Effect of modulation structure on the microstructural and mechanical properties of TiAlSiN/CrN thin films prepared by HiPIMS process

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Abstract

The TiAlSiN/CrN multilayer coatings were deposited on silicon Si (100) substrates and cemented carbide (WC-10 wt.%, Co) substrates at 80℃ using both metallurgical TiAlSi alloy target and Cr target, with varying modulation period (Λ) from 27 nm to 2 nm, by reactive high power impulse magnetron sputtering technique (HiPIMS). The modulation structure characteristics of the TiAlSiN/CrN multilayer was first investigated, and then the microstructure evolution and mechanical properties of TiAlSiN/CrN coatings with decreasing modulation period (Λ) were analyzed by TEM, SEM, XRD, Scratch test, Rockwell hard meter and Nano-indenter. It was found that the grain size of TiAlSiN/CrN multilayer increased with an decreasing modulation period (Λ). The hardness and elastic modulus of the multilayer reached their maximum when Λ is about 8.5 nm. The hardness, H^3/E^{*2} ratios and critical loads *LC* in scratch test showed an initial increase, followed by a decrease with an decreasing modulation period (Λ). The modulation period (Λ) at 8.5 nm exhibited highest hardness, H^3/E^{*2} ratios and critical loads.

Results and discussion

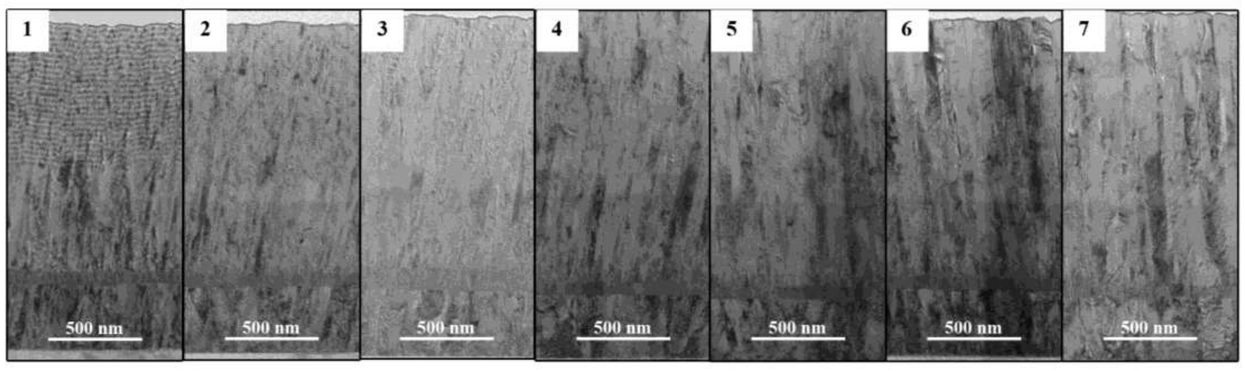

Fig 1. Cross TEM overall micrograph of TiAlSiN/CrN coating with various modulation period Λ(1=27nm;2=11nm;3=8.5nm;4=7.5nm;5=4.5nm;6=3.0nm;7=2.0nm)

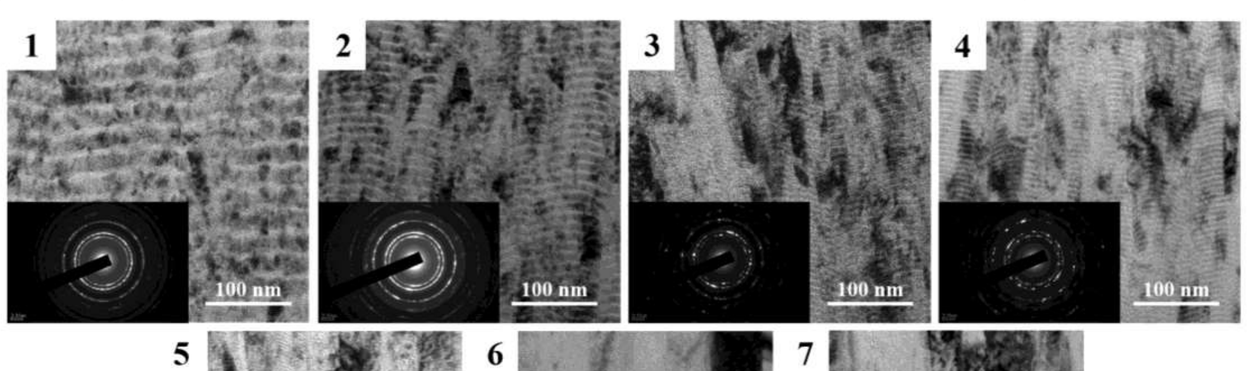

Fig 2. Cross TEM micrograph and SAD patterns of TiAlSiN/CrN multilayer with various modulation period Λ(1=27nm;2=11nm;3=8.5nm;4=7.5nm;5=4.5nm;6=3.0nm;7=2.0nm)

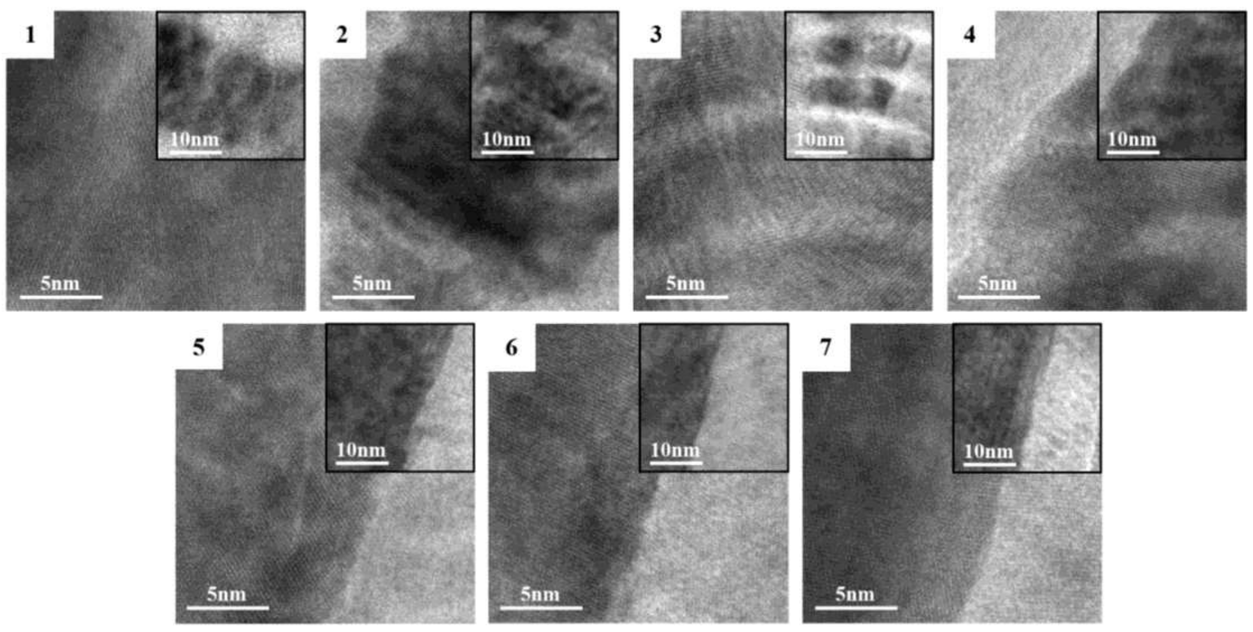

Fig 3. HRTEM micrograph of TiAlSiN/CrN multilayer with various modulation period Λ(1=27nm;2=11nm;3=8.5nm;4=7.5nm;5=4.5nm;6=3.0nm;7=2.0nm)

Table 1 . Crystallite size and lattice strain TiAlSiN/CrN multilayer with various modulation period Λ

Λ (nm)	Orientation (111)		Orientation (200)	
	Crystallite size (nm)	Lattice strain(%)	Crystallite size (nm)	Lattice strain(%)
2.0	87	1.01	82	1.15
3.0	94	0.89	72	1.18
4.5	128	0.63	112	0.80
7.5	114	0.77	134	0.68
8.5	131	0.70	139	0.68
11.0	136	0.61	122	0.70
27.0	145	0.63	145	0.64

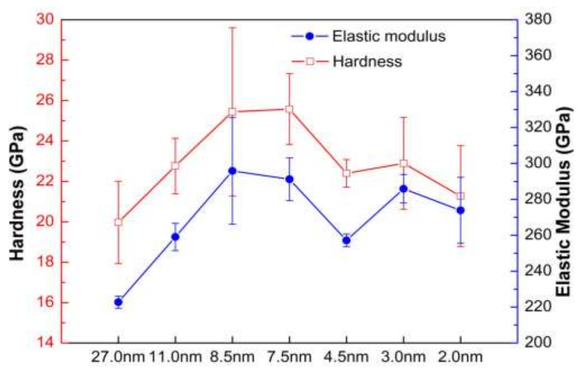

Fig 5. Hardness and Young's modulus of TiAlSiN/CrN multilayer with various modulation period

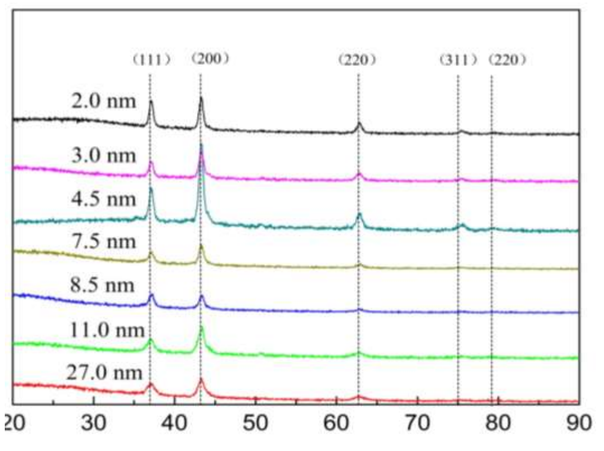

Fig 4. HAXRD patterns of TiAlSiN/CrN multilayer with various modulation period Λ

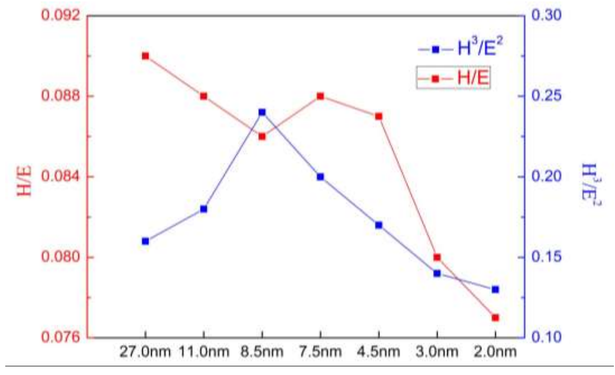

Fig 6. H/E* and H^3/E^{*2} ratios of TiAlSiN/CrN multilayer with various modulation period

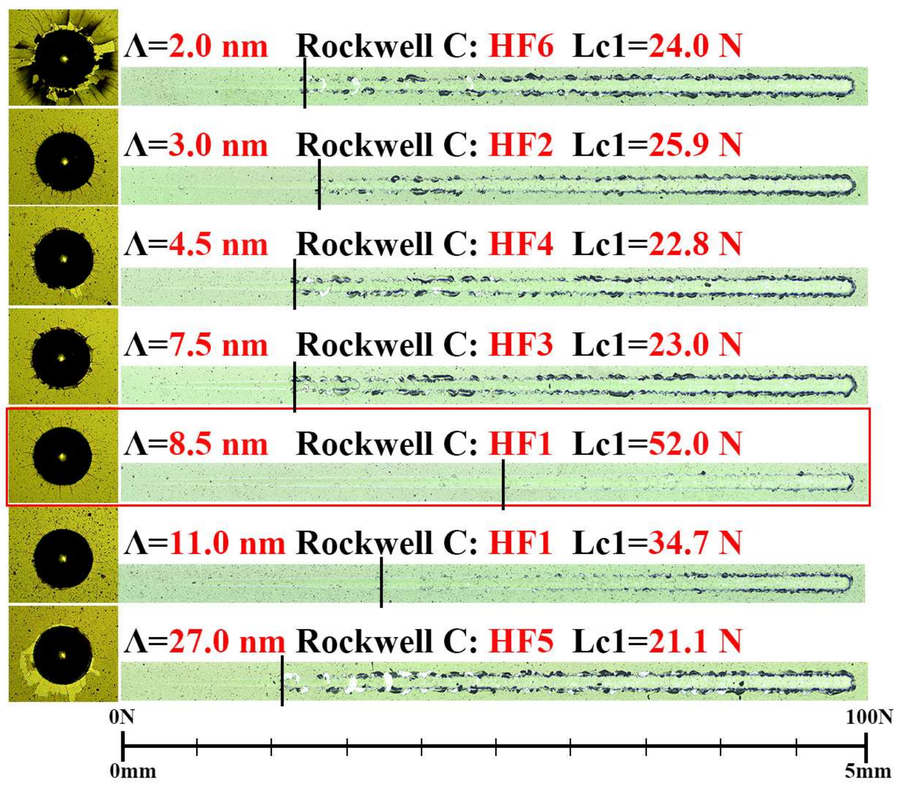

Fig 7. The optical morphologies of scratch tracks and Rockwell of TiAlSiN/CrN multilayer with various modulation period

Results and discussion

- All multilayers with clear interfaces displayed in cross-section TEM by using HiPIMS deposition technology.
- When an increasing modulation period (Λ), lattice strain is decreased with crystallite size increasing.
- The maximum hardness of 26 GPa and the critical load of 52 N were obtained for the multilayer with a Λ of 7.5 – 8.5 nm.
- Therefore, the microstructure and mechanical properties of the TiAlSiN/CrN nano-multilayers thin films strongly depended on the thickness of the modulation structure.