his existence on earth from the beginning. The importance of materials, and the need for efficient methods of harnessing benefits from the ecosystem has prompted man to composite materials. As the world is ushering into a future of Smart Cities, Renewable energy production, and Environmental sustainability, Materials sciences researches are still needed to help increase the efficiency of today's materials and to invent new materials that allow for higher efficiency during product use. Because the problem of Environmental Pollution affects everyone on Earth, there is the need for every country to take materials science research seriously, as it is a saviour to our problems. All countries must come together to support materials science research.

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