Ceramic-Ceramic Multi-Material Components by Lithography-based Ceramic Manufacturing (LCM)

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Introduction

Increasing demand of future applications on single ceramic components with site-specific and conflicting properties and functions led to the design of multi-material components [1]. Conventional methods have some limitations in fabrication of near-net-shaped and complex components in a cost-efficient manner.

Significant developments in additive manufacturing (AM) enable us nowadays flexibility in terms of design and material selection [2]. Lithography-based Ceramic Manufacturing (LCM) technology, developed by Lithoz GmbH, as an enhancement of stereolithography (SLA) and digital light processing (DLP) offers manufacturing multi-material ceramic components with complex architectural features [3, 4].

Various methodologies have been introduced that enable multi-layered and functionally graded ceramic-ceramic multi-material combinations of different compositions, microstructure, and porosity. This study investigates the performance of printing methodologies of multi-materials in terms of printability, precision, and functionality.

Lithography-based Ceramic Manufacturing (LCM)

A photosensitive formulation is cured via a mask-exposure process using the concept of DLP in the required areas through selective light exposure to blue light [5] **(see Fig. 1)**. As a building speed, up to 100 slices/hour, meaning up to 10 mm/h can be achieved [6].

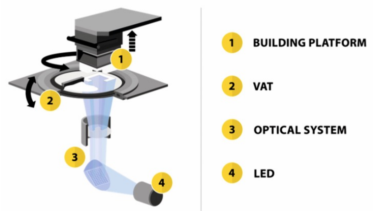

Figure 1. Schematic representation of LCM

Multi-material 3D Printing with LCM

The newly developed multi-material 3D printer CeraFab Multi 2M30 with two vat-system allows simultaneous processing of two photocurable suspensions in manufacturing of customized and multifunctional components with a control of the architecture and microstructure at all scales [7] (see **Fig. 2**).

Figure 2. CeraFab Multi 2M30 printer with two-vat system

Layer-by-layer Approach

In this approach, individual layers can be assigned to respective suspension, namely Material 1 or Material 2 in **Fig. 3 (a)**. A functionally graded ceramic can be fabricated by increasing the number of the layers of one material by one in every repeated specific number of layers in the deposition direction.

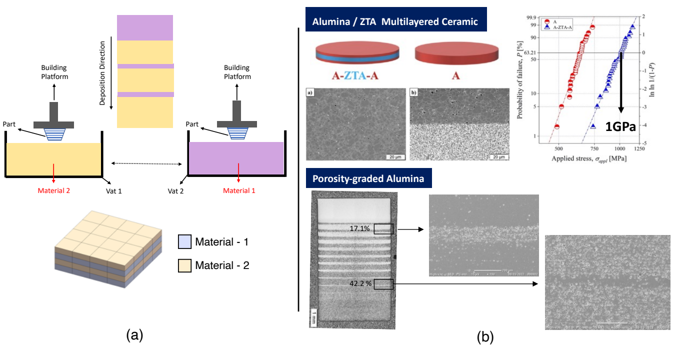

Figure 3. (a) Representation of layer-by-layer approach (b) multi-material samples with heterogenous and gradient transition zones [7, 8]

Within-layer Approach

In this approach, the combination of two materials was achieved by curing different fractions of two materials on the same layer according to the designed architecture (see **Fig. 4(a)**). The gradient of material/material property is introduced by increasing the content of one material to another after each layer in the deposition direction.

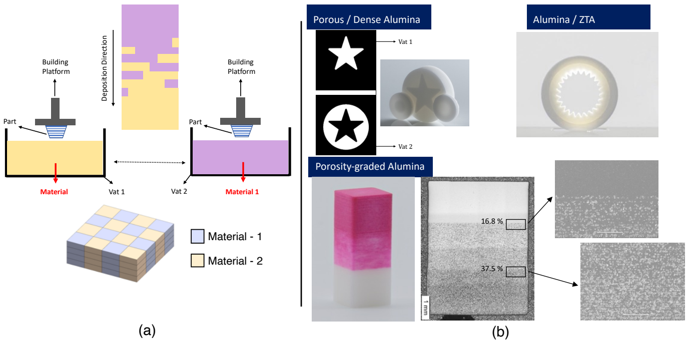

Figure 4. (a) Representation of within-layer approach (b) multi-material samples with heterogenous and gradient transition zones [8]

Future Aspects

Interest on combination of biomaterials that provide specific properties that mimic the natural bone for bone replacement and regeneration has increased in last years (see **Fig. 5(a)**). At this, resorbable implants that also can be used in load-bearing applications are of particular interest.

Furthermore, combining metals with ceramics in a single component with controlled properties find applications in electronics. In **Fig. 5(b)**, a copper/glass ceramic component is shown for a potential use in low temperature co-fired ceramic (LTCC) systems.

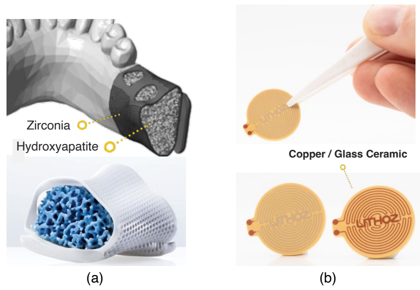

Figure 5. (a) Zirconia/hydroxyapatite ceramic for bone repair and replacement (b) Copper/glass ceramic combination for electronics applications

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