Preface

Advanced manufacturing process using laser material processing has helped to solve a number manufacturing problems that are faced with the traditional manufacturing processes. This book presents different laser material processing technologies that have helped to provide solution to lots of challenges in the manufacturing industries. The help of laser additive manufacturing technology has been sought in many industries including medicine to produce customized implant which are patient specific in nature at a more cost effective manner. Laser additive manufacturing is the subject of the first chapter. The authors in the Chapter 1 present various laser additive manufacturing processes with their advantages and disadvantages as well as their areas of applications. The laser manufacturing processes for the aerospace parts is presented in the second chapter. The third chapter described a specific laser additive manufacturing technology, the laser metal deposition process. The fourth chapter is focused on the Enhancement of surface properties of titanium alloy with copper using the laser metal deposition process. An overview of the developmental trend in the use of laser for surface modification is presented in Chapter 5. The authors of the sixth chapter present the tailoring of material properties through Microstructural Optimization using laser. The process of reducing the Wear Damage through Laser Surface Alloying Technique is the subject discussed in the seventh chapter. The authors of the eighth chapter present the computational dynamics of anti-corrosion property of metallic materials that are laser alloyed. The book concludes with a review of titanium based implants using the Laser additive manufacturing technology.

ORGANIZATION OF THE BOOK

The book is organized into nine (9) chapters. A brief description of each of the chapters is as follows:

Chapter 1: Laser additive manufacturing is an advanced manufacturing process that can be used for making prototypes and functional parts directly from the three
dimensional (3D) Computer-Aided Design (CAD) model of the part. The fabrication is achieved by adding materials layer after layer to build up the required part following the path dictated by the 3D CAD model, until the part is competed. Laser additive manufacturing technology is more favoured in the manufacturing industry because of the advantages offer by the energy source used, laser. Laser is characterized by collimated linear beam that can be accurately controlled. This chapter explains the various laser additive manufacturing technologies including the selective laser sintering and melting, the stereolithography and the laser metal deposition process. Each of these laser additive manufacturing technologies are described with their merits and demerits as well as their areas of applications.

Chapter 2: The authors described the laser manufacturing processes for aerospace applications. The latest developments in Laser manufacturing technologies and processes that are used in the aerospace industry are discussed in this chapter. The current developments in the aerospace industry was found require a reduction in the manufacturing that has necessitated the need for advanced manufacturing technologies and processes in the industry that will offer cost effective products with improved life cycle. Lasers can be used in many industrial machining processes for a variety of materials including metals, ceramics, glass, plastics, and composites. Laser beams, used as machining tools, are not accompanied by problems such as tool wear, tool breakage, chatter, machine deflection and mechanically induced material damage, phenomena which are usually associated with the traditional machining processes. The effectiveness of Lasers depends on the thermal nature of the machining process. However, difficulties also arise in these processes as a result of the differences in the thermal properties of the various components.

Chapter 3: Laser metal deposition process is an advanced manufacturing process that belongs to the directed energy deposition class of additive manufacturing process which is capable of producing highly complex part directly from the 3D CAD model of the component by adding materials layer after layers. Laser metal deposition process is a very important additive manufacturing process and it is the only class of additive manufacturing process that can be used to repair high valued component parts which were prohibitive to repair not repairable in the past. Laser metal deposition process can handle multiple materials simultaneously and it is used to produce part with functionally graded material. Some of the features of the laser metal deposition process are described in this chapter. Some research studies on the laser metal deposition of Titanium alloy- composite are also presented.

Chapter 4: Enhancement of the surface integrity of titanium alloy with copper by means of laser metal deposition process is the focus of this chapter. The laser metal deposition process uses a combination of metallic powder and laser beam respectively to form part. However, these combinations create an adhesive bonding that permanently solidifies the laser deposited powders. Titanium alloys (Ti6Al4V)
have been regarded as the most used alloys for the aerospace applications, due to
their light weight properties and in marine application due to their excellent corro-
sion resistance. The improvements in the surface integrity of this alloy have been
achieved successively with the addition of Cu through the use of Ytterbium laser
system. The motivation in this research work can be attributed to the dilapidation
of the surface of titanium alloy, when exposed to the sea water for a long period of
time. This chapter describes how the surface modification of titanium alloy with the
addition of Cu within its lattices is produced. The results obtained from this study
showed improved surface properties.

Chapter 5: Trend and development in laser surface modification for enhanced
materials properties has been presented in this chapter. The chapter presents a
process review of some commonly available laser surface modification techniques
for surface property enhancement. The progression from simple surface modifica-
tion to the production of components with multifunctional characteristics known
as functionally graded material is also discussed in combination with emerging
research focus on the computational simulation of laser surface modification for
the optimization of process dynamics.

Chapter 6: The laser surface processing for tailoring the properties by microstruc-
tural optimization was discussed in this chapter. The laser surface processing involves
the heating and melting which assisted in the modification of surface microstructure
and/or composition of the near surface region of a component using a high power
laser beam for improving the surface properties. The advantages of laser surface
processing over the conventional equilibrium surface processing includes rapid
processing rate, retention of non-equilibrium microstructure, alloying in liquid state
and development of processed zone with superior properties when compared to the
ones developed by equilibrium processing route are presented. The microstructure
plays an important role in controlling the final properties of the tailored component
and hence, it is important to optimize the process parameters to attain the desired
microstructure after the processing. The microstructures developed under optimum
conditions by different laser surface processing are discussed with the corresponding
improvement in properties achieved.

Chapter 7: The mitigation of wear damage by laser surface alloying technique
is the focus of this chapter. Today’s increasingly extreme and aggressive industrial
production environments require that machine components be made with materi-
als having specific surface properties such as high wear resistance. Unfortunately,
nature does not provide such materials, and alloys having these specific properties
are usually very expensive and their utilization drastically increases the components
and the production costs. The economic implications of wear, is loss of material
and revenue which are very severe. These include the replacement costs, and all
downtime costs related to such replacement. Companies are increasingly interested
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in wear reduction as a direct and an immediate avenue for maintaining output quotas and for cutting production costs. By enhancing the wear resistance of alloys by using laser to coat their surfaces with wear resistance materials is one efficient and economical means of achieving this objective. This chapter discusses the application of laser coatings for wear prevention. The types of coatings for different materials within specific environment are also discussed.

Chapter 8: The computational dynamics of laser alloyed anti-corrosion properties of metallic materials is the subject of this chapter. Laser alloying is a material processing method that utilizes the high power density available from defocused laser beam to melt both metal coatings and a part of the underlying substrate. Since melting occur solitary at the surface, large temperature gradients exist across the boundary between the melted surface region and underlying solid substrate, that results in rapid self-quenching and re-solidifications process. How alloyed powders are deposited in a molten pool of the substrate material to improve the corrosion resistance of the substrate by producing corrosion resistant coatings are discussed in this chapter. A 3D mathematical model is developed to obtain insights on the behaviour of the laser melted pools subjected to various processing parameters. Simulation using 3D model of how different values of various processing parameters such as laser power, scanning speed and powder feed rate influence the geometry and dynamics of the melt pool and the cooling rates is presented. The melt pool flow, thermal and solidification characteristics were found to have a significant influence on the microstructure of the solidified regions.

Chapter 9: The laser additive manufacturing of titanium based implants was reviewed in this chapter. Titanium and its alloys exhibit a unique combination of mechanical, physical properties and corrosion resistance behaviour which makes them desirable in the aerospace, industrial, chemical, medical and energy industries. The selective addition of alloying elements to titanium enables a wide range of physical and mechanical properties to be obtained. Ti-based alloys are finding ever-increasing applications as biomaterials due to their excellent mechanical, physical and biological performance. Intense researches are being pursued in the development of new Ti-based alloys with bio-functionalization closer to human bone because of their excellent mechanical strength and resilience when compared to alternative biomaterials, such as polymers and ceramics. Several manufacturing techniques are capable of producing porous materials. There is a need to control pore size, shape, orientation and distribution. This chapter reviews the application of Ti-based alloys in the biomedical industry and also proposes laser additive manufacture process for the manufacture of medical implants.