Morphology of Magnesium Surface after Irradiation by Pulsed X-ray Radiation

Mikhail Zhidkov[1], Aleksandr Ligachev[2], Sergey Sorokin[3],

Geliy Potemkin[4], Yuriy Kolobov[5], B Bobryshev[6]

[1]Belgorod State National Reseacrh University, Belgorod, Russia
[2]Prokhorov Institute of General Physics RAS, Moscow, Russia
[3]Institute of High Current Electronics SB RAS, Tomsk, Russia
[4]Tomsk Polytechnic University, Tomsk, Russia
[5]Institute of Problems of Chemical Physics RAS, Chernogolovka, Russia
[6]Moscow Aviation Institute, Moscow, Russia

Introduction

It is well known that after processing metals and alloys with pulsed electron, ion beams and laser radiation, the relief and structure of the near-surface layer of the irradiated material change significantly. The results of the impact of pulsed soft X-ray radiation on the surface of metals are practically unknown to us. To date, we have studied the topography of the surface of titanium (its melting point does not exceed ~1700^{o}C), which was exposed to pulsed beams of soft X-ray radiation [1]. In this case, topography of the surface of titanium differs significantly from the relief obtained when processing titanium and its alloys with pulsed power ion beams.

Therefore, for further investigation of processes occurring on the surface and in the near-surface layer of pure metals during and after their irradiation with pulsed soft x-ray radiation, we selected magnesium, whose melting temperature is almost three times lower than the melting temperature of titanium and is equal to ~ 650^{o}C

[1] A.E. Ligachev, M.V. Zhidkov, S.A. Sorokin, Yu.R.Kolobov, G.V. Potemkin "Condition of Surface of Titanium after Pulsed X-ray Exposure", Inorganic Materials: Applied Research, 2019, Vol. 6,pp. 541-543

Materials and methods

The surface of the samples was subjected to mechanical grinding and polishing to “specular gloss” with the use of abrasive paper and diamond suspensions. Soft pulse X-ray irradiation (energy quanta of 0.1-1.0 Kev) were carried out on a high-current MIG generator [4]. The sample of magnesium was located at a distance of 10 cm from the X-ray source. Since the distance to the sample significantly exceeded the size of the x-ray beam, it can be assumed that the density of the X-ray radiation flow to the magnesium sample was uniform. The duration of the radiation pulse was 100 ns, and the radiation energy density in the pulse varied from 13 to 19 J/cm^{2}.

The surface topography was checked by scanning electron microscope FEI Nova NanoSem 450 with field emission

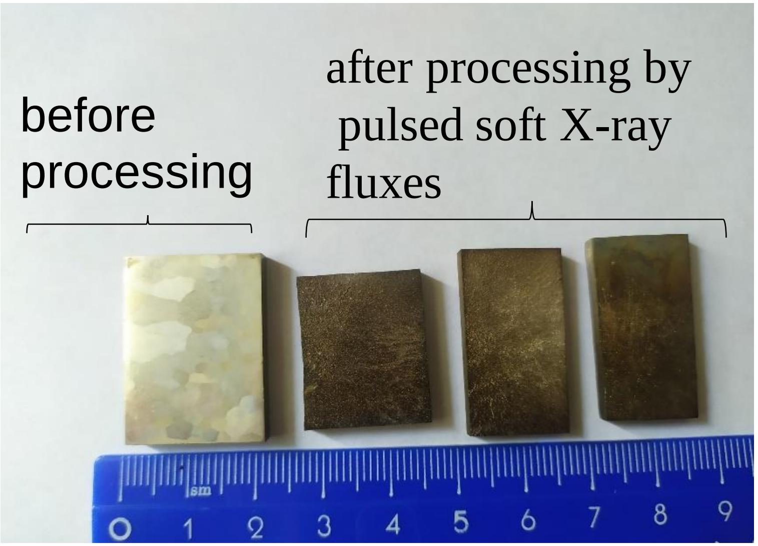
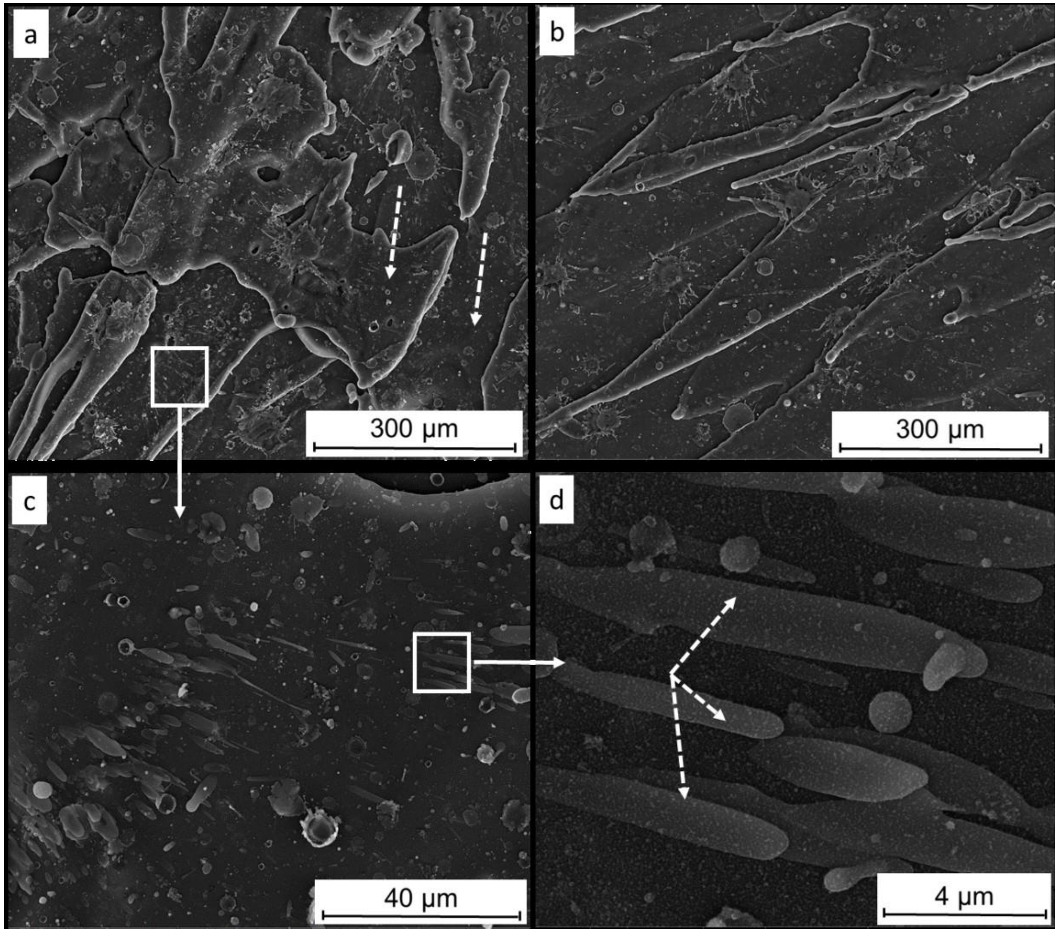


Figure 1. Top-view of the Mg samples before and after processing by pulsed soft X-ray fluxes

Results and discussion



areas of solidified liquid magnesium waves during high-speed crystallization

waves of elongated shape, the length of which is 10 or more times their width

Figure 2. Topography of the surface of magnesium after PSXF -radiation (single pulse ~13 J/cm^2)

- During the exposure of the X-ray pulse to the surface layer of magnesium melts.
- After the end of the x-ray pulse, a relief is formed in the form of chaotically arranged relative to each other frozen waves of liquid magnesium.

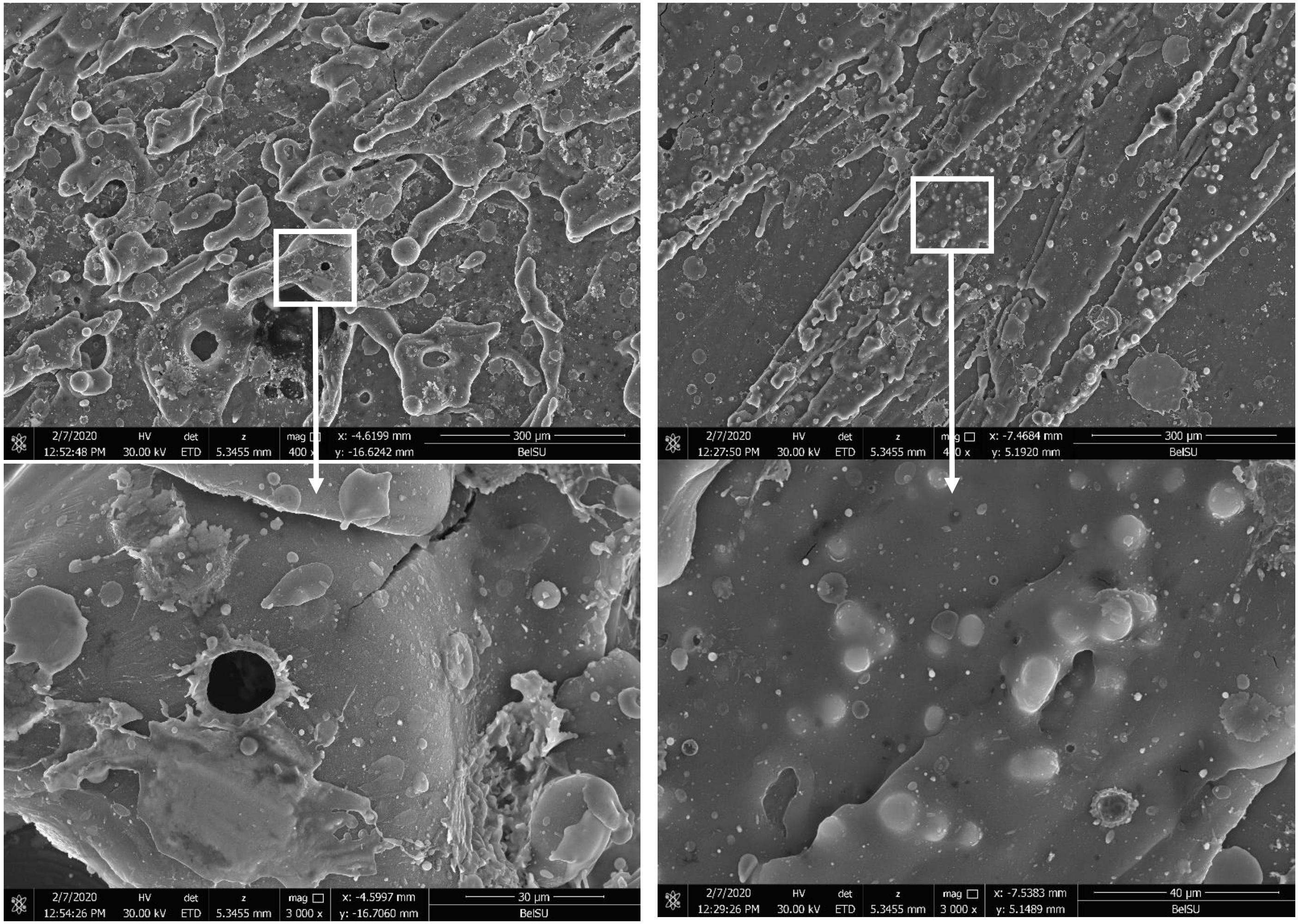
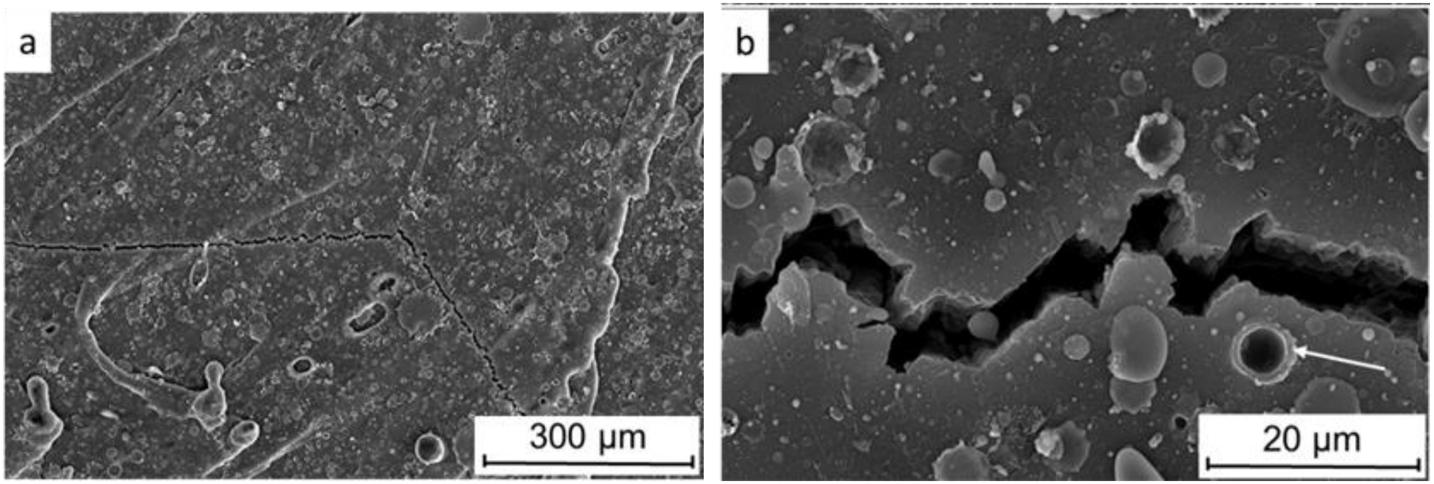


Figure 3. Topography of the surface of magnesium after PSXF -radiation (single pulse ~17 J/cm^2)

Craters of regular round shape were found, which were formed because of the penetration of tungsten particles into liquid magnesium.

The bubbles of boiling magnesium that have solidified as a result of high-speed solidification of the near-surface layer of liquid magnesium



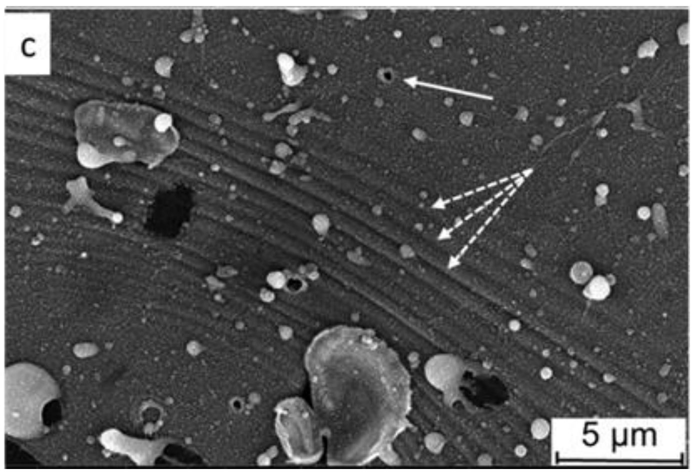


Figure 3. Topography of the surface of magnesium after PSXF-radiation (single pulse ~19 J/cm^2)

- Cracks are formed on the surface of magnesium after exposure to pulsed X-rays due to the action of internal stresses.
- Practically on the entire surface of magnesium after PSXF - radiation, a microwave structure with a wave period of 0.25-0.4 µm is formed on the surface of magnesium

CONCLUSION

After exposed to nanosecond pulses of soft X-ray radiation on the surface magnesium metal is melting and then rapidly solidifying, resulting in a wavy relief. Defects in the form of craters, usually occurring on the surface of magnesium and its alloys after exposure to pulsed beams of electrons, ions and plasma, were not detected. The surface shows areas of frozen bubbles formed during high-speed solidification of the boiling metal, traces of interaction of liquid magnesium droplets on its surface and areas with a uniform wavy structure