Biomedical Ceramic 3D-Printing

Ceramics are parts of the market for biomaterials, a growing market due to the many properties (biodegradable, bioinert, antibacterial effect, etc.) making them unavoidable in the medical sector. Applied to the biomedical market, 3D-printing allows the realisation of bone substitutes, custom ceramic implants and surgical tools. Their outstanding biocompatibility, extremely regular porous structure and mechanical strength are the main qualities of these 3D-bioceramics.

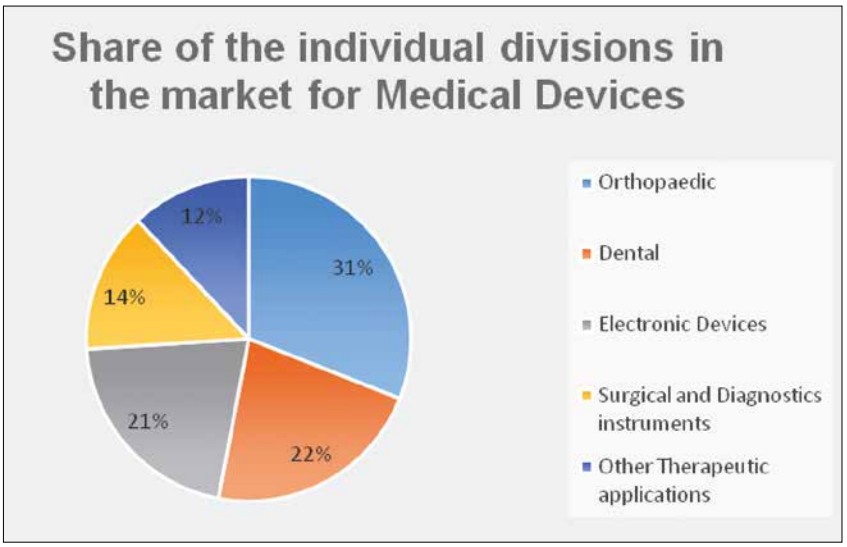

Fig. 1
Share of the individual divisions in the market for medical devices

Market forcast

The main benefits of Additive Manufacturing (AM) for orthopaedics is the bone ingrowth capabilities. It also enables the manufacture of complex parts, simultaneously and for different sizes, shapes and design.

AM brings a new dimension to the standard biomedical process. Several ceramics 3D-printing technologies have been developed to answer to the new challenges of biomedical sector.

3DCERAM Sinto leverages SLA 3D-printing technology for more than 10 years to manufacture custom-made or small series of bone substitutes (intervertebral cages and tibial osteotomy wedges) and cranial or jawbone implants. This technology enables to produce ceramic components by successive layers using a laser which polymerizes a paste composed of photosensitive resin and ceramic. The parts are then subjected to a heat treatment (debinding followed by sintering) which eliminates the resin and densifies the ceramic.

Various applications

AM makes possible to use ceramic for many applications in the biomedical field:

- Cages and wedges: AM makes possible to control the location and geometry of the pores of ceramic substitutes, unlike implants that are made porous by adding organic foam or porogens. Porosity structured in three dimensions and constant diameter of the fully interconnected pores promote osteointegration and mechanical strength of substitutes. Compressive mechanical strength is between three and five times higher than that of conventional porous structures.
- Bones substitutes: 3DCERAM Sinto has developed a stereolithography technology for the manufacture of custom-made bioceramic cranial or jawbone implants named BioCranium®. The custom hydroxyapatite ceramics implants allow the replacement of the important osseous defects of the dome of the skull and the jawbone part, thus guaranteeing the protection of the subjacent anatomical structures. This custom method is also used in reconstructive surgery for the patients carrying of a loss of craniofacial osseous substance, after a surgical act. The ceramic implants are an alternative to the osseous grafts which very often come from the patient himself, and thus avoid him additional pains.

Calcium phosphates, such as hydroxyapatite or tricalcium phosphates, are the synthetic materials closest to bone. They are widely renowned in medical circles for their osteoconductive properties, especially when the macropores size and porosity of interconnection are controlled. They have minimal risk of rejection.

- Surgical tools and instruments: as part of the European Project H2020 NEXIS (Next

Keywords
3D-printing, biomedical application, cages, bone substitutes, dental replacements

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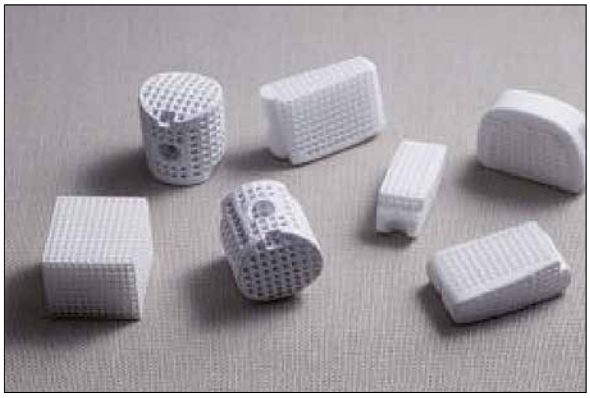

Fig. 2
Intervertebral cages in Al_2O_3

Generation X-ray Imaging System), 3DCERAM Sinto has been selected in the consortium for its 3D-ceramic printing technologies. The goal of the NEXIS European Project is to develop a new spectral detector to improve image quality and features for a quick diagnosis of stroke directly in the intervention room. 3DCERAM Sinto will be responsible for manufacturing scintillators by 3D-printing for the system detector.

- Dental: this sector could potentially become one of the largest through the implementation of 3D-printing processes. The ideal mechanical, biocompatibility and aesthetic properties of ceramics, combined with 3D-printing for production of complex shapes, could enable ceramics to fully replace polymer and metal implants. The implementation of zirconia 3D-printing greatly improve efficiency, saving on materials and costs as well as time.

The market interest for components produced by ceramic additive manufacturing is growing steadily.

A significant increase in demand beyond simple surgical instruments to intelligent components and assemblies has been identified. This tendency is based on the need for:

- increased safety for patient and the medical doctor in complicated surgical procedures;
- gentler surgical procedures, leading to shortened healing time and therefore to reduced overall healthcare costs;
- next-generation components containing the highest degree of functional integration, such as sensors, antennas or actuators.

Diversity of materials

The following ceramics that are mainly used in biomedical sector and proposed by 3DCERAM Sinto:

Alumina: basic material being useful in medical prostheses: good mechanical behaviour, great hardness, good wear resistance, chemical slowness.

Zirconia: useful in surgical instrumentation and odontology prosthesis (crowns and bridges), porous coating dentistry: material with very good mechanical properties, great hardness, good wear resistance, good chemical slowness.

Hydroxylapatite: non-resorbable material used in the biomedical applications for the manufacture of the osseous substitutes,

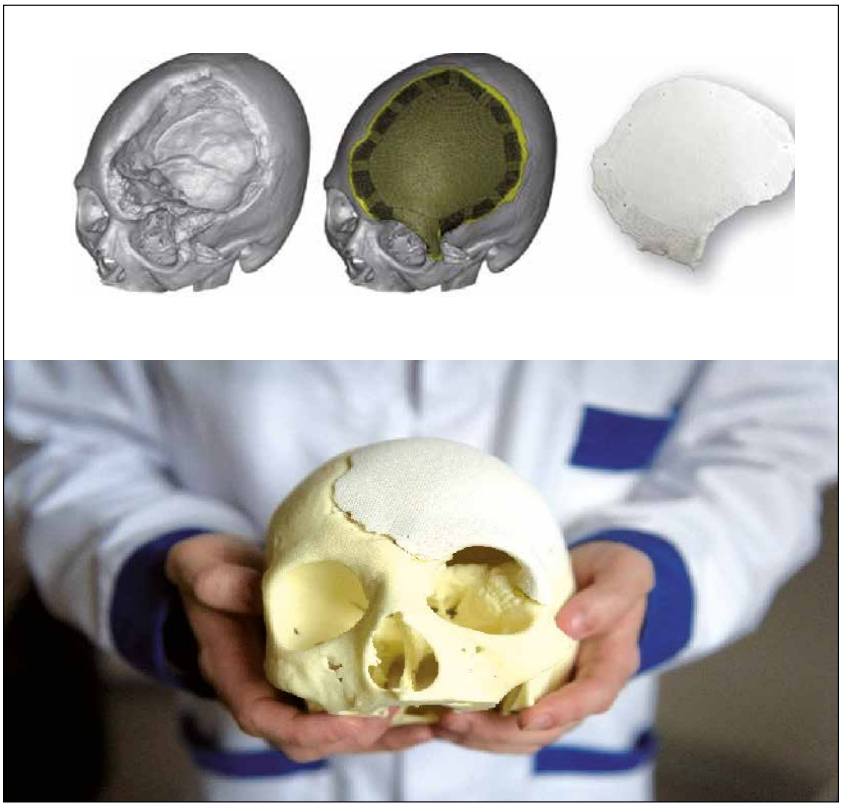

Fig. 3
Custom made HAP implant for the repair of large and complex craniofacial bone defects

chemical composition close to bone, osseointegration.
Tricalciumphosphate: resorbable materials in vivo.
Alumina toughened zirconia: orthopaedic prosthetics.

Complete solutions for ceramic AM

With the CERAMAKER machine, 3DCERAM Sinto offers a custom engineering solution and a complete line for high quality production:

- turnkey line;
- a reliable and proven open 3D-printer;
- cleaning cabin;
- debinding and sintering kilns.

In addition, the future of 3D-printing is multiple materials. To answer to this request, 3DCERAM Sinto has developed the multi- material CERAMAKER® 900H: the only printer on the market able to produce parts by these diverse specifications and needs of the end user. The innovation is to use stereolithography technology to produce complex multi-material parts of ceramic-ceramic or ceramic-metal or ceramic-polymers.
Albert Tarançon, Senior Scientist of the Cell3Ditor Project at L'IREC/FR, declared: "the 3D-printing technology developed by 3DCERAM Sinto via their hybrid machine revolutionises the production of ceramics and develops the 3D-printing of multi-materials and eventually of complete devices".

Fig. 4
Headquarters in Limoges

Support and training

This industry is highly regulated. One key factor in 3D-printing for biomedical sector is obtaining the certifications to produce parts. 3DCERAM Sinto is certified ISO 9001 and ISO 13485 and proposes to accompany its customers in getting the right certifications. 3DCERAM Sinto pioneered ceramic AM and has built an expertise in biomedical based on more than 15 years of experience. Combining its ceramic and 3D-printing expertise, 3DCERAM Sinto has designed services offers: taylor-made process audit and training sessions to help its customers and give a new dimension to their ceramic projects. 3DCERAM Sinto provides an expert insight in the domain of 3D-printig in ceramics for the development of parts production using the CERAMAKER. 3D-ceramic printing is a disruptive technology and can have an effect on the traditional business organisation channels. Several modules and levels of training are available: from the introduction to the principals of 3D-ceramic printing, detailing the important parts of the process, the why, how and when of ceramic printing, while studying real life examples of printing optimisation.

Conclusion

Using 3D-ceramic printing technology optimises and facilitates the production of complex parts to achieve long-term benefits to the final client.
According to a 10-year opportunity analysis paper, produced by Smartech Markets, the future for ceramic AM of Technical Ceramics is bright. Encouraging a shift from research to scale production of Technical Ceramics, 3DCERAM Sinto with its new disruptive technologies and expertise in biomedical sector is well placed to attack the exciting future with high aspirations.