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Review

Material issues in additive manufacturing: A review

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ABSTRACT

Today, *Additive manufacturing* (AM) is a well known technology for making real three dimensional object, with metal or ceramic or plastic or thereby combination, which may be subjected to various applications. *Additive bio-manufacturing* (ABM) techniques are highly in demand and researches have been going on for making these safer and more versatile. For more utilization and versatility, special attention is required to develop new materials which can help in increasing the service life, bioactivity, cell growth along with the desired mechanical properties. The present paper aims to review some of the most widely used AM techniques for biomedical applications. Special attention has been paid on *Fused deposition modeling* (FDM) based AM technique as it is economical, environmentally friendly and adaptable to flexible filament material. This review paper will be helpful to the researchers, scientists, manufacturers, etc., working in the field of ABM.

Contents

1. Introduction

AM is one of the most widely used technique for constructing prototypes with higher dimensional accuracy and much less time. In today's scenario, modern industries are liable to implementing several AM techniques such as: *Stereo-lithography* (SLA), *Selective laser sintering* (SLS), *Laminated object manufacturing* (LOM), *Fused deposition modeling* (FDM), *Direct metal laser sintering* (DMLS), *3D printing* (3DP), etc. Basically, all these AM techniques employ the same basic principle wherein the final component is fabricated with layer by layer addition of the material. A brief schematic for fabricating implant in medicine is shown in Fig. 1, while Fig. 2 describes a detailed classification of various types of ABM techniques.

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Table 1
Commercial AM techniques, their manufacturer(s) and material provider(s).

Name	Manufacturer(s)	Material provider(s)
SLS, selective heat sintering	3DSYSTEMS, Farsoon Technologies, Blueprinter (Denmark), eos, MC Machinary Systems, Wuhan Binhu Mechanical & Electrical Co., Ltd.	3DSYSTEMS, Paramount Product Development Specialists, Farsoon Technologies, Concept Laser, eos, LuxExcel, Wuhan Binhu Mechanical & Electrical Co., Ltd.
Selective laser melting	MICROFABRICA, REALIZER, SLM Solutions, Wuhan Binhu Mechanical & Electrical Co., Ltd.	MICROFABRICA, REALIZER, SLM Solutions, Wuhan Binhu Mechanical & Electrical Co., Ltd.
Metal laser melting	Concept Laser	Concept Laser
EBM	Arcam (Sweedon), Sciaky	Arcam (Sweedon), Sciaky
Laser metal deposition	BEAM (France)	BEAM (France)
Inkjet, poly jet, binder jet	Envisiontec, ExOne, MicroFab, Stratasys, Solidscape	Envisiontec, ExOne, MicroFab, Prodways, Stratasys, Solidscape
SLA, lithography-based ceramic manufacturing	3DSYSTEMS, CMET Inc., Somos, Lithoz, Prodways, Wuhan Binhu Mechanical & Electrical Co., Ltd.	3DSYSTEMS, CMET Inc., Somos, Lithoz, Prodways, Wuhan Binhu Mechanical & Electrical Co., Ltd.
Digital wax machine	DWS	DWS
FDM	UP-3D, Stratasys, CandyFab, Fab@Home, MAKERBOT, Solidscape, Polyflex	UP-3D, Stratasys, CandyFab, Fab@Home, MAKERBOT, LuxExcel, RepRap, Solidscape, Argyle Materials Inc., Polymakers®
DMLS	Insstek	Concept Laser, Insstek
Metal powder bed fusion	Renishaw	Renishaw
Ultrasonic additive manufacturing	Fabrisonic	Fabrisonic
LENS	Optomec	Optomec, Concept Laser
LOM	Cubic Technologies	Cubic Technologies
3DP	Asiga, Keyence Corporation	Asiga, Keyence Corporation
ZCast	ZCast	ZCast

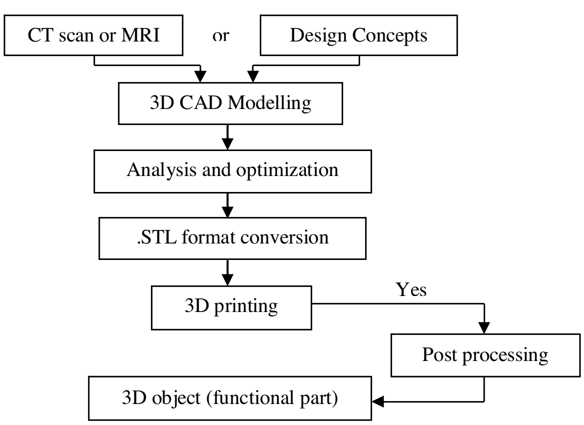

Fig. 1. Schematic of implant fabrication, [142].

AM has a strong share market in medical and dental industry and it is the 3rd largest sector [1]. The new era of AM enables the designer to simulate the implant design prior to their manufacturing. AM techniques cut the cost and time of implant manufacturing. The ability of AM technology to produce actual functioning parts is also a contributing factor to its newly acquired popularity [2]. Generally in medicine, AM usually work integrated with digital imaging techniques such as computed tomography (CT) and magnetic resonance imaging (MRI). The data collected from CT or MRI scans (in Ducom format) is converted into a 3D bio-model with the help of Mimics or 3D-doctor like computer software. Further, the 3D bio-model is converted to *Standard Triangulation Language* (.STL) file format and imported into an AM setup, [147]. Till date, numerous medical applications have been fabricated with available AM which includes: soft scaffold, human osteosarcoma, blood vessels, cartilage, hip joint, knee joint, bone, soft tissues, etc. [3,4,5]. Currently, a number of vendors are available for a single AM technique and for their materials too. Table 1 shows the manufacturer(s) of various types of AM techniques and their recognized materials provider(s).

2. Materials for AM

A variety of materials are used for AM applications and the research for further development of new materials is in progress. Today, various categories of biomedical materials are available with us in-terms of metals, alloys, ceramics, bioactive glass, plastics

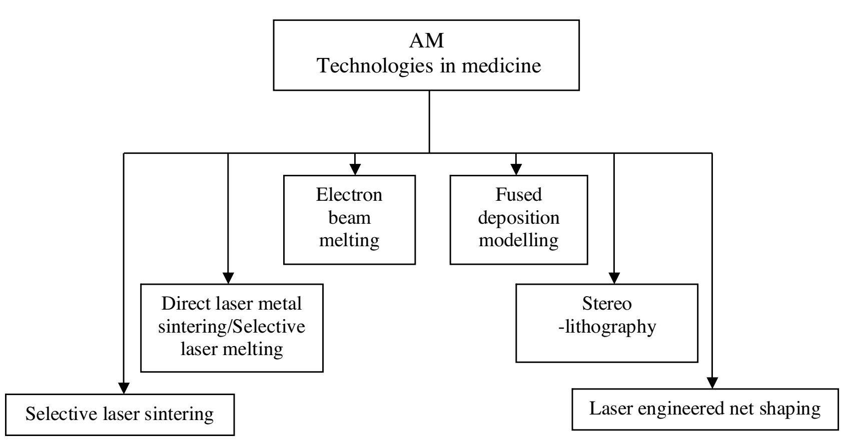

Fig. 2. Classification of various types of AM techniques in medicine.