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Self-Assembly of TaC@Ta Core-Shell-Like Nanocomposite Film via Solid-State Dewetting: Toward Superior Wear and Corrosion Resistance

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Abstract : The improvement of comprehensive properties including hardness, toughness, wear, and corrosion resistance in the transition metal carbides/nitrides (TMC(N)) films, especially avoiding the trade-off between hardness and toughness, is strongly required to adapt to various applications. Although incorporating ductile metal (DM) phase into the TMC(N) via thermally-induced phase separation has been emerged as an effective approach to toughen TMC(N)-based films, the DM is just limited to some soft ductile metal (i.e. Cu, Ag, Au) immiscibility with the TMC(N). Moreover, hardness is highly sensitive to soft DM content and can be significantly worsened. Hence, a novel preparation method should be attempted to broaden the DM selection and assemble much more ordered nanocomposite structure for improving the comprehensive properties. Here, we provide a new strategy, by activating solid-state dewetting during layered deposition, to accomplish the self-assembly of ordered TaC@Ta core-shell-like nanocomposite film consisting of TaC nanocrystalline encapsulated with thin pseudocrystal Ta tissue. That results in the superhard (~45.1 GPa) dominated by Orowan strengthening mechanism and high toughness attributed to indenter-induced phase transformation from the pseudocrystal to body-centered cubic Ta, together with the drastically enhanced wear and corrosion resistance. Furthermore, very thin pseudocrystal Ta encapsulated layer (~1.5 nm) in the TaC@Ta core-shell-like structure helps for promoting the formation of lubricious TaO_x Magnéli phase during sliding, thereby further dropping the coefficient of friction. Apparently, solid-state dewetting may provide a new route to construct ordered TMC(N)@TM core-shell-like nanocomposite capable of combining superhard, high toughness, low friction, superior wear with corrosion resistance.

Keywords : corrosion, nanocomposite film, solid-state dewetting, tribology
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