FRACTURE BEHAVIOUR OF Ti/TiN MULTILAYER THIN FILM – MODELING AND EXPERIMENTAL VALIDATION

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Key Words: Multilayers, Titanium nitride, FEM, Cantilever bending, Fracture mechanics

Although titanium nitride is used as a hard protective coating, it is brittle. The multilayering of Ti/TiN film improves the nitride coating's damage tolerance and expands its applications. The influence of layer spacing on multilayer fracture toughness (K_{IC}) is not known and quantification is important for designing a multilayer with enhanced damage tolerance. The effect of multilayering on the crack tip driving force is investigated using finite element method (FEM) in this work. Elastic-plastic mismatch in Ti/TiN system is incorporated in simulation. Numerical simulations are performed for varying layer spacing for Ti/TiN systems. The crack tip driving force for increasing a/W ratios is computed using FEM as shown in Figure 1a for 10 layer Ti/TiN. When the crack tip is in a compliant layer (Ti) and faces a stiffer layer (TiN) ahead, it reduces the crack tip driving force, this phenomenon is known as the shielding effect. When it is in a stiffer layer (TiN) and faces a compliant layer (Ti) ahead, the crack tip driving force increases, which is known as the anti-shielding effect. In a 10 layer Ti/TiN system, shielding and anti-shielding effects can be seen (Figure 1a). Magnetron sputtering is used to deposit 3, 10 and 50 layer Ti/TiN multilayers, as well as homogeneous Ti and TiN. Nanoindentation and unnotched micro-cantilever bending are used to determine the properties of individual materials (Ti and TiN). Micro-cantilever bending is used to measure the fracture toughness of Ti/TiN multilayers, which was compared to a homogeneous TiN film. Figure 1 b-c shows the micro-cantilever beam bending of the 10 layer Ti/TiN system. While maintaining a similar hardness, the 50 layer Ti/TiN has an 82 % higher fracture toughness than homogeneous TiN. However, due to the weak inter-columnar boundary in sputtered films, which causes a catastrophic fracture, the increase in K_{IC} expected under ideal conditions is not fully realised in an actual experiment. General multilayer design recommendations are offered based on the findings of the study.

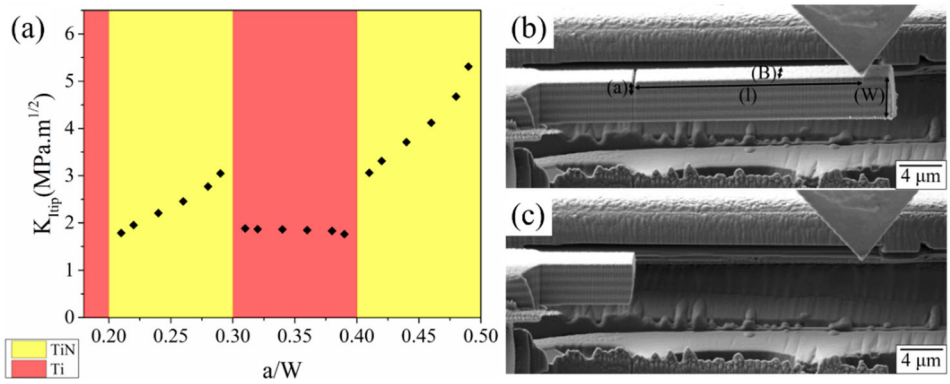

Figure 1 a) K_{Itip} vs a/W for 10 layer Ti/TiN system, micro-cantilever bending b) before c) after test for 10 layer Ti/TiN [1]

References:

[1] A.K. Mishra, H. Gopalan, M. Hans, C. Kirchlechner, J.M. Schneider, G. Dehm, B.N. Jaya, Strategies for damage tolerance enhancement in metal/ceramic thin films: Lessons learned from Ti/TiN, Acta Mater. 228 (2022) 117777. https://doi.org/10.1016/j.actamat.2022.117777