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The effect of induction heat treatment on the surface structure and modulus of elasticity of 3D medical blocks

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Currently, it is increasingly proposed to use additive technologies, such as SLM, for the production of implantable structures, including highly porous blocks (scaffold) to replace bone defects. The SLM process has a number of features that lead to the occurrence of internal stresses, defects in the microstructure of the finished product (cracks, pores, uneven phase composition). A rational method for regulating the mechanical properties of metals is heat treatment. For example, for Ti-6Al-4V blocks, according to the requirements of GJB 3763A-2004, it is proposed to carry out annealing in a neutral atmosphere. The process of induction thermal treatment (IHT) is known, which makes it possible to form nanostructured oxide layers on titanium and change the mechanical properties of the product as a whole [https://doi.org/10.1016/j.ceramint.2019.01.131]. Therefore, the aim of this work was to determine the effect of IHT on the surface structure and elastic modulus of 3D-blocks obtained by the SLM method from Ti-6Al-4V.

Methodology

The experimental samples were 3D-blocks formed by the SLM method. Heat treatment was carried out by the IHT method in air at a temperature of 800-1000 ºC and duration 120, 300 s. The surface morphology of the samples was studied using scanning electron microscopy (SEM). SEM was performed on "MIRA II LMU". Determination of the modulus of elasticity and ultimate strength in compressive testing was carried out on a universal testing machine "IR 5082-100". The study of stress distribution over the longitudinal section of 3D-blocks was carried out by measuring the microhardness in transverse microsections and mapping the metal hardness. The microhardness was determined by the Vickers method on a "PMT-3M" microhardness tester with an indenter load of 50 gf.

Results

The initial blocks (***fig.1a***) were cylinders consisting of layer-by-layer sintered particles (***fig.1b***). After IHT, nano- and submicrometer-sized oxide crystals formed on the surface of the particles (***fig.1c***). The size of oxide crystals depended on the ITO regimes.

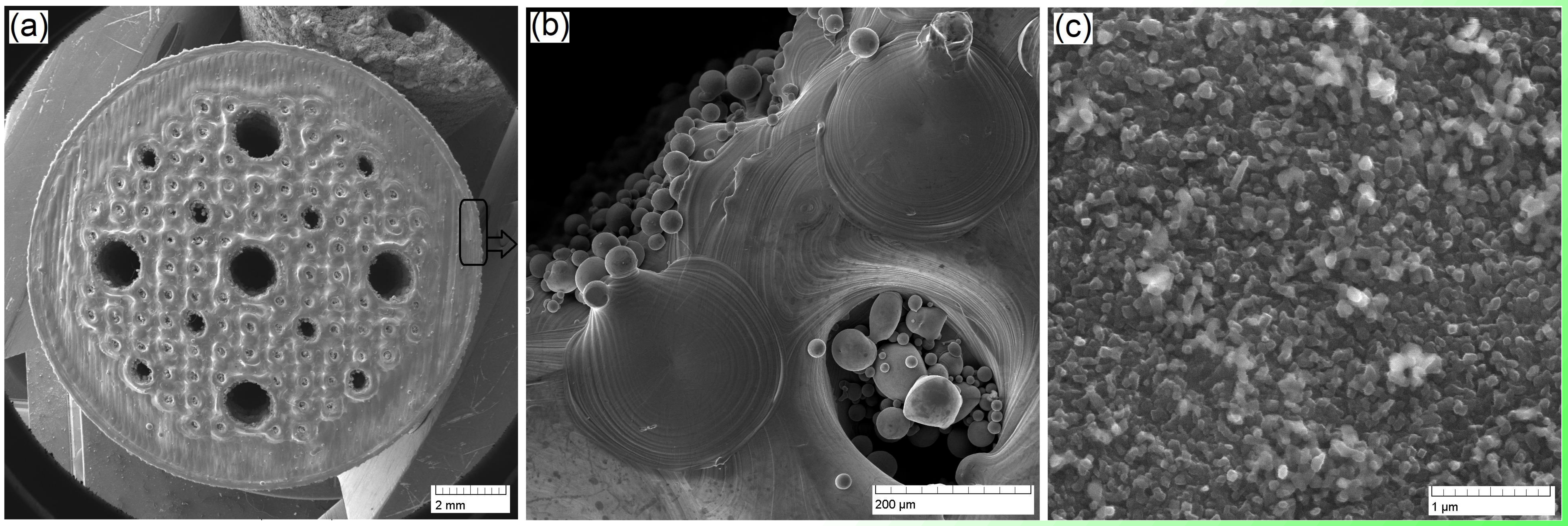

Figure 1 (a,b,c). Structure of the initial titanium (Ti-6Al-4V) 3D blocks (a) consisting of splats (b), on the surface of which oxide crystals are formed as a result of IHT (c).

The microhardness of the original 3D-blocks varied over the cross section in the range of 140–460 HV, which indicates the uneven distribution of internal stresses and the defectiveness of the structure as a whole. After IHT, the microhardness of the blocks, on average, regardless of the modes, was 200–300 HV. Probably, the metal was annealed during induction treatment. In addition, it was found that there was an insignificant change in the strength properties, namely, the tensile strength decreased, and the elastic modulus changed depending on the IHT modes (***table.***).

Table. Influence of induction heat treatment on the modulus of elasticity and tensile strength of 3D-blocks

№	Sample type	Modes of IHT		Elastic modulus E^c, GPa	Tensile strength σ_U, MPa
		Temperature, °C	IHT duration, s		
1	compact material	-	-	115.7	1140
2	3d-block	-	-	37.5	918
3	3d-block	-	-	33.2	883
4	3d-block	800–830	120	43.2	859
5	3d-block	800–830	300	36.9	945
6	3d-block	850–880	120	39.4	854
7	3d-block	850–880	300	28.7	780
8	3d-block	950–1000	120	31.8	841
9	3d-block	950–1000	300	32.9	808

Conclusions

As a result of the research, it was found that IHT makes it possible to remove internal stresses in 3D titanium blocks, change the elastic modulus, and form nanosized oxide structures on the metal surface.

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