陶瓷，从未如此精细

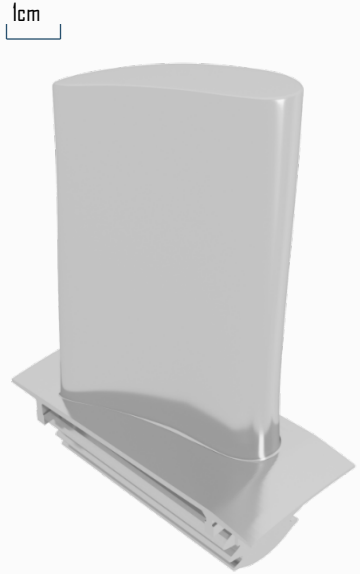
从叶片到人工骨的柔性制造

万力

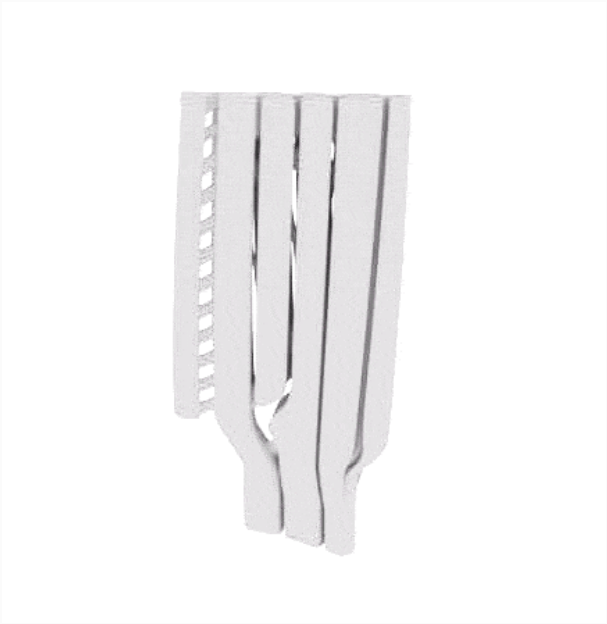
没有金刚钻，别揽瓷器活

3D打印擅长复杂镂空结构

航空发动机涡轮叶片陶瓷芯



涡轮叶片



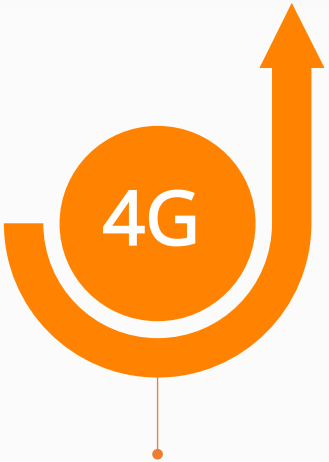
陶瓷芯（一次性模具）

研发周期2年

样件成本>100万

良品率<50%

替代性技术

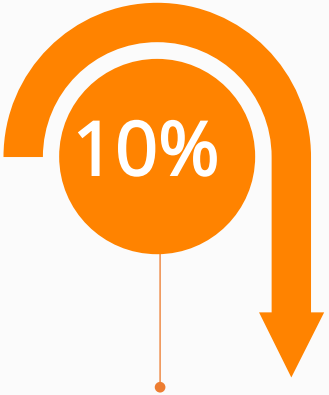


制造新一代叶片

国外领先，我们必须**追赶**和**超越**。

新产品周期**缩短**。迭代速度增加3倍以上。

大幅度**降低试错成本**。



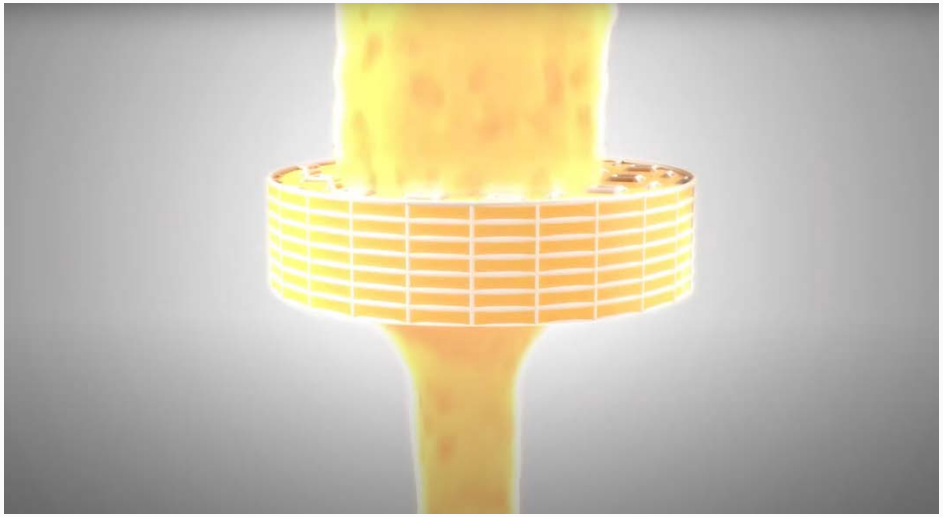
制造**周期缩短**

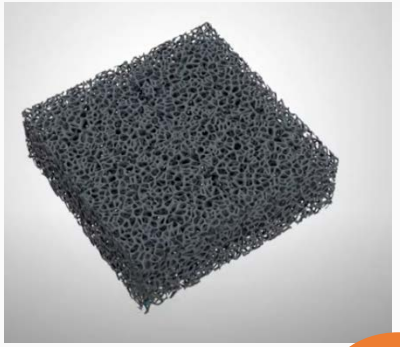
提高近一倍良率

金属液过滤器

提高材料性能，铸件不良率降低一半

铸造、冶金行业，过滤金属液中的杂质





- 泡沫塑料作模版
- 结构不可控
- 容易破损掉渣

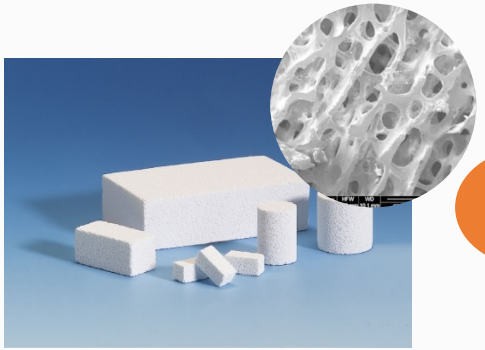
VS

- 3D打印结构优化
- 强度高、干扰小
- **铸件不良率降低一半**

个性化人工骨

改善骨骼再生效果

传统模版法或发泡法



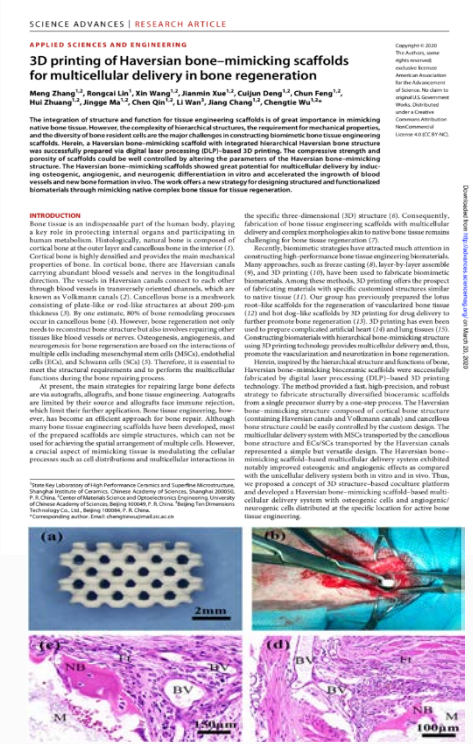
- 孔隙随机
- 再生效果不稳定

VS

3D打印

- 宏观外形和微观空隙精确定制
- 再生效果明显改善

动物和临床实验证明



SCIENCE ADVANCES | RESEARCH ARTICLE

APPLIED SCIENCES AND ENGINEERING

3D printing of Haversian bone–mimicking scaffolds for multicellular delivery in bone regeneration

Meng Zhang[1,2], Rongcai Lin[1], Xin Wang[1,2], Jianmin Xue[1,2], Cuijun Deng[1,2], Chun Feng[1,2], Hui Zhuang[1,2], Jingge Ma[1,2], Chen Qin[1,2], Li Wan[1], Jiang Chang[1,2], Chengtie Wu[1,2]*

The integration of structure and function for tissue engineering scaffolds is of great importance in mimicking native bone tissue. However, the complexity of hierarchical structures, the requirement for mechanical properties, and the diversity of bone resident cells are the major challenges in constructing biomimetic bone tissue engineering scaffolds. Herein, a Haversian bone–mimicking scaffold with integrated hierarchical Haversian bone structure was successfully prepared via digital laser processing (DLP)–based 3D printing. The compressive strength and porosity of scaffolds could be well controlled by altering the parameters of the Haversian bone–mimicking structure. The Haversian bone–mimicking scaffolds showed great potential for multicellular delivery by inducing osteogenic, angiogenic, and neurogenic differentiation in vitro and accelerated the ingrowth of blood vessels and new bone formation in vivo. The work offers a new strategy for designing structured and functionalized biomaterials through mimicking native complex bone tissue for tissue regeneration.

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INTRODUCTION

Bone tissue is an indispensable part of the human body, playing a key role in protecting internal organs and participating in human metabolism. Histologically, natural bone is composed of cortical bone at the outer layer and cancellous bone in the interior (1). Cortical bone is highly densified and provides the main mechanical properties of bone. In cortical bone, there are Haversian canals carrying abundant blood vessels and nerves in the longitudinal direction. The vessels in Haversian canals connect to each other through blood vessels in transversely oriented channels, which are known as Volkmann canals (2). Cancellous bone is a meshwork consisting of plate-like or rod-like structures at about 200-μm thickness (3). By one estimate, 80% of bone remodeling processes occur in cancellous bone (4). However, bone regeneration not only needs to reconstruct bone structure but also involves repairing other tissues like blood vessels or nerves. Osteogenesis, angiogenesis, and neurogenesis for bone regeneration are based on the interactions of multiple cells including mesenchymal stem cells (MSCs), endothelial cells (ECs), and Schwann cells (SCs) (3). Therefore, it is essential to meet the structural requirements and to perform the multicellular functions during the bone repairing process.

At present, the main strategies for repairing large bone defects are via autografts, allografts, and bone tissue engineering. Autografts are limited by their source and allografts face immune rejection, which limit their further application. Bone tissue engineering, however, has become an efficient approach for bone repair. Although many bone tissue engineering scaffolds have been developed, most of the prepared scaffolds are simple structures, which can not be used for achieving the spatial arrangement of multiple cells. However, a crucial aspect of mimicking tissue is modulating the cellular processes such as cell distributions and multicellular interactions in the specific three dimensional (3D) structure (6). Consequently, fabrication of bone tissue engineering scaffolds with multicellular delivery and complex morphologies akin to native bone tissue remains challenging for bone tissue regeneration (7).

Recently, biomimetic strategies have attracted much attention in constructing high-performance bone tissue engineering biomaterials. Many approaches, such as freeze casting (8), layer-by-layer assemble (9), and 3D printing (10), have been used to fabricate biomimetic biomaterials. Among these methods, 3D printing offers the prospect of fabricating materials with specific customized structures similar to native tissue (11). Our group has previously prepared the lotus root–like scaffolds for the regeneration of vascularized bone tissue (12) and hot dog–like scaffolds by 3D printing for drug delivery to further promote bone regeneration (13). 3D printing has even been used to prepare complicated artificial heart (14) and lung tissues (15). Constructing biomaterials with hierarchical bone-mimicking structure using 3D printing technology provides multicellular delivery and, thus, promote the vascularization and neurotization in bone regeneration.

Herein, inspired by the hierarchical structure and functions of bone, Haversian bone–mimicking bioceramic scaffolds were successfully fabricated by digital laser processing (DLP)–based 3D printing technology. The method provided a fast, high-precision, and robust strategy to fabricate structurally diversified bioceramic scaffolds from a single precursor slurry by a one-step process. The Haversian bone–mimicking structure composed of cortical bone structure (containing Haversian canals and Volkmann canals) and cancellous bone structure could be easily controlled by the custom design. The multicellular delivery system with MSCs transported by the cancellous bone structure and ECs/SCs transported by the Haversian canals represented a simple but versatile design. The Haversian bone–mimicking scaffold–based multicellular delivery system exhibited notably improved osteogenic and angiogenic effects as compared with the unicellular delivery system both in vitro and in vivo. Thus, we proposed a concept of 3D structure–based coculture platform and developed a Haversian bone–mimicking scaffold–based multicellular delivery system with osteogenic cells and angiogenic/neurogenic cells distributed at the specific location for active bone tissue engineering.

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*Corresponding author. Email: chengtiewu@mail.sic.ac.cn

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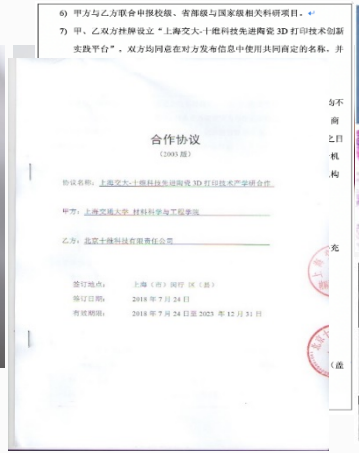
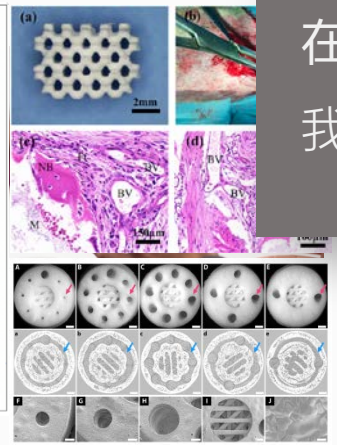

6）甲方与乙方联合申报校级、省部级与国家级相关科研项目。
7）甲、乙双方共同设立“上海交大-十维科技先进陶瓷 3D 打印技术创新实践平台”，双方均同意在对方发布信息中使用共同商定的名称，并
合作协议
（2005 版）
协议名称：上海交大-十维科技先进陶瓷 3D 打印技术产学研合作
甲方：上海交通大学 材料科学与工程学院
乙方：北京十维科技有限责任公司
签订地点：
签订日期：2018 年 7 月 24 日
有效期限：2018 年 7 月 24 日至 2023 年 12 月 31 日

与最大的过滤器
企业形成供货



临床实验
修复效果良好

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资质和奖励


发明专利证书
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发明名称：基于神经网络的3D打印误差补偿方法、系统、装置
专利申请日：2019年01月03日
专利权人：中国科学院自动化研究所；北京十维科技有限责任公司
地址：100190 北京市海淀区中关村东路95号
授权公告日：2020年06月16日
授权公告号：CN 109808183 B
局长
申长雨


高新技术企业
证书
企业名称：北京十维科技有限责任公司
证书编号：GR201811006699
发证时间：2018年11月30日
有效期：三年
批准机关：


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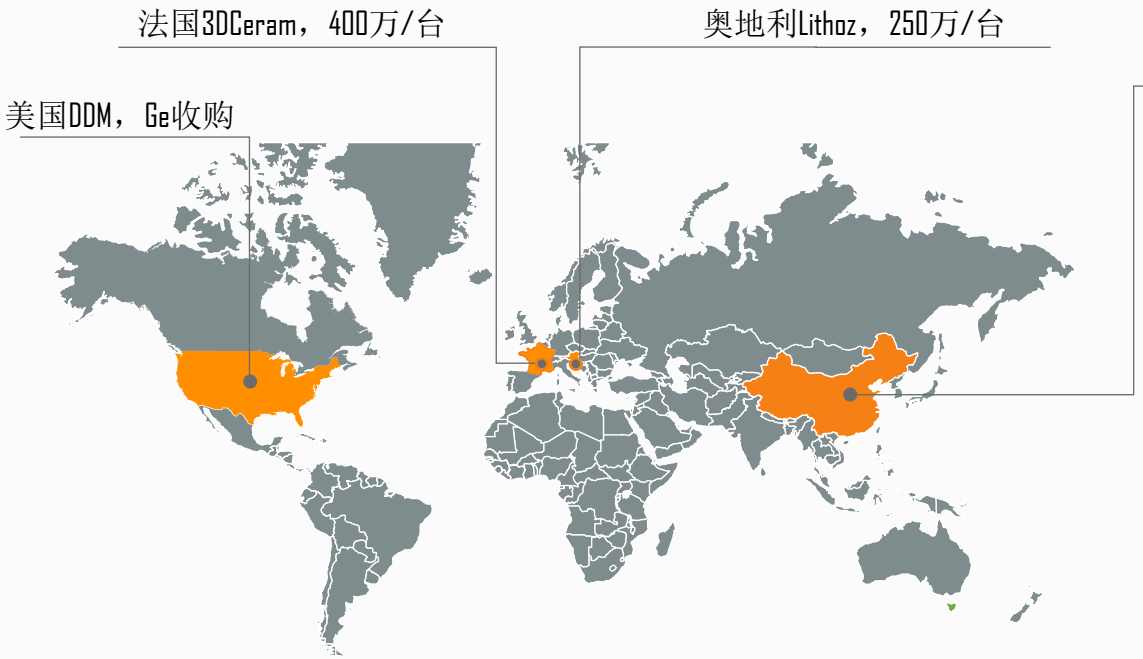

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- 价格优势
- 地域优势：为客户服务的时效和成本

与国内相比

- 时间领先。国内首家陶瓷光刻打印机
- 行业应用领先：国内首家（目前唯一）陶瓷打印量产工厂

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THANK YOU!