Alumina-zirconium ceramics synthesis by Selective Laser Sintering/Melting

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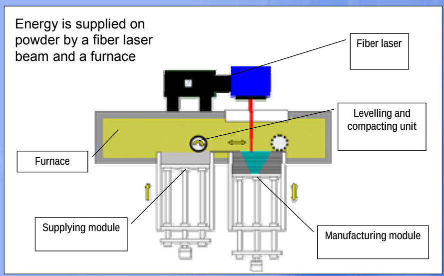
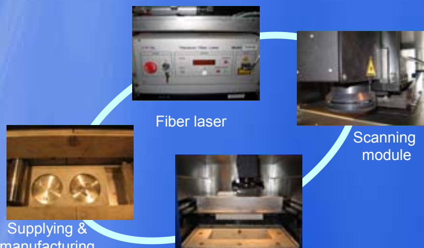
High hardness, stiffness and brittleness make alumina-zirconium ceramics difficult for mechanical processing. Selective Laser Sintering/Melting (SLS/M) is an advanced manufacturing technology which allows fabricating accurate geometrical objects directly from a three-dimensional computer image. In the present paper, porous refractory ceramics synthesized by SLS/M from a mixture of zirconium dioxide, aluminum and/or alumina powders were analyzed by optical metallography and X-ray method from the point of view of their microstructure and phase composition depending on the laser processing parameters. It was shown that high-speed laser treatment in air yields ceramics with uniform and thin structure and a stabilized phase distribution. The obtained ceramic-matrix composites may be used in high temperature oxidation and electrical insulators, anti-thermal and wear resistant coating, solid oxide fuel cells, crucibles, heating elements, medical tools. The possibility to reinforce the refractory ceramics by laser synthesis was shown on the example of tetragonal dioxide of zirconium with hardened micro inclusion of Al_2O_3. By applying finely dispersed Y_2O_3 powder inclusions, the type of the ceramic structure has been significantly changed.

Selective Laser Melting



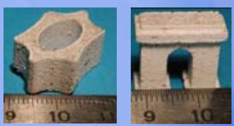
Functional scheme

PM 100



Accuracy : +/-100 µm/100 mm
Details size : 300 µm
Repeatability : 50 µm on x, y, z

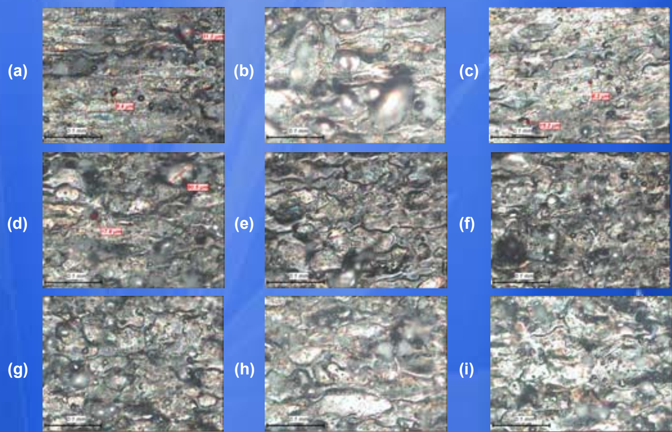
Ceramic materials



Alumina

Zirconium oxide

Mullite



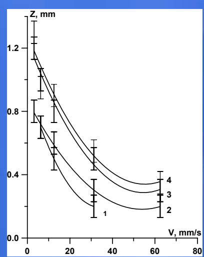
Microstructure of the melted ceramics ZrO_2-Al
Magnification x 200.

Laser irradiation parameters: *P* = 50 W, *D* = 80 µm.
Scanning velocity: (a), (d), (g) *V* = 1,5 m/s; (b), (e), (h) *V* = 1,75 m/s; (c), (f), (i) *V* = 2 m/s.
Hatch distance: (a), (b), (c) 20 µm, (d), (e), (f) 30µm, (g), (h), (i) 40 µm.

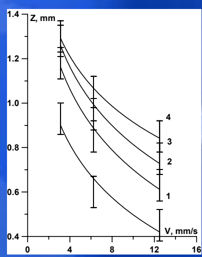
Figure represents results of the optical metallography evaluation of SLM of yttria-stabilized zirconia with aluminium (one monolayer) on the metal substrate. While porosity is minimal, cracks are developed because of high-speed cooling of the metal substrate thus making SLM results unsatisfactory. By increasing laser scan velocity and hatch distance, larger mosaics can be achieved (compare (a) and (i)).

Selective Laser Sintering

The technological setup for SLS



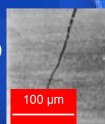
(a)



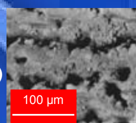
(b)

Thickness *Z* of the monolayer sintered
(a) in air and (b) in argon versus laser scan velocity *V*. Laser power: (1) *P*=9,7 W, (2) *P*=16 W, (3) *P*=21,2 W, (4) *P*=24,1 W

(a)

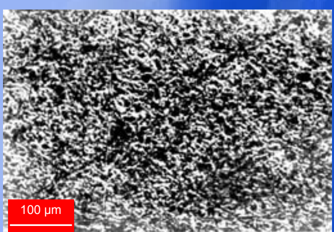


(b)

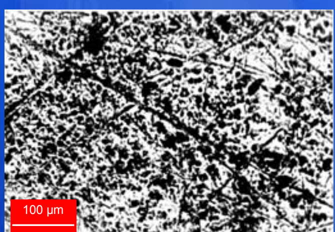


Surface morphology of the sintered ceramics at *P* = 24,1 W; *V* = 3,1 cm/s. Magnification: (a) x50 (in air), (b) x20 (in argon).

SLS in air yields a practically uniform and sufficiently thick structure. Monolayers sintered under *P*>16 W in air cracked during high-speed cooling (see (a)). This phenomenon can be explained by destabilization of the high-temperature tetragonal phase ZrO_2 with transition to a monoclinic phase. For stabilization of the tetragonal phase ZrO_2. The addition of the Al_2O_3 phase that will be formed under sintering in air also contributes to ceramics durability. Under sintering in argon, a pore system is developed (fig. (b)) with pore size reaching >100 µm and shape elongated to the laser scan direction.



(a)



(b)

Microstructure of the sintered ceramics ZrO_2-Al_2O_3-Al.
Centre (a) and edges (b). Magnification X 800.
Laser irradiation parameters: *P* = 24 W, *V* = 2,9 cm/s , *D* = 90 µm.

3D parts

(a), (b) CMMC - a porous filter element for the catalytic process;
(c) PZT ceramic; (d) Composite PZT ceramics in a mix with SiO_2;
(e) Synthesis of piezoceramics from a oxide mix TiO_2 + ZrO_2 + PbO

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