Influence of nitrogen pressure on mechanical properties of nanostructured VMoN coatings

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INTRODUCTION

Transition-metal (TM) nitrides are refractory ceramics with exceptional properties, including high hardness, good wear and abrasion resistance, low friction, high-temperature stability, and chemical inertness. To achieve tool durability under various operating conditions it is, therefore, necessary to design hard coating materials with enhanced ductility [1]. Density functional theory predicted on toughness enhancement in hard ceramic films, by increasing the valence electron concentration for example the $V_{1-x}Mo_xN$ alloy system [2].

The goal of this study was to investigate structure and mechanical properties of VMoN coatings deposited using cathodic arc evaporation with different nitrogen pressure.

EXPERIMENT

The VMoN coatings were deposited using unfiltered cathodic arc plasma method at reactive gas N_2 with different pressure. A "Bulat-6" system equipped with a V (99.99%) and Mo (99.9%) cathodes was applied as a deposition system. The thickness of all deposited coatings was about 10 µm.

The surface morphology, microstructure and chemical composition of VMoN coatings were investigated using Scanning Electron Microscopy (SEM), X-ray Diffraction (XRD, Cu-Kα ($\lambda_{Cu-K\alpha}$ = 0,154178 nm) and Energy Dispersive X-ray Spectroscopy (EDS). The mechanical properties of coatings were characterized using nanoindentation (Nano Indenter G200). The adhesion was also studied using the Rockwell test. The additional estimation of the crack propagation in VMoN coatings was used via Vickers indentation at the load of 10 N.

RESULTS

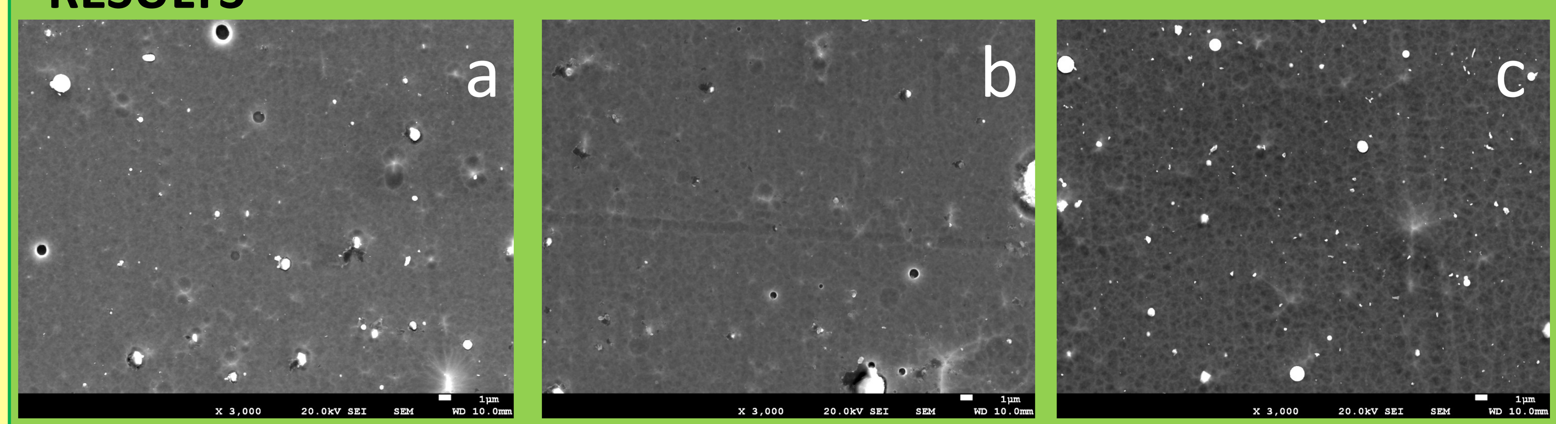

Fig. 1. Surface morphology of VMoN coatings investigated using SEM: (a) VMoN (1), VMoN(2) (b) VMoN(3) (c).

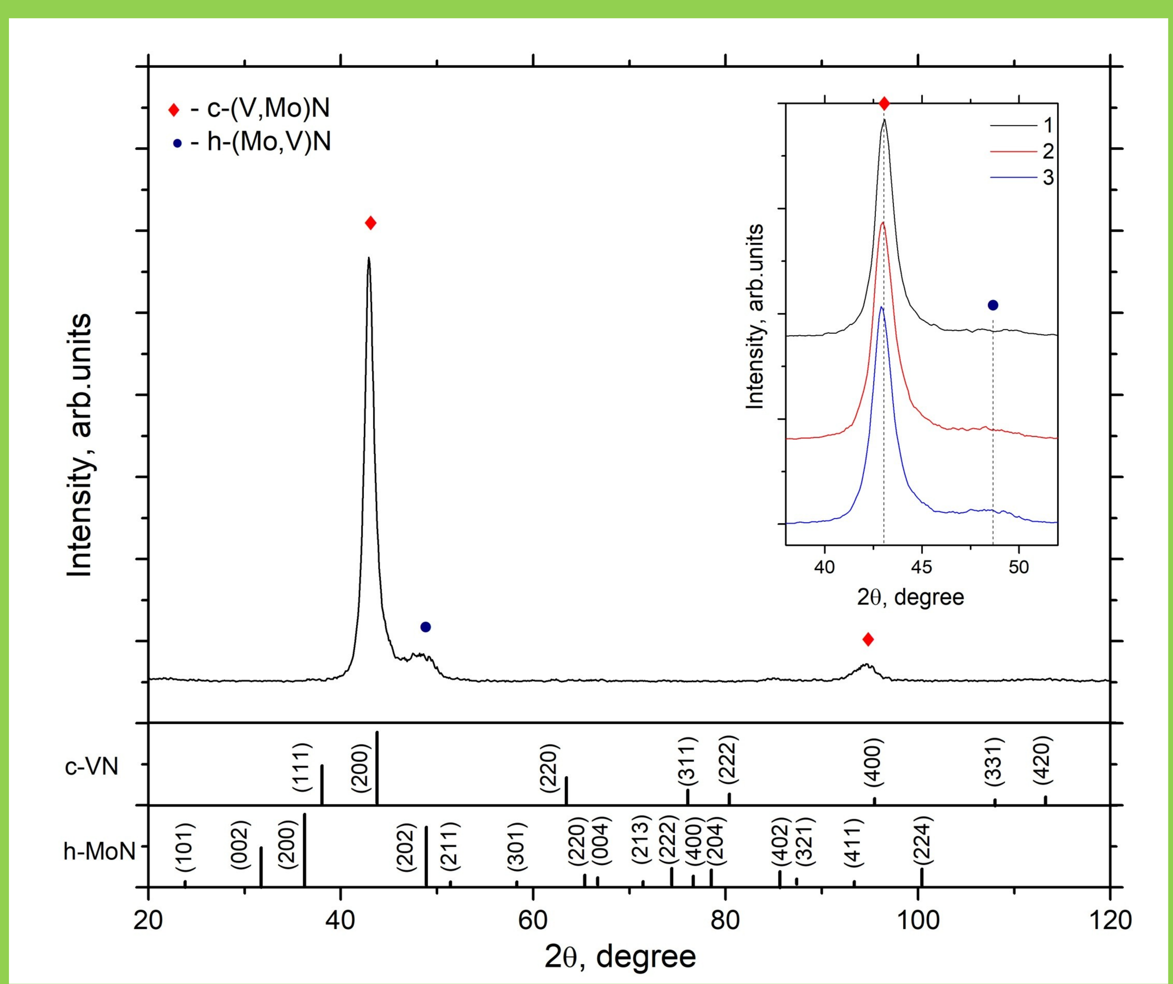

Fig.2. Diffraction patterns of V-Mo-N coatings obtained at different nitrogen pressures.

The possibility of the formation of cubic solid solutions in the V-Mo-N system with a wide range of element concentrations is largely due to the fact that the VN (JCPDS No. 35-0768) and γ-Mo_2N (JCPDS No. 25-1366) compounds have a similar crystal structure. The metal atoms are located at the sites of the fcc lattice, and the nitrogen atoms occupy the octahedral voids of the base metal, and in the case of molybdenum, only half of the voids are filled. Apparently, in the obtained coatings, the components are on the verge of solubility.

With an increase in the content of Mo and N, which is observed with an increase in the gas pressure during the deposition of the coating, an increasing number of these elements are unable to dissolve in the c- (V, Mo) N cubic lattice and are precipitated as a hexagonal phase h- (Mo, V) N.

Table 1. Chemical composition, hardness, elastic modulus, deformation relative to yielding (H/E), resistance to the plastic indentation (H^3/E^2) of VMoN coatings.

Nitrogen pressure, Pa	Element concentration, at%	H, GPa	E, GPa	H/E	H^3/E^2, GPa
1	$V_{29}Mo_{21}N_{50}$	32±3	425±25	0.075	0.181
2	$V_{23}Mo_{25}N_{52}$	30±2	400±10	0.075	0.169
3	$V_{20}Mo_{26}N_{54}$	31±2	450±20	0.069	0.147

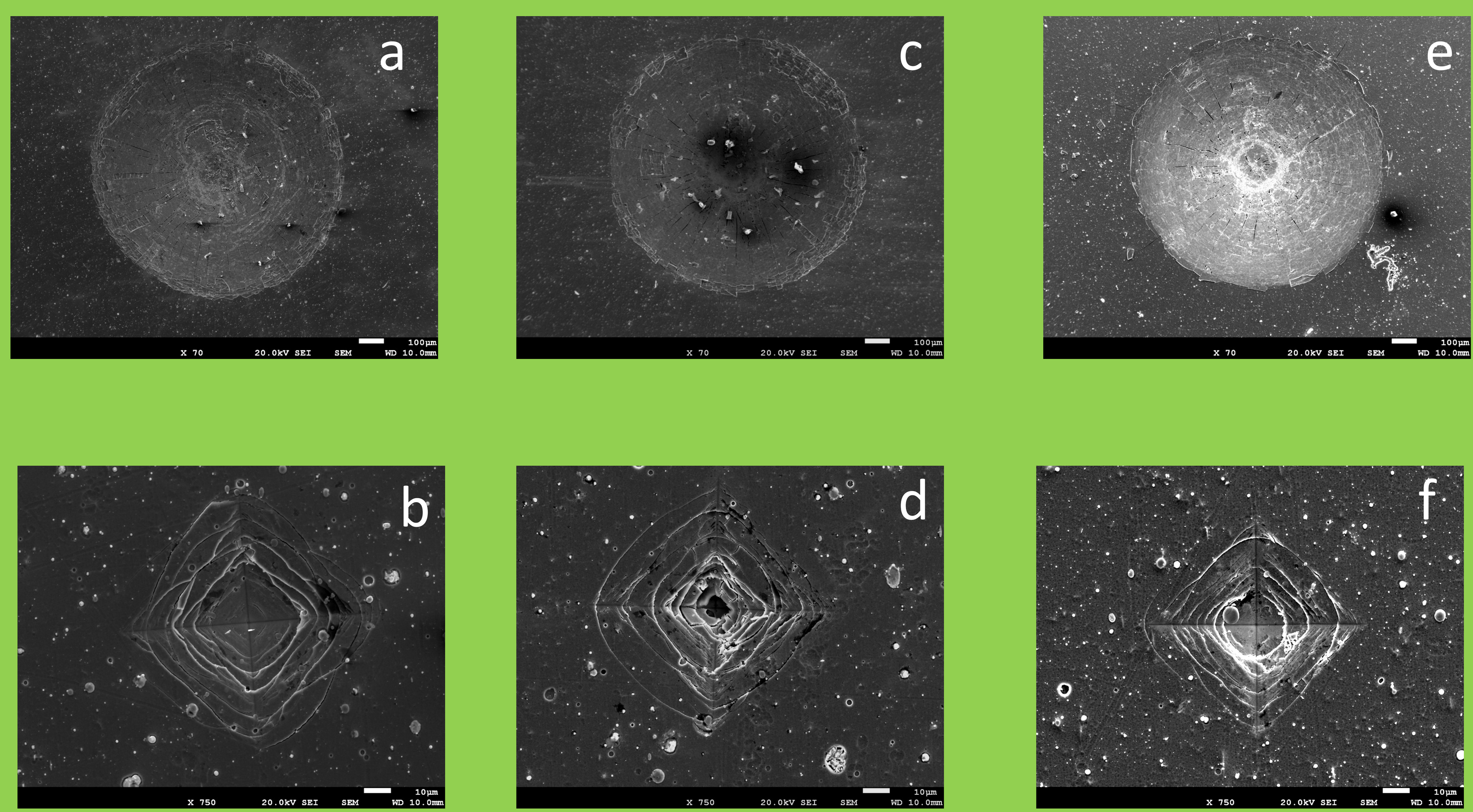

Fig. 3. Images of failure modes after Rockwell C (a,c,e) and Vickers (b,d,f) indentations for: VMoN(1) (a,b), VMoN(2) (c,d), and VMoN(3) (e,f).

Table 2. X-ray structural analysis results of VMoN coatings.

Nitrogen pressure, Pa	Main phase	Structure type	Crystallite size, nm	Lattice parameter, nm
1	(V,Mo)N	NaCl (B1)	9,5	0,4199
2			8,0	0,4204
3			7,7	0,4208

CONCLUSION

The absence or slight radial cracks were observed, indicative of good cohesion and no delamination on good adhesion of VMoN coatings independent on element concentration.

According the results of Vickers indentation and SEM scans of imprints in VMoN coatings Palmquist cracks around the imprints were not observed.

The obtained results demonstrate that VMoN coatings deposited by CAE at 1 Pa nitrogen pressure have high hardness and ductility.

References:

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2. H. Kindlund, D.G. Sangiovanni, I. Petrov, J.E. Greene, L. Hultman. A review of the intrinsic ductility and toughness of hard transition-metal nitride alloy thin films // *Thin Solid Films* 688 (2019) 137479.