Selective Laser Melting of Ti Orthopedic Implants

Dr. Chris Sutcliffe University of Liverpool
Director Fusion Implants
R+D Director Renishaw AMPD
Abstract

3D printing has captured the public’s attention. People making things at home...surely not...don’t we all just drink lattes whilst listening to mp3s on our Ipads contemplating the Ikea catalogue...and watching film on media streaming subscription services. Well you can connect them to your computer you know...really?...and make anything you want...its like a magic machine...print your dreams...

I have 50+ slides 20 minutes

Oh yes I forgot...you can print a bionic man...and perhaps make him work.
Introduction

- AM in the news
- Things am can do
- Hype
- AM in Medicine
- Laser melting
- History
- Orthopaedic implants by SLM
- Porous surfaces
- IP
- In vivo tests
- Patents
- Exploitation
- Opportunities
Picture of RM in the News
Equipment (AM)

Various
What can it do
Consumer Products

Materialise MGX Freedom of Creation and 3D systems
Consumer Products

Materialise MGX Freedom of Creation and 3D systems
Consumer Products

Materialise MGX Freedom of Creation and 3D systems
Large Structures
Jewellery

Manufactured by: CPM
Designed: Lionel Dean

Ecouterre.com, Realizer, Lionel Dean
Optimised Flow Paths
Weight Reduction
Customisation
Parts Consolidation

(A) Conventional Duct fabricated from VAC Formed plastic

Part Count = 16 (plus glue)

(B) Component modified and consolidated for fabrication via Additive Rapid Direct Manufacture

Part Count = 1
Geometry
Why now? Democratised 3D Printing

Mendel Max, PWDR, Rostock MAX, Formlabs
Thingiverse

Featured Things

Rubik's Companion Cube
Created by caries2

Introducing the Rubik's Companion Cube. More entertaining than a regular companion cube and less dangerous to have around than whistlet. In solving the cube it seems you too much you can easily undermine the interest by dropping it into a giant waterbottle.

This is just a print of Rom's companion cube and caries2's Rubik's cube. Thanks to both for your great designs.

More Featured Things
- cuddling Owls
  Created by mooses
- Fully Printable Microscope
  Created by knales
- SLIDE | Printable iPhone Slider
  Created by ibudmen

Featured Collections
- coolstrusion
  by Annel
- Architecture
  by melodieusb
- Flexible Inspiration
  by Pretty Small Things

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  by Winkenbark
- 3D Printed Wing
  by Humpalotus
- 10DC Case
  by Littermills
- Rose @r-Feet
  by plantmeade
So its just another manufacturing method…

Design freedom

No tools

You can build anything you can draw

You can make smart parts

You can make them at home

Let’s have a look what it can do now
Materialise, Startasys, BaroSense 3D Systems
Prosthetics and Orthotics

3D Systems, Popular Science, Fripp Design, Prof Kenny Dalgarno
Dentistry

Impressions are taken of your teeth by your doctor.

The impressions are used to make plaster models of your teeth.

Plaster models converted into 3D digital image.

A movie depicting the movement of your teeth from the beginning to the final position is created.

A customized set of aligners is made from these models.

SLA is used to build models that reflect each stage of your treatment plan.

Your dentist reviews the file and if necessary, makes adjustments.

All Pictures Courtesy of Invisalign
www.invisalign.com

HowardModels.com
Hearing Aids
Laser Melting
History Early Years SLM Development
Typical Aluminium Heat Sinks
Structured components and functional materials

- Lightweight parts
- Medical implants
- Thermal management parts
- Substitution of solid mass to boost production
- Engineered materials
- Actuation
Implantable devices from 2000

The model (reconstructed from machine input files) shows how a unit cell is constructed with each ball representing a lasered spot 6 of which form a strut and 8 struts form an octahedral shape contained in a unit cell. Many unit cells are joined together (tessellated) to form the final porous structure. There are 10’s of millions of these spots in each implant.

Standard CAD can not produce these structures. Our developed software techniques have or is currently being ported to commercial software.
Implantable devices

- Developed software at the university
- Developed hardware at the university and with partners
- Invented techniques and know-how
- Transferred technology via our PhD cohort
Implantable Devices

Unit cell 600 µm and Regular

Unit cell 600 µm and 20% Random

Unit cell 1000 µm and 30% Random
IP Portfolio

- Extensive patent portfolio of 7 families with 25 issued patents and 22 pending patents which include strategic continuations
Medical Parts
Machine Development
Implantation
Summary

• The implants are produced from CP Grade 1 Titanium
• Constructed as an integral build of solid and porous sections
• Can have co moulded bearing surfaces
• Optimising both strength and biological performance.
• The bone ingrowth region is optimised to 65 % fully interconnected porosity
• 100-600 μm pore size distribution.
• We have 3 software tools to allow us to manufacture the parts so we aren’t reliant on commercial software
• We have a developed set of expertise to allow us to manufacture these porous devices to high (FDA) standards
**In Vivo Studies**

![SLM implant (lhs) and Endopore (rhs)](image)

<table>
<thead>
<tr>
<th>Surface characteristics</th>
<th>SLM</th>
<th>Bone</th>
<th>Endopore</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interconnectivity</td>
<td>Fully</td>
<td>Fully</td>
<td>Partially</td>
</tr>
<tr>
<td>Porosity (%)</td>
<td>60</td>
<td>60-70</td>
<td>35</td>
</tr>
<tr>
<td>Average pore size (µm)</td>
<td>200</td>
<td>300</td>
<td>100</td>
</tr>
<tr>
<td>Pore size distribution (µm)</td>
<td>100-300</td>
<td>100-600</td>
<td>50-150</td>
</tr>
</tbody>
</table>
In Vivo Studies

Two time periods 4 and 8 weeks

Surgical procedure for implant placement

An incision was made to expose the tibia and lubricated drilling of the bone was carried out in accordance with the Endopore protocol, prior to implant placement.
**In Vivo Studies**

SLM (LHS) and Endopore (RHS) showing the position of the implants in the rabbit tibia.
In Vivo Studies

Cross sections of SLM and Endopore implants after 4 weeks at a magnification of 20 x

Stevenel’s blue (soft tissue) and Alizarin red S (bone) staining
In Vivo Studies

Longitudinal sections of SLM and Endopore implants after 4 weeks at magnification of 10 x
In Vivo Studies

Longitudinal sections of SLM and Endopore implants after 8 weeks at magnification of 5 x.
BS-SEM Bone Formation

4 week SLM (a) and Endopore (b) implants x 30, SLM (c) and Endopore (d) implants x 100.
BS-SEM Bone Formation

8 week SLM (a) and EP (b) implants x 30, SLM (c) and Endopore (d) implants x 100
Metrology and Process Control

• How do we improve part accuracy?
• Which measurement do we take and how do we feed the data back to the process?
• Can we use the data to inform
• Or can we use the data to control

Pore diameter > 100 µm
Volume percentage (>100 µm) = 90%

Prof Peter Lee, Prof Eric Jones and Dr Sheng Yue
Interrupted in situ compression test
Opportunities Exploited

Plant 5 Years ago
Opportunities Exploited

3-D Printed Implants Hit The Market, Pave The Way For More Personalized Devices

Health News Daily – 11/04/2013

Companies have recently started to launch implants constructed via 3-D printing to increase product customization and to save on costs. FDA says the additive manufacturing techniques are a promising form of personalized medicine. Multiple companies have recently used 3-D printing to make implantable devices that are customized to specific patients or to improve manufacturing precision and efficiency. is one large orthopedic firm that has recently starting using 3-D printing to manufacture its implants. It employed the technique for its Triathlon Tritanium Tibial Baseplate device, which was launched in June following 510(k) clearance. The baseplate is used with the company’s Triathlon Total Knee System for total knee arthroplasty. The device is made using laser rapid manufacturing. Stryker CEO Kevin Lobo specifically highlighted the product and the promise of 3-D printing, particularly as a cost-saving tool, during the firm’s 2013 analyst meeting on Sept. 5. 3-D printing has “really exciting potential for us,” Lobo said. “The potential for significant cost savings is real, but it’s an industry that’s kind of in its infancy. So it will take time to play out.” “3-D printing provides us with design and manufacturing flexibility, simplicity and the potential to reduce time to market” – Stryker’s Patrick Treacy.
Opportunities Exploited

• Fusion Implants Ltd formed in March 2013
• Company structure set up
• Design and manufacture of veterinary devices
• Sales will comprise instruments and implants
• Online web shop
• Clean, package and dispatch from Liverpool HQ
• Develop the UK market in Y1
• Establish distribution networks in EU and US in Y2
• Expand into EU and US in Y3
Opportunities Exploited

- Panel of 3 vets all highly qualified orthopaedic specialists
- Implant design development
- Process development
- “Sawbone” models
- 3 Cadaver trials
- Final design release
- Ethical approval
- Clinical evaluation
- Packaging sterilisation and delivery
Opportunities Exploited
Opportunities Available Dental Implants

- Exclusive license opportunity for a proprietary, patented method of producing **porous titanium** dental implants by Laser Rapid Manufacturing (**LRM**)—generically referred to as 3D printing or additive manufacturing) co-developed by the University of Liverpool and Stryker Corporation.
- Extensive patent portfolio of 7 families with 25 issued patents and 22 pending patents which include strategic continuations.
- Provides the clinical advantage of initial stability through its porous titanium structure in a solid one-piece implant (**not** a coating).
- Unique opportunity to gain access to an enabling technology in the dental implant market leveraging expert technical experience in additive manufacturing and orthopaedic clinical experience.
- Additive Manufacturing provides a capability for cost efficient future designs for implant manufacturing.
So why is that important Chris?
Further Comments

- Sometimes I’m a bit of a luddite.
- Next Industrial revolution…well it’s the slowest one so far
- In or near the patient…let’s regulate that
- Customised implants, that’s the easy part the FDA are quite concerned
- Now try and make money out of it