Decorative wear-resistant coatings produced on aluminum alloys by plasma electrolytic treatment (PET)

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Moscow, 2017

Present work objectives

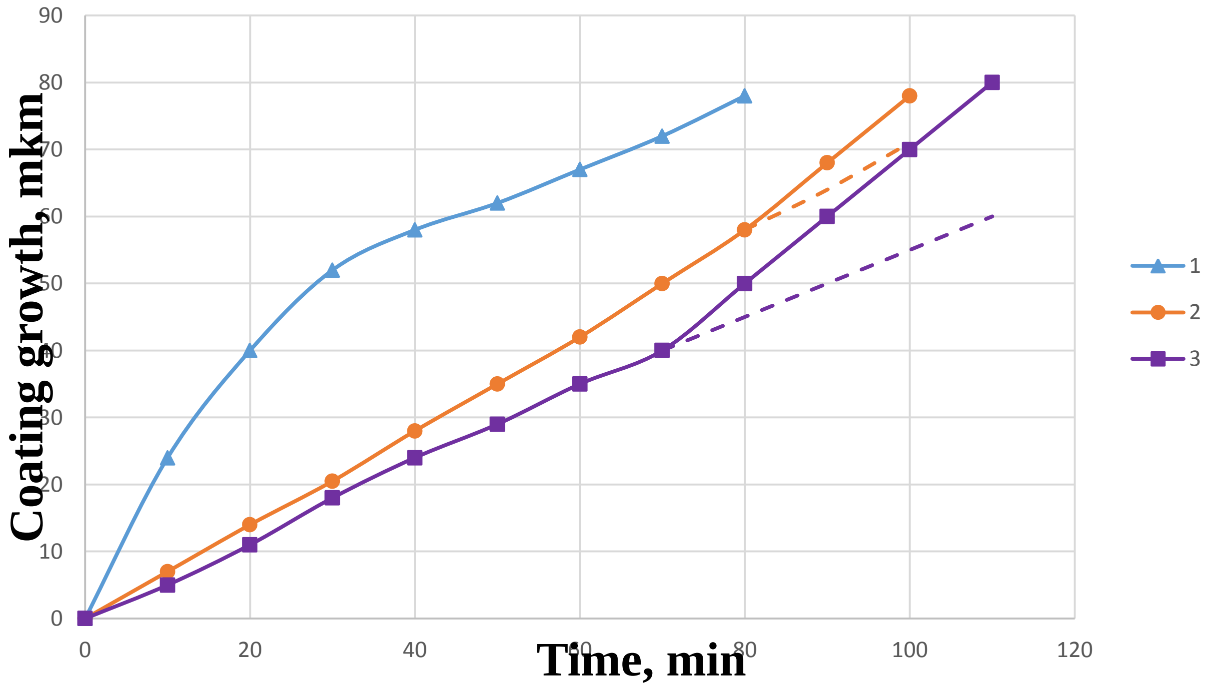
- Produce a variety of wear-resistant decorative coatings on aluminum alloys (including 2024 alloy) by PET method

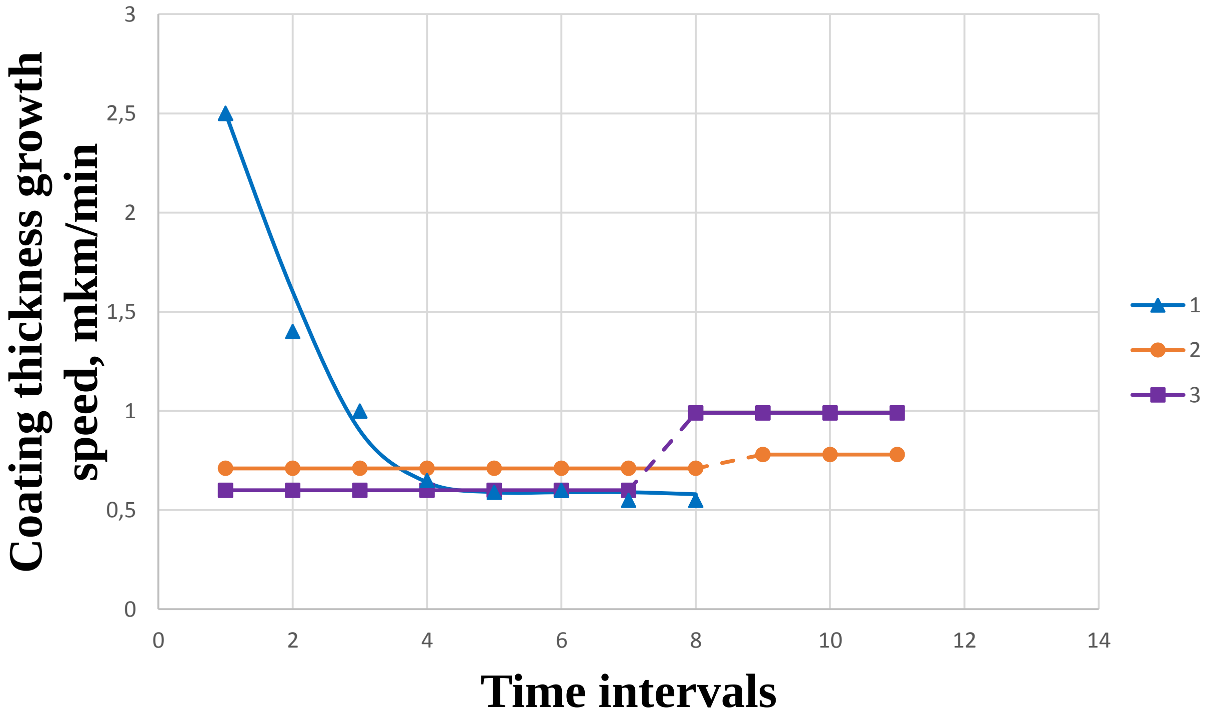
- Discover the reasons of different proportions of working mechanisms of coating growth at different time intervals of PET process and of start of effective electrolysis of anions and polyanions changing the coating color

Main coating growth mechanisms on metals by PET

- 1.Migration and diffusion of metal cations and oxygen anions towards phase interfaces “oxide layer – metallic substrate” and “oxide layer - electrolyte” on areas close to microdischarges (1^{st} mechanism)
- 2.Thermochemical conversion of condensed on working electrodes ions and polyanions (electrolysis) or dipoles (electrophoresis) (2^{nd} mechanism)
- 3.High-temperature oxidation of metallic substrate of bottom of transverse pores, where anodic plasma microdischarges had proceeded, by the mechanism of metallic substrate anodizing in gaseous plasma (3^{rd} mechanism)

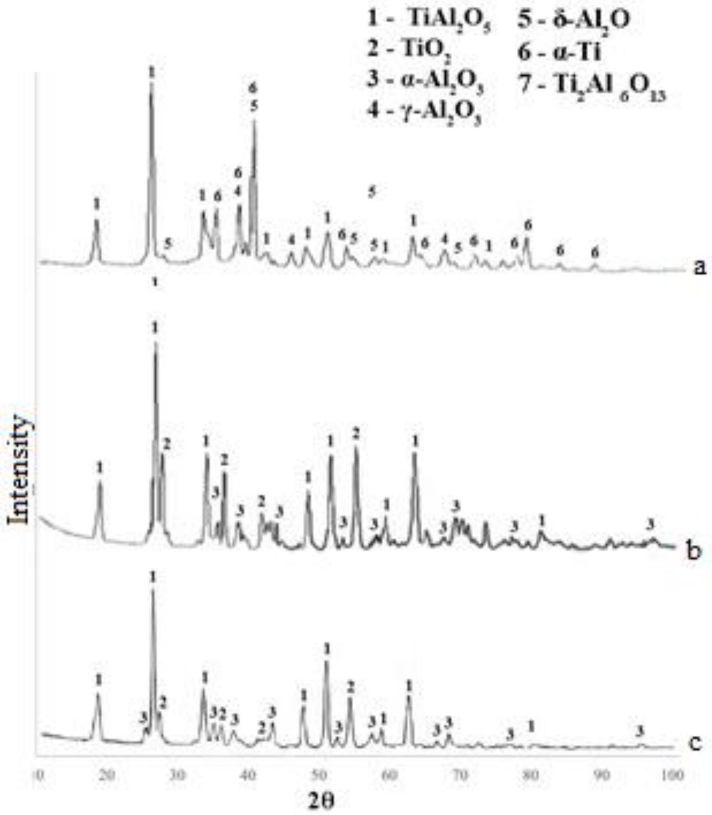
Growth kinetics average coatings thickness in time intervals of PET of Ti-6Al-4V (1) and aluminum 2024 alloy (2, 3)



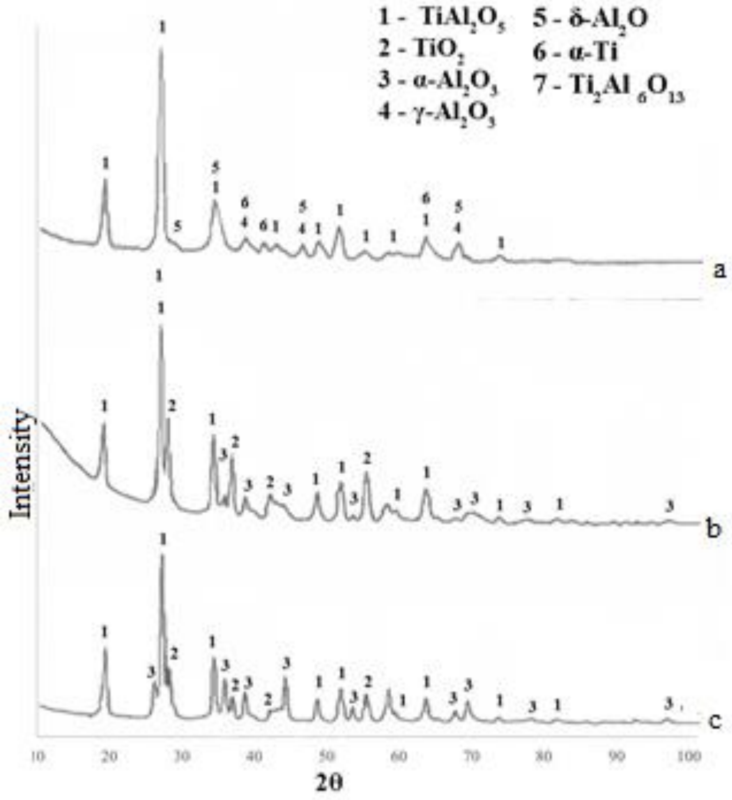


XRD patterns of coatings of various thickness produced by PET on Ti-6Al-4V

symmetrical view

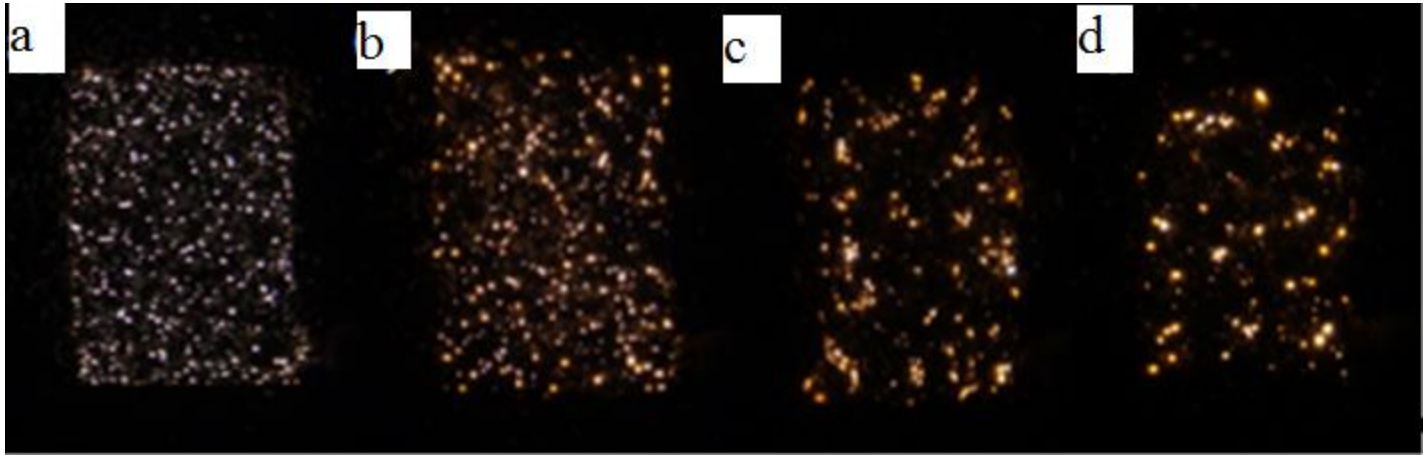


asymmetrical view (5°)

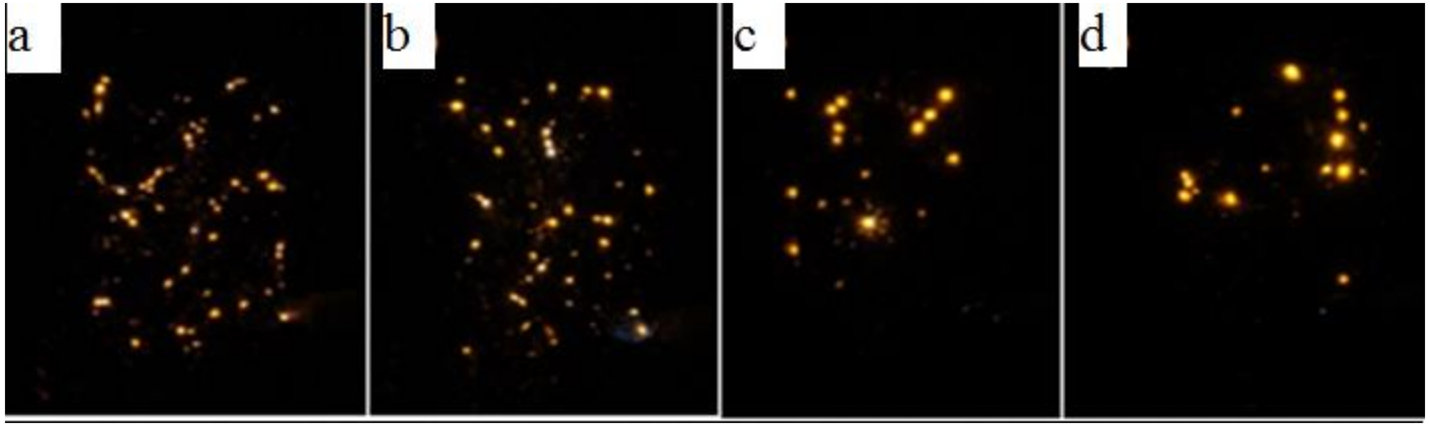


a) 30,4 ± 2,0 mkm, b) 40,0 ± 2,5 mkm, c) 80,2 ±3,6 mkm

Transformation of anodic plasma microdischarges density on working electrode surface at various time intervals of PET



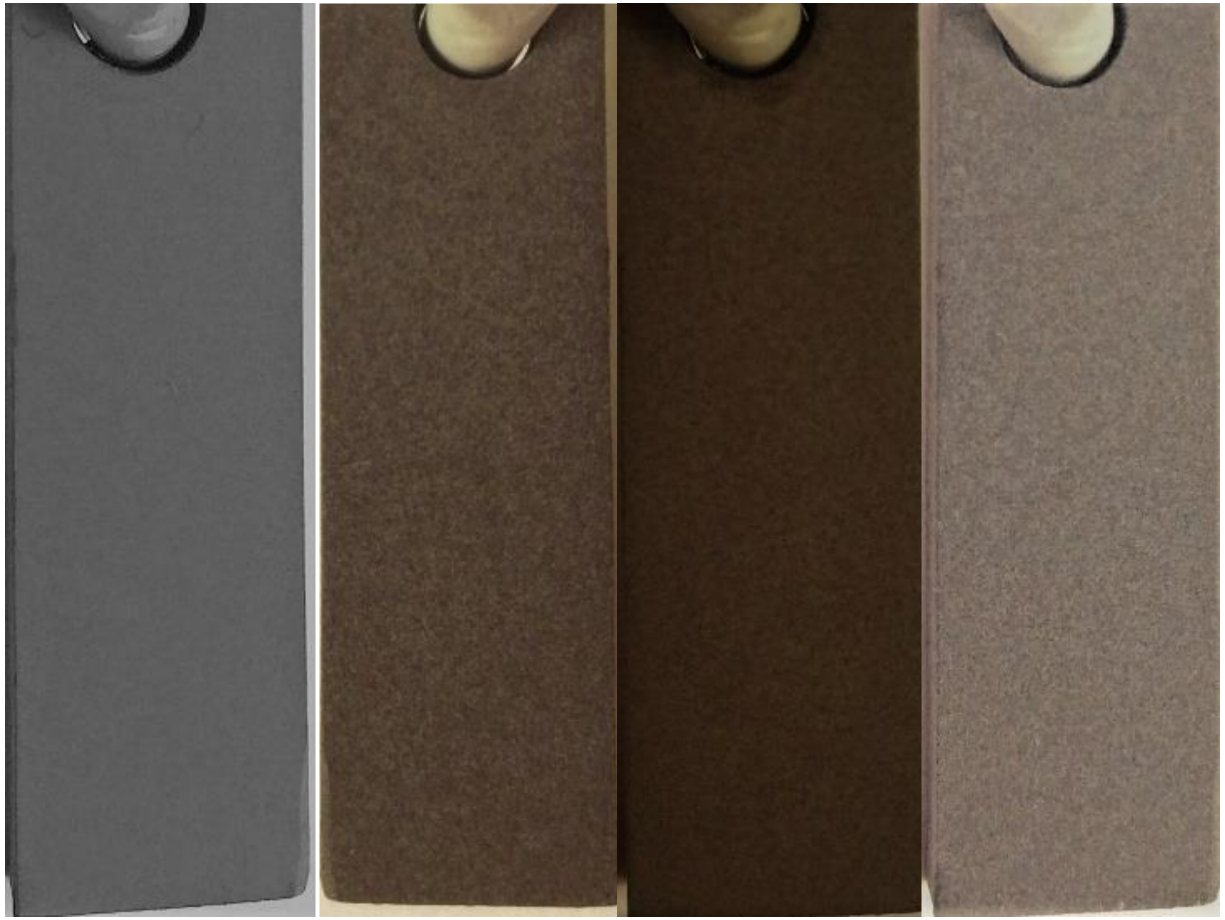
2024 alloy



Ti-6Al-4V

a) 10 min, b) 30 min, c) 60 min, d) 70 min

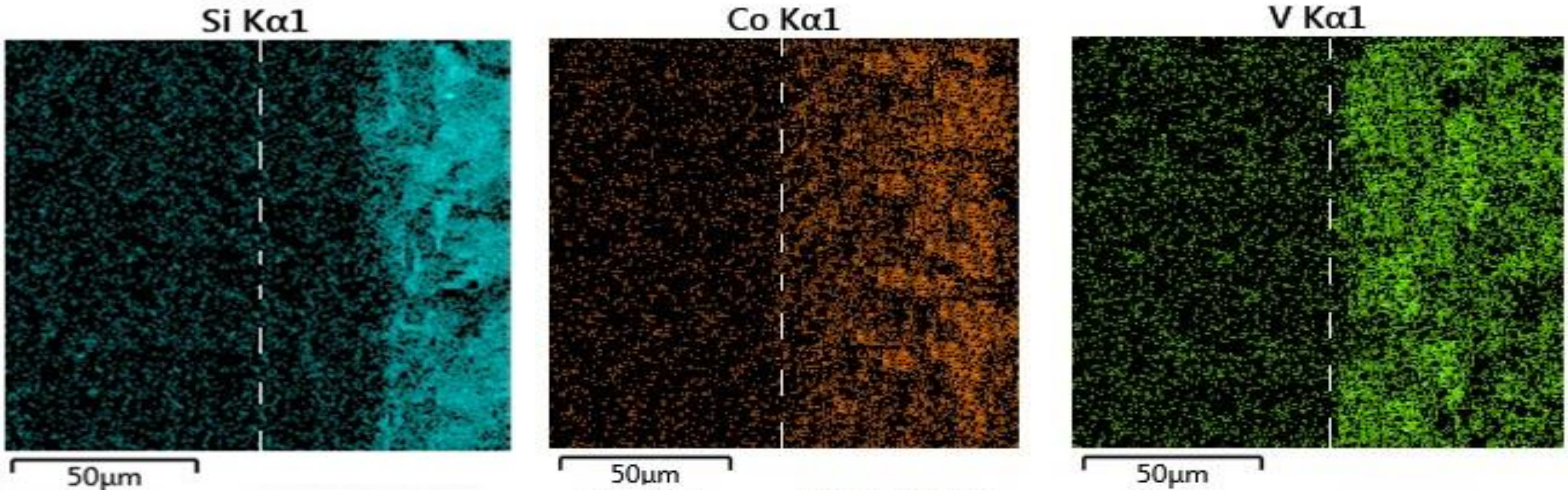
2024 alloy samples with coatings produced in basic electrolyte



a b c d

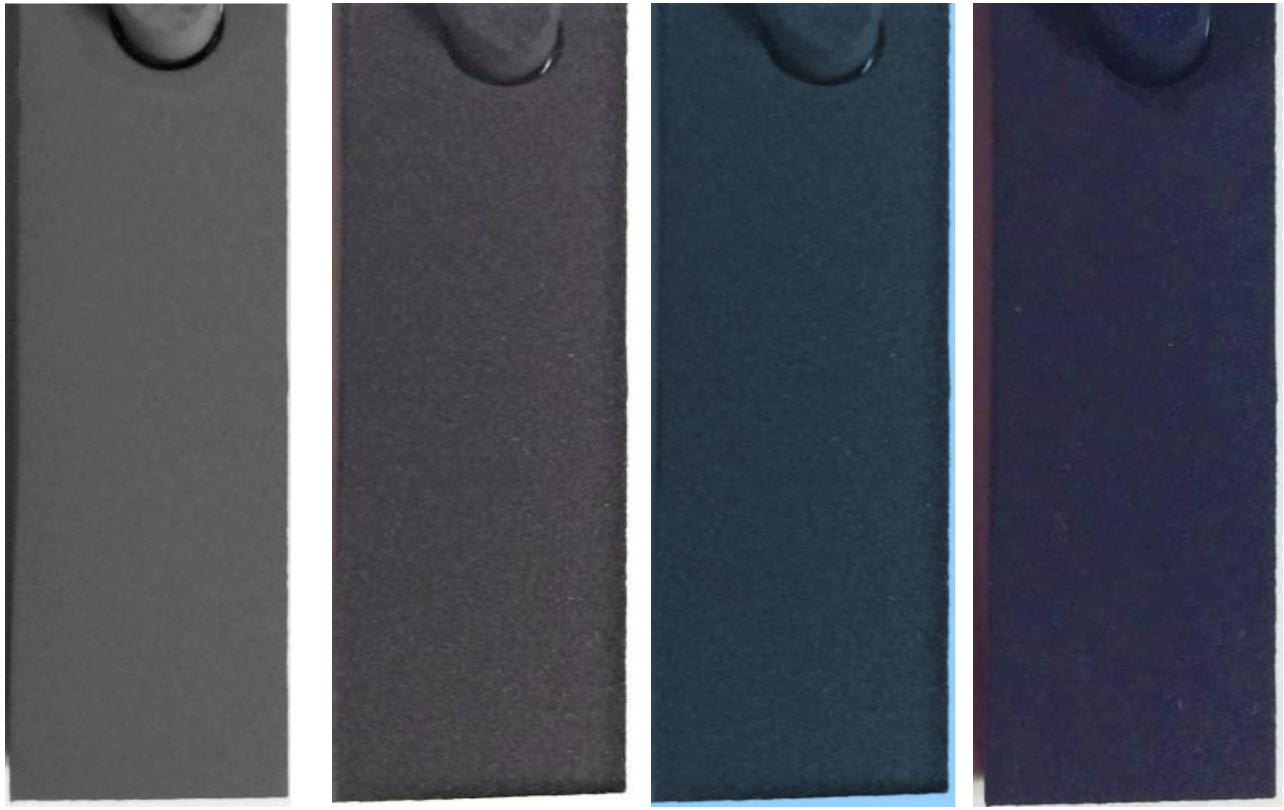
Coating thickness: a)10 mkm, b) 25 mkm, c) 50 mkm; d) 80 mkm

Si, Co, V allocation maps in coatings with thickness 80 mkm



alloy coating alloy coating alloy coating

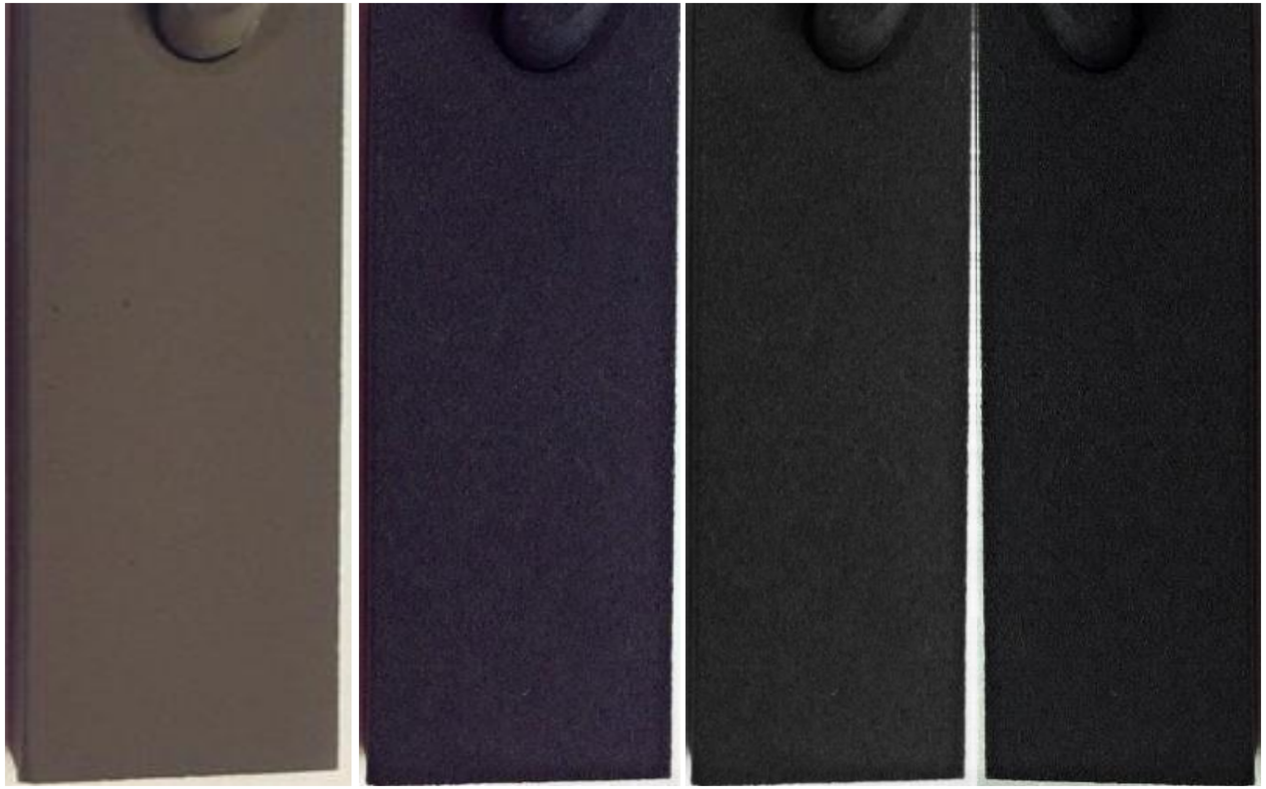
2024 alloy samples with coatings produced in basic electrolyte with addition of 3 g/l $Co(OH)_3$



a b c d

Coating thickness: a) 10 mkm; b) 25 mkm, c)50 mkm, d) 80 mkm

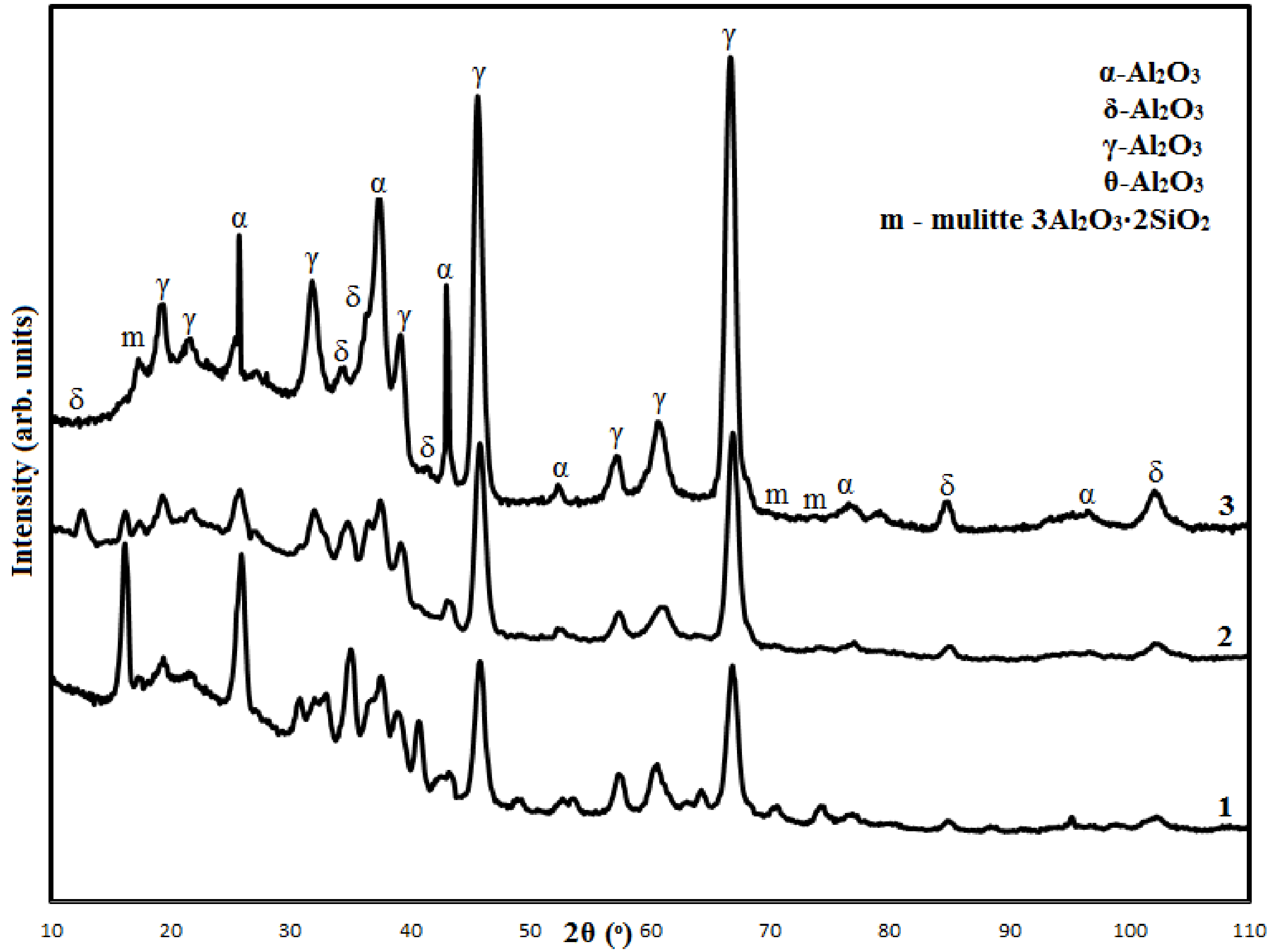
2024 alloy samples with coatings produced in basic electrolyte with addition of 3 g/l $Co(OH)_3$ and 3 g/l V_2O_5



a b c d

Coating thickness: a) 10 mkm; b) 25 mkm, c)50 mkm, d) 80 mkm

XRD patterns of coatings produced by PET on 2024 alloy in basic electrolyte (1), with addition of 3 g/l $Co(OH)_3$ (2), 3 g/l $Co(OH)_3$ and 3 g/l V_2O_5 (3)



Normalized wear of 2024 alloy (γ) and coatings ($\gamma_п$) with thickness 80 mkm

2027 alloy and coatings produced in aqueous electrolytes containing (g/l):	Average normalized wear ($mm^3/m*N$)	$\gamma/\gamma_п$
2027 alloy	$6{,}41 \cdot 10^{-4}$	—
Light grey coating produced in 2 NaOH, 10 Waterglass	$0{,}51 \cdot 10^{-4}$	12,6
Deep blue coating produced in 2 NaOH, 10 Waterglass, 3 $Co(OH)_2$	$0{,}29 \cdot 10^{-4}$	22,1
Black coating produced in 2 NaOH, 10 Waterglass, 3 $Co(OH)_2$, 3 V_2O_5	$0{,}60 \cdot 10^{-4}$	10,07

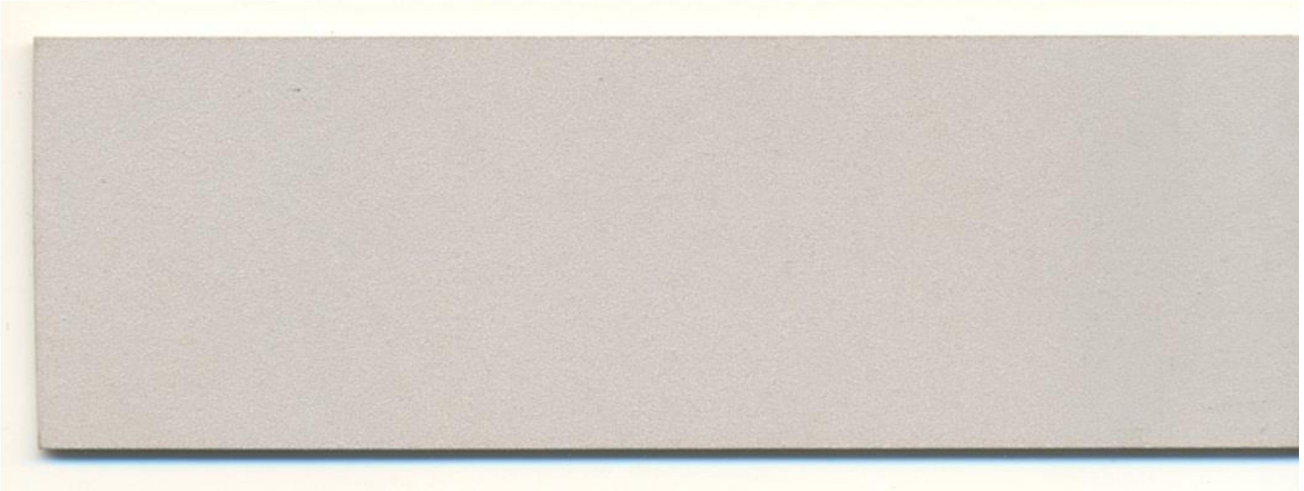
Deep blue (a) and black (b, c) coatings produced by PET on 2024 alloy samples

a) Ball valve b) Power supply adapter chassis

c) Weapon part

Aluminum samples with coatings produced by PET in alkaline solutions containing 180 g/l waterglass without (1) and with (2) addition of 8 g/l V_2O_5

1



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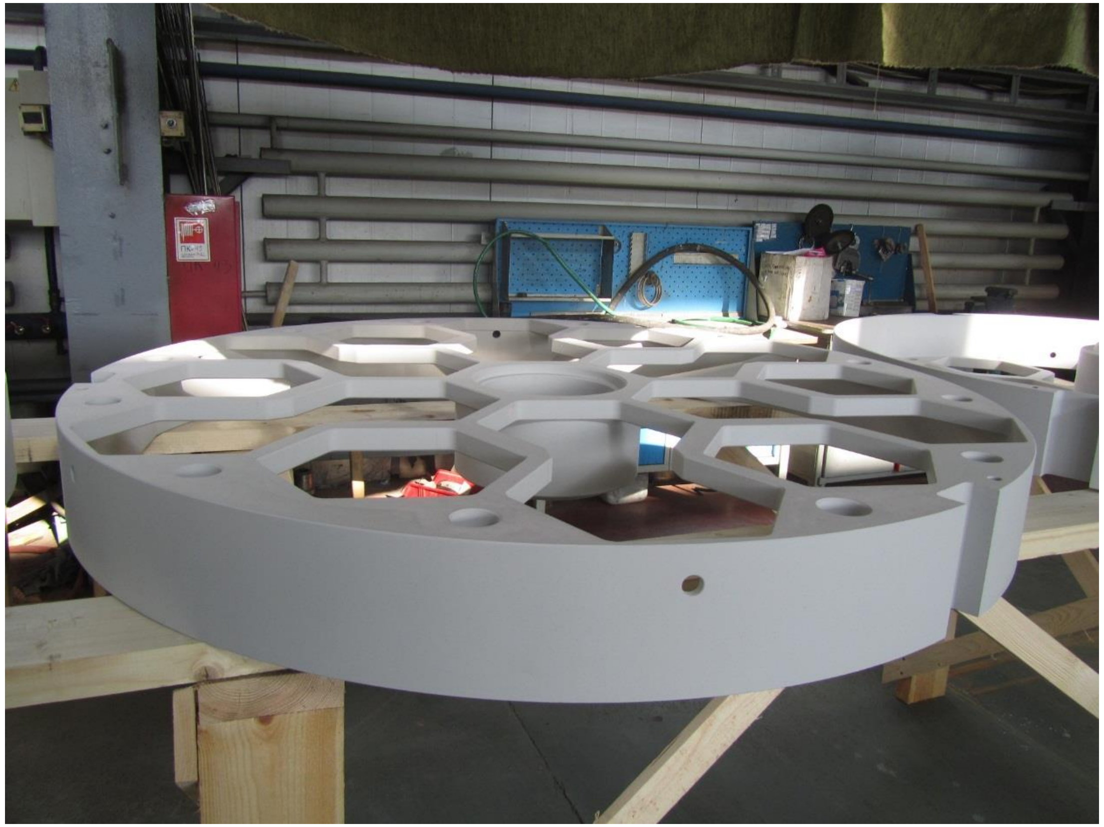
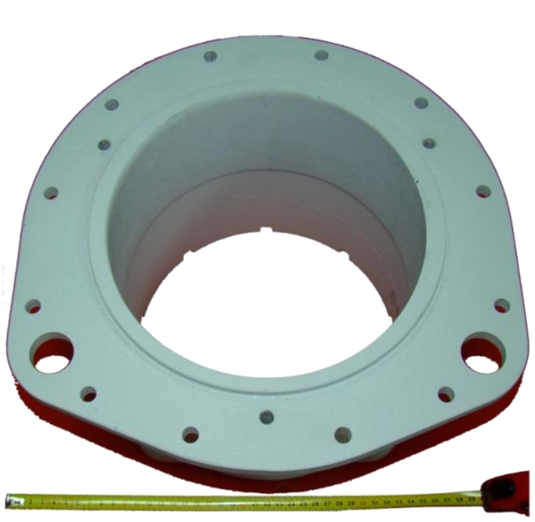
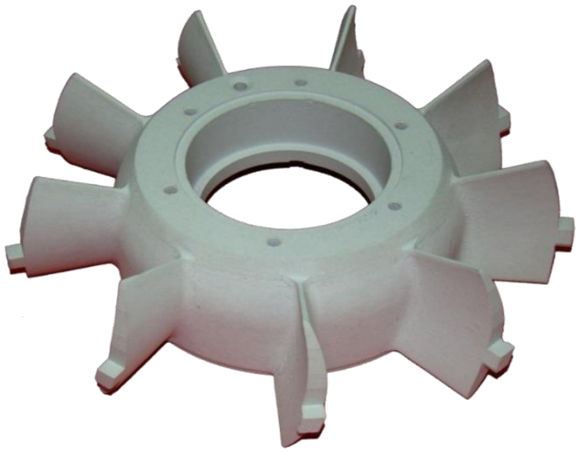
Part (diameter 3 m) of the inner shell of the reactor for radioactive waste storage (AK8 alloy coated with amorphous SiO2)



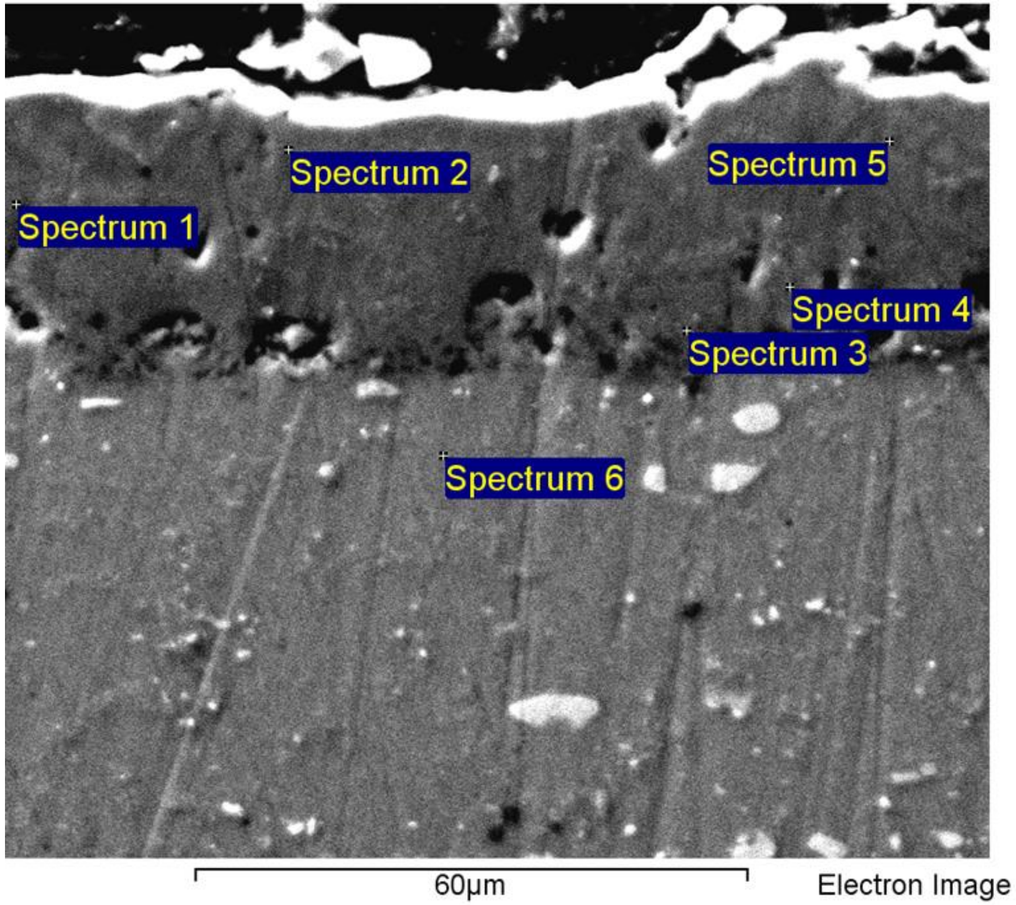
Examples of parts with a gray-white coating based on amorphous SiO2



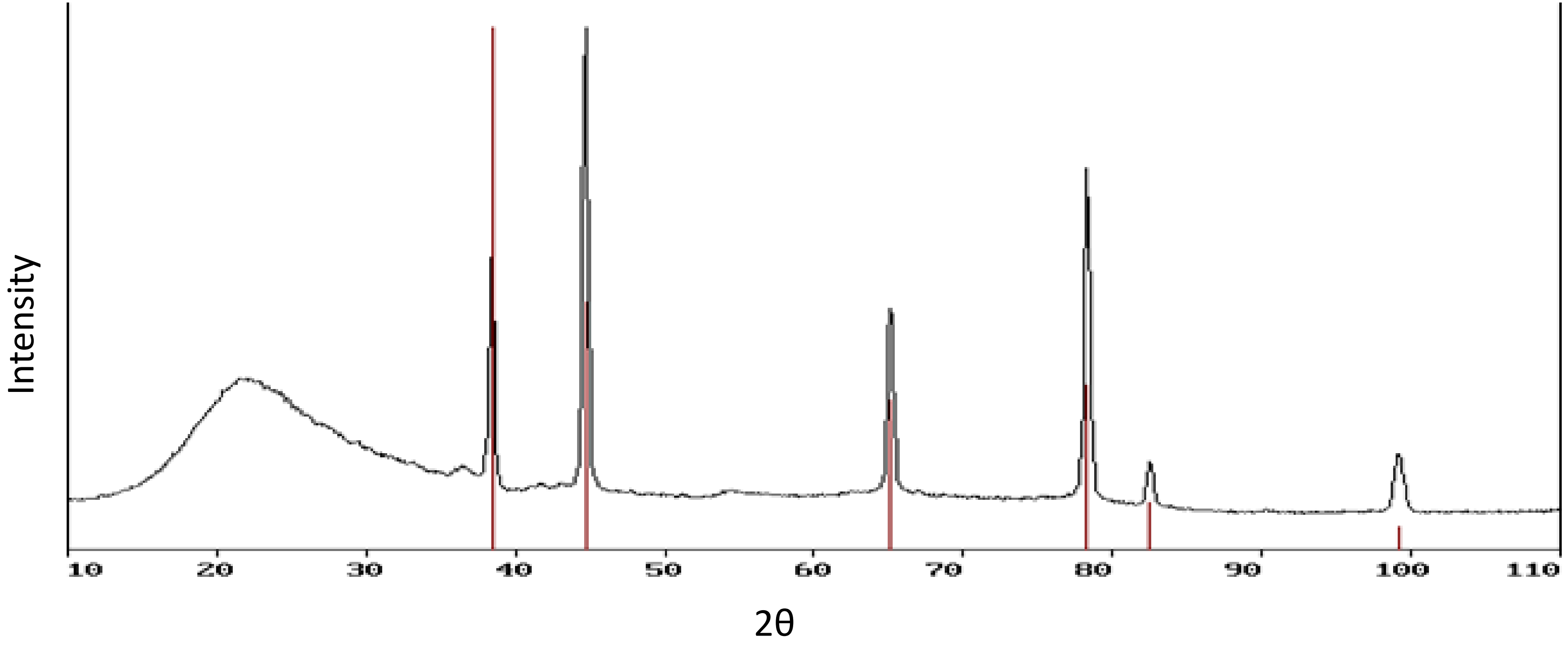
Photographs of samples after application of paintwork coatings on a gray-white sublayer based on SiO_2

Distribution of elements in coating and close layers of 2024 alloy



Spectrum	Contains, %wt.					
	Mg	Al	Si	V	Mn	Cu
1	-	13.62	73.38	13.00	-	-
2	-	3.59	79.06	17.35	-	-
3	-	96.27	-	-	1.23	2.50
4	-	95.14	2.63	-	-	2.23
5	0.73	9.36	70.08	19.83		-
6	1.66	95.04				3.30

XRD pattern of black coating with thickness 40 mkm produced by PET on 2024 alloy at 4 A/dm² current density



Samples with black anticorrosion resistance coatings on aluminum alloys

Conclusions

- Technological modes has been developed for producing coatings by PET: a) with different color on 2024 alloy. Black, light grey and deep blue coatings with thickness 80 mkm show high corrosion resistance and improve wear resistance more than 10, 12.5, 22 times correspondingly in “ball - disc” test with 5N load; b) light grey and black coating with high growth speed (more than 4 mkm/min on current density 4 A/dm^2). Coating color in that case doesn’t depend on wrought and cast aluminum alloys.
- It has been revealed that color transformation of coatings produced on aluminum alloys depends not only on compound’s nature (oxides, hydroxides), introduced into the composition of alkali-silicate electrolytes, but also on their geometric size and duration of the experiments. With an increase in the duration of PET processes, the density of surface microdischarges decreases and the intensity of the occurrence of the processes of entry into the coating of compounds from the electrolyte increases.
- It is shown that, in contrast to PET of a titanium alloy, in the case of PET of aluminum alloys, the growth of coatings primarily proceeds by the mechanism of oxidation of the pore bottom, and not by mechanisms of migration and diffusion of ions through the oxide coating and electrolysis, electrophoresis and / or thermolysis processes. Only with an increase in the duration of PET of aluminum alloys, the intensity of these processes increases significantly.

Thank you for your attention

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