

Ceramic Units Manufactured by Additive Technologies: the Problem of Final Product Porosity. A Brief Review

V.G. Konakov^{1,2}, A.V. Soudarev³, O.Yu. Kurapova^{1,2} and I.Yu. Archakov^{1,4}

¹Scientific and Technical Center “Glass and Ceramics”, ul. Dudko 3, St. Petersburg, 192029, Russia

²Saint Petersburg State University, 7/9 Universitetskaya nab., St. Petersburg 199034, Russia

³“Boyko Center”, ul. Dudko 3, St. Petersburg, 192029, Russia

⁴ITMO University, 49 Kronverksky Pr., St. Petersburg, 197101, Russia

Received: November 16, 2019

Corresponding author: V.G. Konakov

Abstract. The paper reviews the additive technologies application for the ceramic products manufacturing. Advantages and drawbacks of current approaches are mentioned; it shows that the porosity of the final ceramic product is one of the main problems preventing the wide use of such ceramics at extreme exploitation conditions: high temperature and chemically aggressive gas ambience. A possible pathway to solve this problem is suggested: it is shown that chemical impregnation could provide significant porosity decrease coupled with mechanical properties increase.

REFERENCES

- [1] David L. Bourell, *Perspectives on Additive Manufacturing*, Annual Review of Materials Research, 2016, vol. 46 pp. 1-18.
- [2] W.J. Sames, F.A. List, S. Pannala, R.R. Dehoff, and S.S. Babu, *The Metallurgy and Processing Science of Metal Additive Manufacturing*, International Materials Reviews, 2016, vol. 61, no. 5, pp. 315-360.
- [3] X. Tian, D. Li, and J. G. Heinrich, *Rapid Prototyping of porcelain products by layer-wise slurry deposition (LSD) and direct laser sintering*, Rapid Prototyping Journal, 2012, vol. 18, no. 5, pp. 362-373.
- [4] Thomas Muhler, Jurgen Heinrich, Cynthia M. Gomes, and Jens Gunster, *Slurry-based Additive Manufacturing of Ceramics*, International Journal of Applied Ceramics Technology, 2013, vol. 12, no. 1, pp. 1-8.
- [5] Ch. W. Hull, *Method For Production Of Three-dimensional Objects By Stereolithography*, US Patent US 5174943A, 1992.
- [6] T. Chartier, C. Dupas, M. Lasgorceix, J. Brie, N. Delhote, and Chr. Chaput, *Additive Manufacturing to Produce Complex 3D Ceramic Parts*, The Journal of Ceramic Science and Technology, 2015, vol. 6, no. 2, pp. 95-104.

- [7] B. Derby, *Inkjet printing ceramics: From drops to solid*, Journal of the European Ceramic Society, 2011, vol. 31, no. 14, pp. 2543-255.
- [8] C. Hinczewski, S. Corbel, and T. Chartier, *Ceramic suspensions suitable for stereolithography*, Journal of the European Ceramic Society, 1998, vol. 18, no. 6, pp. 583-590.
- [9] J. W. Halloran, V. Tomeckova, S. Gentry, S. Das, P. Cilino, D. Yuan, R. Guo, A. Rudraraju, P. Shao, T. Wu, T. R. Alabi, W. Baker, D. Legdzina, D. Wolski, W. R. Zimbeck, and D. Long, *Photopolymerization of powder suspensions for shaping ceramics*, Journal of the European Ceramic Society, 2011, vol. 31, no. 14, pp. 2613-2619.
- [10] Dongdong Gu, Yves-Christian Hagedorn, Wilhelm Meiners, Konrad Wissenbach, and Reinhart Poprawe, *Selective Laser Melting of in-situ TiC/Ti₃Si₃ composites with novel reinforcement architecture and elevated performance*, Surface & Coatings Technology, 2011, vol. 205, no. 10, pp. 3285-3292.
- [11] Jan Wilkes, Yves-Christian Hagedorn, Sörn Ocylok, Wilhelm Meiners, and Konrad Wissenbach, *Rapid Manufacturing of Ceramic Parts by Selective Laser Melting*, In: *Advanced Processing and Manufacturing Technologies for Structural and Multifunctional Materials, Part III*, Ceramic Engineering and Science Proceedings, vol. 31, no. 8, pp 137-148.
- [12] A.V. Soudarev, V.G. Konakov, N.F. Morozov, I.A. Ovidko, and B.N. Semenov, In: *Proceedings of GT2008, 2008 ASME Turbo Expo Power for Land, Sea & Air* (Berlin, Germany, June 9-13, 2008, GT2008-50549), CD N200.
- [13] A.V. Sudarev, A.S. Molchanov, A.A. Surjaninov, and V.G. Konakov, In: *Proc. III Int. Conference Engines for Aircrafts in XXI century* (TSIAM, Moscow, 2010), p. 393, In Russian.
- [14] A.V. Sudarev, V.G. Konakov, and P. Avran, *Procédé de fabrication d'une poudre métal-céramique appropriée pour la fabrication d'une pièce de céramique dure et procédé de fabrication correspondant*, Demande de brevet d'invention, FR20160054195 20160511, 2017-11-17.
- [15] V.G. Konakov, E.N. Solovyeva, I.Yu. Archakov, and S.N. Golubev, *Strength of Al₂O₃-SiC-BN-Si₃N₄-based ceramics*, Materials Physics and Mechanics, 2013, vol. 18, no. 1, pp. 93-100, In Russian.
- [16] V.G. Konakov, A.V. Sudarev, N.F. Morozov and I.A. Ovid'ko, *An approach to produce non-shrinkable ceramic construction unit*, Russian patent Ru 2399601, November 19, 2008.
- [17] V.G. Konakov, I.A. Ovid'ko, and B.N. Semenov, *An approach to produce non-shrinkable nanomodified ceramic construction unit*, Russian patent Ru 542073, December 26, 2013.
- [18] S.R. Stock, *MicroComputed Tomography: Methodology and Applications* (CRC Press Boca Raton, 2008).
- [19] J. Timonen, M. Mylly, V. G. Konakov, A. V. Soudarev, and I. Yu. Archakov, *Structure of a ceramic material developed by laser prototyping techniques*, Reviews on Advanced Materials Science, 2011, vol. 29, no. 2, pp. 175-179.
- [20] Y. Chivel, A. Sudarev and V. Konakov, *Additive manufacturing technology of ceramic turbomachines*, conference paper in World PM2016 Proceedings: AM - Special Aspects in AM Technology (Hamburg; Germany; 9 - 13 October 2016); ISBN: 9781899072484.
- [21] K.D. Keefer, *Silicon Based Polymer Science: A Comprehensive Resource*; In: *Better Ceramics Through Chemistry II* (Springer, 1984), pp.15 - 24.
- [22] E. R. Pohl and F. D. Osterholtz, *Kinetics and Mechanism of Aqueous Hydrolysis and Condensation of Alkyltrialkoxysilanes*, In: *Molecular Characterization of Composite Interfaces*, ed. by H. Ishida and G. Kumar (Plenum, New York, 1985), pp. 157-170.
- [23] R. Aelion, A. Loebel, and F. Eirich, *Hydrolysis of ethyl silicate*, J. Am. Chem. Soc., 1950, vol. 72, pp. 5705-5712.
- [24] A.A. Appen, *Glass Chemistry* (Khimiya, Leningrad, USSR, 1974), In Russian.