Ultra-tough, strong and ductile Al2O3/Al hybrid nanolaminates

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Abstract

Amorphous alumina is hard but brittle like all ceramic type materials which affects durability under impact or scratch. In order to produce alumina-based ductile and tough coatings, alumina layers below 100 nm thickness were stacked with aluminium interlayers of thickness of 10-20 nm. The idea is that below 100nm alumina is ductile while the aluminium interlaminar can play a role of toughening agent. The Al2O3/Al nanolaminate exhibits exceptional performances including toughness equal to 300 J m-2 determined by on chip nanomechanics. This is almost two orders of magnitude higher than bulk alumina and higher than any other thin hard coatings. A hardness above 8 GPa combines with a fracture strain above 5 %. The origin of this excellent set of properties is unravelled via in–situ TEM and mechanical models. The combination of constrained alumina layers with ductile behaviour, strong "accommodating" interfaces, giant shear deformability of Al layers, and plasticity-controlled crack shielding cooperate to stabilize deformation, dissipate energy and arrest cracks. These performances unlock several options of applications of Al2O3 in which brittleness under contacts prevents benefiting from remarkable functional properties and chemical stability.

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