

List of Figures

1.1	Joint-stock company FED	1
2.1	Vacuum-plasma cluster Avinit	3
2.2	The protocol of the automated system of registration of the basic technological parameters	9
2.3	Avinit C unit	10
2.4	Avinit V Unit (CVD)	13
2.5	CVD flow chart	13
2.6	Schematic diagram of the Avinit V gas-phase unit	16
2.7	Avinit V gas-phase mnemonic diagram	16
2.8	Avinit M unit	19
2.9	Avinit N unit	21
2.10	Avinit T unit to carry out thermal and chemical treatment processes. Own production	25
3.1	Discussion of scientific issues	28
3.2	Fragment of the automated process control system protocol of the TiN-AlN nanocoating: <i>a</i> – TiN-AlN (50/50) nanocoating with a recurrence period of 20 nm and the similar thickness of individual nanolayers; <i>b</i> – TiN-AlN nanocoating (30/70) with a recurrence period of 12 nm and a thickness of individual nanolayers of 4 and 8 nm	32
3.3	Distribution of characteristic X-ray radiation of element atoms in Avinit C320 coating: <i>a</i> – % Ti; <i>b</i> – % Al	34
3.4	Avinit C320 coating: <i>a</i> – appearance of Avinit C320 coating (cross-section); <i>b</i> – approximate chemical composition of the analyzed areas	35
3.5	The appearance of the Avinit C310 coating (cross-section) in the mapping mode of the coating area. The higher element content corresponds to the more intense coloring	36
3.6	Appearance of Avinit C310 coating in the in-line analysis mode	36
3.7	Load diagram for Measuring Nanohardness and Young's Modulus of Avinit C320 coating	37
3.8	Dependences of secondary Al ⁺ , Ti ⁺ ions currents on sputtering time: <i>a</i> – Avinit C320 coating; <i>b</i> – Avinit C310 coating	38
3.9	The appearance of the Avinit D/P 100 coating (Ti-C system-based) (cross-section) with the indicated areas of analysis – <i>a</i> ;	

List of Figures

	approximate chemical composition of the analyzed areas – <i>b</i> . The coating thickness is ~3.5 μm	44
3.10	Appearance of Avinit D/P 100 coating (Ti-C system based) (cross-section) in the mapping mode of the coating area. The higher element content corresponds to the more intense coloring. The coating thickness is ~3.5 μm	44
3.11	Appearance of Avinit D/P 200 coating (Mo-C system based) in the in-line analysis mode. The coating thickness is ~6 μm	44
3.12	Microstructure of Mo coatings	48
3.13	Prints of microhardness measurements of Mo coatings	48
3.14	The appearance of Mo coating on DIN 1.2379 steel samples with indicated analysis areas – <i>a</i> and chemical composition of analyzed areas – <i>b</i>	48
3.15	The appearance of Mo coating on DIN 1.2379 steel samples in the mapping mode. The higher element content corresponds to the more intense coloring	49
3.16	Microrelief of the sample surface (steel DIN 1.773)	49
3.17	Microrelief of the sample surface ((steel DIN 1.2379)	49
3.18	The appearance of Mo-C coating on DIN 1.2379 steel sample in the mapping mode	50
3.19	The results of chemical composition study MoS ₂ coatings	51
3.20	The results of chemical composition study coatings Cu-MoS ₂	52
3.21	Electron microphotography with marked X-ray spectral microanalysis areas	53
3.22	Friction factors	54
3.23	Dependence of the friction coefficient on the load for friction couples, worked without wear and scoring	55
3.24	The friction coefficient and temperature in the contact area over time	56
3.25	Generalized tribological test results	61
3.26	Development of new solutions with colleagues	64
3.27	Spherical surface of the plunger with a nanolayer Ti-based coating	67
3.28	Plunger with microlayer Mo-based coating	68
3.29	Avinit C350 coating based on (Ti-Al-N)	68
3.30	Avinit D100 coating based on Ti-C	68
3.31	Microstructure of molybdenum-carbide Mo-C coatings	69
3.32	Aviation units stems with molybdenum-carbide Mo-C coating	69
3.33	Typical volt-ampere characteristic (VAC) of a probe at a pressure of $1.2 \cdot 10^{-2}$ Torr, using which the plasma parameters (ion current, plasma density, electron temperature, degree of flow ionization) were calculated	71
3.34	Plasma spectral parameters	71
3.35	Depth of nitrided layer on 34NiCrMoV14-5 steel ($\times 500$)	72

3.36	The microstructure of the nitrided layer on 34NiCrMoV14-5 steel ($\times 500$)	72
3.37	The nitrided layer depth ($\times 500$)	73
3.38	Imprints of microhardness measurements (unetched polished section)	73
3.39	Imprints of microhardness measurements (etched polished)	73
3.40	Scheme of a technological sample from DIN 3.7165 titanium alloy	74
3.41	The hardness of the nitrided layer. Side No. 1	74
3.42	The hardness of the nitrided layer. Side No. 2	74
3.43	The microstructure and thickness of the nitrided layer Side No. 1, $\times 200$	75
3.44	The microstructure and thickness of the nitrided layer Side No. 2, $\times 500$	75
3.45	Alphated nitrided layer from side No. 1, $\times 500$	75
3.46	Nitrided layer from side No. 2, $\times 500$	75
3.47	The microhardness measurements imprints. Side No. 1	75
3.48	The microhardness measurements imprints. Side No. 2	75
3.49	Plasma nitriding of Avinit N steels 34NiCrMoV14-5. Depth of the nitrided layer 0.3 mm. Microhardness $H\mu=730-930$	78
3.50	Freewheel clutch separator. Plasma nitriding of Avinit N+coating Avinit C	79
3.51	The structure of the nitrided layer. Depth of the nitrided layer 0.2 mm. Microhardness $H\mu=730-830$. Coating thickness Avinit C 1.5 μm . Microhardness $H\mu=3000$	79
3.52	Plasma nitriding of Avinit N	79
3.53	Housing from DIN 3.7165 titanium alloy. The structure of the nitrided layer on the inner cylindrical part of the housing surface	79
3.54	Slide valve. Structure of nitrided layers on slide valve surface	80
3.55	Authors process development	80
3.56	Parts of aircraft units coated with molybdenum disulfide	81
3.57	Parts of aircraft units coated with molybdenum disulfide	81
3.58	Pistons D80.0406-1 of the D80 diesel engine with Avinit C220 anti-scoring wear-resistant coatings	83
3.59	Valve oil piston rings with Avinit hardening coatings	84
3.60	Avinit anti-friction coatings on the sliding bearings (liners) work surface for internal combustion engines	84
3.61	Technological equipment for producing liners with Avinit hardening anti-friction coating	84
3.62	Diesel unit	85
3.63	Multifunctional fuel cell system	86
3.64	Layer of layers of single FC with electrolyte based on barium cerates	86

List of Figures

3.65	Sketch of a single fuel cell: 1 – Bearing base; 2 – Collector; 3, 7 – Current leads; 4 – Cathode; 5 – Solid electrolyte; 6 – Anode	87
3.66	Comparative diffraction spectra of BCN in coatings and spray targets	87
3.67	Raster microscopy of the test specimen: BCN (base) – MLS (coating) – Pt (baked paste), $\times 3300$	87
3.68	Surface morphology: <i>a</i> – BCN electrolyte; <i>b</i> – Ni-BCN layer; <i>c</i> – Ni-Cr coating at Ni-BCN anode, $\times 1500$	88
4.1	Certificates of JSC FED	91
4.2	Parts of Avinit C310 serial aviation hydraulic units with nanocoating	92
4.3	Hydraulic units cradles with Avinit C310 nanocoating	92
4.4	Slide valves of hydraulic units coated with Avinit C320 [21–24]	93
4.5	Slide valves of hydraulic units with Avinit C 310 coating [25–28]	93
4.6	Serial parts of aviation hydraulic units, nitrided by plasma precision nitriding	94
4.7	Serial nitriding of gear wheels (34NiCrMoV14-5)	95
4.8	Serial nitriding of titanium DIN 3.7165 housings	95
4.9	Upgraded automated vacuum-thermal installation for diffusion welding and thermal treatment with horizontal loading, forced gas cooling of the melting charge	95
4.10	One-chamber vacuum automated installation of diffusion welding and heat treatment of parts with forced gas cooling of melting charge	96