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Atomic-scale strengthening mechanism of transition-metal nitrides (TM=Ti, Zr, Hf, V, Cr) single phase films with large composition ranges

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Five groups of transition-metal nitride(TM=Ti, Zr, Hf, V, Cr) films with different nitrogen contents were synthesized on the Si(100) substrates by magnetic filtering arc ion plating for further study on the atomic-scale strengthening mechanism. The morphologies, thickness, microstructures, residual stress, composition, hardness and elastic modulus of as-deposited films were characterized by FESEM, GIXRD, XPS and NanoIndenter. The results showed that TMNx films all have the single-phase structure within large composition ranges. The preferred orientation, thickness, grain size and residual stress keep consistent in the five groups respectively. The nanohardness and elastic modulus of TMNx films all first increase and then decrease as the nitrogen content x rise, TiNx, ZrNx and HfNx films reaching the top near x=0.82, VNx films at x=0.93, CrNx films at x=1.0. The strengthening mechanism was discussed and found the decisive factors of hardness enhancement come from the atomic-scale chemical bonding and the different electronic structure, rather than the conventional meso-scale factors, such as preferred orientation, gain size and residual stress.

Keywords

Transition-metal nitride films
Arc ion plating
Mechanical properties
Nitrogen content x
Strengthening mechanism