

# Preface

The introduction of functionally graded composite materials was as a result of the failure of the traditional composite materials when used in harsh working environments. The failure of the traditional composite materials occurred along the distinct well-defined interface that exists between the laminate composite materials. The interface causes a high stress concentration at this site, and it promotes crack initiation and eventual crack propagation that result in the ultimate failure of the composite. This process is referred to as ‘delamination’. The problem faced with the researchers in Japan during a space plane project (when the functionally graded material was developed) was how this interface can be removed—so that the composite can survive the intended thermal barrier application. The researchers were able to eliminate systematically the sharp interface in the traditional composite material by a gradually changing interface, thereby reducing the stress concentration at this interface, and the functionally graded material developed was able to withstand the extreme working conditions without failing. Subsequently, functionally graded materials have been applied for various engineering applications—apart from the thermal barrier, for which the material was originally developed. Functionally graded materials are advanced composite materials with varying composition, together with the varying properties across the volume of the bulk material.

This book provides the state-of-the art in this advanced composite material. The book was introduced in Chap. 1 by giving a brief historical background of this material. Functionally graded materials occur naturally in nature, as found in human teeth for example, and this was emulated in science, in order to solve engineering problems. Some of these naturally occurring functionally graded materials were also reviewed in Chap. 1. The different types of functionally graded materials that are now produced, together with their areas of application, are reviewed in Chap. 2.

The various conventional manufacturing methods of functionally graded materials for both thin coating and bulk functionally graded materials are analysed, and presented, in Chap. 3. The limitations and many problems that are encountered in the conventional manufacturing process could be overcome by producing functionally graded composite materials—using the additive manufacturing

technologies. Additive manufacturing technology is capable of producing three-dimensional components by simply adding materials, layer after layer, as dictated by the computer-aided design model of the part. This process is explored and presented in Chap. 4. Some of the research works in this field are also presented. An experimental analysis of the laser metal deposition process, an additive manufacturing technology, is presented as a case study in Chap. 5 of this book. The summary of the book and the future research direction is presented in Chap. 6.

The organization of the book is as follows:

Chapter 1—An introduction of functionally graded material is presented, together with a brief historical background of functionally graded materials. The presence of functionally graded material in nature is also presented and extensively discussed in this chapter.

Chapter 2—Functionally graded materials are used to solve a number of engineering problems, and it is also used as biomedical implants for the replacement of human tissues. These materials are used to eliminate the stress singularities that occur from the property mismatch between human organs and the implant used to replace them. The different types of functionally graded materials depend on the type of application. The different types of functionally graded materials and their areas of application are presented in this chapter.

Chapter 3—There are different kinds of manufacturing methods for producing functionally graded material (FGM), depending on whether it is functionally graded material thin coating or bulk functionally graded material. The various processing techniques of functionally graded materials, such as physical-vapour deposition, chemical vapour deposition for thin film functionally graded material coatings, and processes, such as the powder metallurgy technique and the centrifugal casting method for bulk functionally graded materials, are analysed in this chapter.

Chapter 4—Additive manufacturing (AM) technology offers many advantages and possibilities for the fabrication of complex three-dimensional products through material addition, rather than the material removal in the conventional machining process. Some of the AM technologies have also been used for the fabrication of complex parts made with functionally graded materials in a single manufacturing run. Some of the AM technologies that are used to produce FGM are the selective laser sintering; the selective laser melting; the laser metal deposition process; and fused deposition modelling. These AM technologies are presented in this chapter, and some of the research work with these technologies for the fabrication of functionally graded materials are also reviewed.

Chapter 5—A case study on the laser metal deposition of functionally graded material (FGM) of titanium alloy composite is presented in this chapter. A functionally graded composite material of an important titanium alloy—Ti64/TiC was fabricated by the Laser Metal Deposition (LMD) process with different TiC percentages of up to 50% on a Ti64 substrate. The microstructures, mechanical and tribological properties of the produced FGM were studied; and the results were compared with the substrate material, as well as with a plain composited material. The microstructure of the fabricated FGM showed a continuous microstructure,

without any sharp interface between the substrate and the deposited layers. The results are presented and discussed in detail in this chapter.

Chapter 6—The future research need in functionally graded materials—from the manufacturing process to the material characterization are presented in this chapter, together with an extensive summary of this book.

Johannesburg, South Africa

Rasheedat Modupe Mahamood  
Esther Titilayo Akinlabi

Functionally Graded Materials

Mahamood, R.M.; Akinlabi, E.T.

2017, XXI, 103 p. 50 illus., 17 illus. in color., Hardcover

ISBN: 978-3-319-53755-9