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Wear-Resistant Metal-Like Connections

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Abstract: This article discusses proposals and recommendations for increasing the wear resistance of parts by studying the composition and structure of metal-like materials when restoring working surfaces.

Keywords: hardness, wear resistance, metal, carbide, metal-like nitrides, microhardness, chromium, coatings.

Metal-like transition metal carbides with unfilled d-electron shells have high hardness and wear resistance. They represent phases of embedding or structures close to them, in which carbon atoms occupy octahedral or tetrahedral voids of densely packed metal sub lattices.

Carbide powders are used for metal processing. Some carbide parts are manufactured using powder metallurgy methods (pressing followed by sintering or hot pressing). Carbides are widely used as the main component of hard alloys, surfacing materials, and surface coatings (applied by gas-phase, detonation, and other methods). Carbides serve as the hardening phase of alloy steels and surface layers formed during cementation, nitro cementation, carbonitration, etc. The hardening carbide phase is also formed during the diffusion saturation of carbon steels with active carbide-forming elements (for example, chromium), as well as during contact eutectic melting with carbon (graphite) of steels and nickel alloys containing carbide-forming alloying elements.

An effective new technological method for producing carbides, as well as other refractory compounds, is self-propagating high-temperature synthesis (SHS).

Metallophobic transition metal nitrides with unfilled d- and f-shells have high resistance to abrasive wear (Table 1).

Metal-like nitrides - metal conductors with high thermal conductivity - represent the phases of embedding with cubic and hexagonal structures. Their plasticity is higher than that of other refractory compounds (carbides, borides, silicide). A wide area of homogeneity is characteristic of metal-like nitrides. They are used as hardeners of a plastic metal matrix in composite materials, as well as in the form of coatings applied by gas-phase and vacuum ion plasma methods. The hardness of nitride coatings obtained by these methods significantly exceeds the hardness of compact materials. Hard alloys are created using nitrides as a solid component.

Borides of transition metals of groups IV-VI of the Periodic Table of Elements have high hardness and wear resistance (Table. 2) and rare earth metals.

Structure and properties of metal-like nitrides Table 1

Nitride	Crystal lattice	The area of homogeneous news, at. shares N. %	ρ, t/m^3	T$_{pd}$, °C	H, MPa	$\rho_1 \cdot 10^8$, Om·m	E·10^{-5}, MPa	$-\Delta G_{298}$, kJ ·mol^{-1}

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TiN	HCC	37,5-50,0	5,43	3200	20 000	25	3,9-5,0	294,34
ZrN	HCC	46-50	7,09	2980	18 500	21	3,0-4,5	342,96
HfN	HCC	-	13,84	3000	21 500	33	4,8	345,45
V3N	GPU	25-33	5,97	-	19 000	123	-	-
VN	HCC	41-50	6,04	2050	15 200	85	3,5-4,6	192,01
Nb2N	GPU	28,5-33,5	8,23	2420	17 200	142	-	-
NbN	GPU	50,0-50,6	8,40	2300	16 500	78	4,0-4,836	194,83
Ta2N	GPU	28,5-31,0	15,81	2050	12 200	263	-	242,36
Cr2N	GPU	44,5-47,3	15,46	3087	10 800	128	5,758	223,85
Cr2N	GPU	32-33	6,51	1650	15 700	84	3,10	-
CrN	HCC	-	6,14	1500	10 930	640	3,198	-
Mo2N	HCC	32-33	9,44	895	6 300	20	-	
WN	HCC			Decomposes when T>>700 °C				

The structure of the lower borides (metal-rich) is determined by a metal sublattice. In higher borides (boron–rich), the structure is determined by boron atoms forming rigid sublattices with covalent boron-boron bonds in the form of grids.

The formation of mutual solid solutions of borides, as a rule, leads to an improvement in properties compared to the initial borides. For example, double titanium–chromium boride (solid solution TiB 2 and CrB2) has higher hardness, wear resistance and heat resistance than single borides.

With an increase in the boron-metal ratio, the electrical resistivity and the coefficient of thermal expansion decrease, the melting point, microhardness increase and other mechanical characteristics improve. This indicates the strengthening of interatomic bonds in the lattice during the transition from lower borides to higher ones.

During the transition from group IV metal diborides to group V diborides and then to group VI, the melting temperature, microhardness and modulus of elasticity decrease, and the coefficient of thermal expansion increases.

Structure and properties of borides Table 2

Borid	Crystal lattice	ρ, t/m^3	T_{pd}, °C	H, MPa	$\rho_1 \cdot 10^8$, Om·m	$\alpha \cdot 10^6$, °C^{-1}	E·10-5, MPa	$-\Delta G_{298}$, kJ·mol^{-1}
TiB2	Hexagonal	4,45	2980	34800	9,0	4,5	5,405	319,5
ZrB2		6,17	3200	21900	9,7	5,9	4,958	323,62
HfB2		10,5	3250	29000	10,6	6,3	4,797	325,50
VB2		5,1	2400	28000	22,7	7,9	3,404	-
NbB	Rombic	7,6	2300	22000	40,0	12,9	-	-
NbB2	Hexagonal	6,97	3000	26000	25,7	7,7	6,376	-
TaB2		11,7	3037	26000	32,5	7,9	6,867	188,25
Cr2B	Rombic	6,5	1870	13500	107,0	14,2	4,101	-
CrB		6,2	2100	21000	45,5	12,3	3,606	77,04
CrB2	Hexagonal	5,6	2200	22000	30,0	10,5	4,503	123,23
MoB2	Tetragonal	8,8	2600	23000-24500	-	-	-	70,74
WB		16,0	2300-2920					71,11

Borides are used for the manufacture of nozzles of installations spraying liquid metals, boats, crucibles, as protective coatings on hard-melting metals (titanium borides, zirconium, niobium and chromium), as well as highly wear-resistant coatings and surfacing on steels and cast iron (titanium borides, chromium and their alloys).

Silicide of transition metals of groups IV-VI of the Periodic Table of Elements are used in aircraft construction, nuclear, rocket and space technology, mainly as heat-resistant and heat-resistant materials, as well as protective coatings. The properties of the "big nine" metal disilicides of refractory metals are shown in Table 3.

Molybdenum disilicide has received the greatest use due to the fact that it has good electrical conductivity and high resistance to oxidation. Electric heating elements are made of it, which are operated in air at temperatures up to 1600 ° C.

Properties of disilicides Table 3

Material	Density, t/m^3	T_{pd}, °C	H, MPa	E·10^{-5}, MPa	α·10^6,°C^{-1} (in the interval 20-1000°C)	$-\Delta G_{298}$, kJ·mol^{-1}
TiSi2	4,13	1540	8920	3,551	10,3	132,15
ZrSi2	4,86	1700	10630	2,599	8,37	149,36
HiSi2	9,03	1750	9120	-	-	225,94
VSi2	4,66	1660	8900-9600	-	12,0	148,47
NbSi2	5,66	2100	10820	2,551	10,6 (20-1100 °C)	123,32
TaSi2	9,1	2200	14070	-	10,2	116,01
CrSi2	5,0	1500	9960-11500	-	12,9 (20-700 °C)	98,77
MoSi2	6,24	2030	12000-13500	4,405	8,3	118,49
WSi2	9,25	2165	13000-14000	5,307	7,35	91,86

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