Applications of Materials Science and Engineering in the Pharmaceutical Industry: A Short Review and the Current State in Nigeria

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Abstract: This paper briefly reviews the applications of materials science and engineering in the pharmaceutical industry. The materials characterization techniques highlighted in the paper as being utilized in the pharmaceutical industry are dynamic light scattering and photon correlation spectroscopy, mercury intrusion, gas density pycnometry and energy density analysis, thermogravimetric analysis and differential scanning calorimetry, x-ray diffraction, nuclear magnetic resonance and Raman microscopy. The other areas of applications of materials science and engineering in the pharmaceutical industry briefly discussed are materials processing, materials research and development, and materials selection. This paper further highlighted that the program as it is currently offered by various institutions in Nigeria is yet to incorporate the courses in pharmaceutical materials. It concluded by pointing out that some institutions outside Nigeria have incorporated pharmaceutical materials in the programs of materials science and engineering. Suggestions were made for the materials science and engineering programs in Nigeria to build further capacity for effective applications in the pharmaceutical industry.

Keywords: Applications, materials engineering, pharmaceutical industry

1 INTRODUCTION

Materials science and engineering is an interesting and multi-disciplinary area of study. It entails the study of properties, structures, processes, applications and performance of materials for diverse industrial applications. Materials engineers are equipped to create new materials and also develop existing materials for numerous applications. Materials engineers study the materials we see everyday such as metals, ceramics and glass, polymers, as well as other advanced materials used in the aerospace, medicine, communication and information technology, transportation, sports, renewable energy and a host of other industries. The pharmaceutical industry is simply one of the industries where materials engineers make contributions. In the pharmaceutical industry, discovery, development, manufacture and marketing of medicines for human and animal health are the major activities (Tait, 1998). This paper briefly reviews the applications of materials science and engineering in the pharmaceutical industry and highlighted the current state in Nigeria.

2 PHARMACEUTICAL APPLICATIONS OF MATERIALS SCIENCE AND ENGINEERING

Materials engineers play vital roles in the production, selection and characterizations of metals, glass, plastics, rubbers, films, foils, laminates, papers, boards, adhesives and inks used in drugs packaging (Sabah et al., 2014; Bairagi et al., 2018). Skills, knowledge and novel research in that area are major contributions of materials science and engineering in the pharmaceutical industry. Some of the major applications of materials science and engineering in the pharmaceutical industry are discussed in subsequent subsections.

2.1 MATERIALS CHARACTERIZATIONS

Materials characterization techniques are used as tools in the pharmaceutical industry to develop critical quality attributes for drugs (Micromeritics Instrument Corporation, 2017). Data from materials such as powder and liquid characterizations are very essential for processing and performance of products in the pharmaceutical industry. Materials science and engineering is also applied in the development of novel characterization techniques for nano and micro sized particles (Elliott and Hancock, 2006).

Some of the materials characterization techniques employed in the pharmaceutical industry are:

Dynamic light scattering and photon correlation spectroscopy: These are used to analyse particle sizes (nm and pm) of materials used in the pharmaceutical industry. The dissolution rate, stability and performance of drugs are affected by particle sizes. Manipulation of particles properties is also very essential to optimize reactions between materials and catalysts during production. Mercury intrusion: This is used to measure porosity of tablets. The porosity of tablets determines their friability (tendency to break part), solidity and dissolution behaviour.

Gas density pycnometry and energy density analysers: These are used to determine the density of tablets to meet the critical quality attribute.

Thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC): TGA and DSC are established techniques used for thermal characterizations of materials for diverse applications. These techniques are also utilized in the pharmaceutical industry.

X-ray diffraction (XRD), nuclear magnetic resonance (NMR) and Raman microscopy are some of the techniques that are familiar to materials engineers. They are extensively used to study imperfections, surface homogeneity, percentage crystallinity and amorphous content in powders used in the pharmaceutical industry (Chow et al., 2008).
2.2 MATERIALS PROCESSING
Materials processing techniques such as compaction and milling are employed in drugs production. Some knowledge of materials science and engineering are employed in the process control, optimization, design, installation, fabrication and management of such mechanized processes. Understanding and controlling the stress-strain conditions in the processing equipment for tablets production are typical areas where materials engineers function effectively in tablets production. Hot melt extrusion is widely used in the plastics industry for plastics processing. It has been reported that pharmaceutical extruders have been developed and hot melt extrusion is extensively used in the pharmaceutical industry for the production of tablets, pellets and granules (Crowley et al., 2007).

2.3 MATERIALS RESEARCH AND NEW MATERIALS DEVELOPMENT
The challenge of the development of new materials such as catalytic materials to improve the efficiency and sustainability of the basic processes in the pharmaceutical industry are enormous. The knowledge of mass transfer taught in materials engineering classes could be channelled in this area after careful evaluation of the processes. In the pharmaceutical industry, the knowledge from materials science and engineering are also applied in the design of materials with specific properties, the use of theoretical models to ascertain the performance of materials in biological environments and the evaluation of pharmaceutical applications of various materials (Elliott and Hancock, 2006). Materials characterization techniques such as scanning electron microscopy, x-ray diffraction, infrared spectroscopy and UV spectroscopy are part of the analytical techniques extensively employed to study synthesized new materials for pharmaceutical applications and their biocompatibility for efficient drug delivery (Balaure et al., 2016; Grumezescu et al., 2013).

2.4 MATERIALS SELECTION
Materials are selected carefully for the construction and improvement of pharmaceutical plants and processing equipment. Also, the selection of pharmaceutical packaging materials is an area where materials engineers function effectively. Materials are not selected arbitrarily for projects. Factors such as functional requirements, cost, processing requirements, reliability, environment, safety, corrosion, availability, disposability, recyclability, properties of materials and maintenance requirements are meticulously evaluated before plants and processing equipment are either constructed or improved. Materials engineers apply their knowledge and skills in that area for the pharmaceutical industry. The stability of pharmaceutical products in packaging materials such as glass, aluminium foil, plastics, paper and other materials used for primary and secondary pharmaceutical packaging are ascertained through the contributions of materials science and engineering (Sabah et al., 2014).

3 CONTRIBUTIONS OF THE NIGERIAN MATERIALS SCIENCE AND ENGINEERING FACULTIES TO THE PHARMACEUTICAL INDUSTRY
Nigeria currently has over ten universities offering courses in materials science and engineering with established academies. A quick review of curricula of these departments reveals that the courses in pharmaceutical materials have not been incorporated at both the undergraduate and post-graduate levels. Some of the faculty members and erudite professors in these departments have done excellently well in terms of teaching, research and community service. However, it is very rare to see a Nigerian materials science and engineering faculty member working in Nigeria whose research is tailored to pharmaceutical materials. We are yet to build capacity in this area. Materials science and engineering is highly multifaceted with diverse industrial applications. Opportunities abound for graduates in this field both in Nigeria and abroad. While our institutions are yet to delve into the field of pharmaceutical materials, institutions such as Technion-Israel Institute of Technology, Cambridge University, Massachusetts Institute of Technology, Rutgers University and Nanyang Technology University amongst others have incorporated courses in bioengineering, biomaterials, tissue engineering, drug delivery, pharmaceutical materials and other related courses in the curricula of materials science and engineering at both the undergraduate and postgraduate levels.

4 CONCLUSION
This short review has highlighted the techniques, processes and tools utilized by materials engineers that are also extensively utilized in the pharmaceutical industry. It is imperative for the graduates from our institutions and faculty members to get trained in these areas so as explore the opportunities for effective contributions of materials engineers in the pharmaceutical industry. Faculty members can also undergo their postgraduate studies and post-doctoral fellowships in pharmaceutical materials so as to enable us to build capacity. Courses in pharmaceutical materials science and engineering can be introduced in the academic curricula of materials science and engineering especially at the postgraduate levels; and collaboration could be established with other faculties and institutions for effective teaching and research. The facilities for research in this area and other areas should be made available at the Department of Materials and Metallurgical Engineering.

REFERENCES


