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INVESTIGATION OF THE FORMATION MECHANISM OF WEAR-RESISTANT COATINGS BASED ON THE TiB₂ STRENGTHENING PHASE

Recent advancements in surface engineering have highlighted titanium diboride (TiB₂) as an exceptional strengthening phase for wear-resistant coatings. The formation mechanisms of these coatings directly influence their microstructural characteristics and subsequent performance in demanding industrial applications. Chemical vapor deposition (CVD) represents one of the primary methodologies for synthesizing TiB₂-based coatings, wherein precisely controlled deposition parameters facilitate the growth of crystalline structures with extraordinary hardness, chemical stability, and resistance to abrasive wear. During the CVD process, titanium and boron precursors react at elevated

temperatures, creating a uniform TiB₂ layer that exhibits strong adhesion to the substrate while maintaining excellent thermal stability under extreme machining conditions.

The microstructural evolution of TiB₂ coatings significantly impacts their wear behavior, particularly when machining challenging materials such as titanium alloys [1]. Experimental investigations reveal that coating hardness, while traditionally associated with enhanced wear resistance, must be strategically optimized relative to toughness. Coatings characterized by moderate hardness combined with elevated toughness demonstrate superior resistance to wear, primarily attributed to their capacity to mitigate built-up edge formation – a prevalent issue during titanium alloy machining. This phenomenon underscores the complex relationship between formation parameters and resultant mechanical properties, where excessively hard TiB₂ coatings can paradoxically experience accelerated wear through delamination mechanisms when subjected to substantial mechanical and thermal stresses.

Alternative formation techniques, such as High-Velocity Oxy-Fuel (HVOF) spraying, offer distinct advantages for creating composite coatings where TiB₂ particles reinforce metallic matrices. The HVOF process involves milling TiB₂ particles with matrix materials (such as Fe₃Al) before thermal spraying onto substrates. This approach produces dense coatings with minimal porosity (2-4%), where the dispersion of TiB₂ particles critically influences mechanical performance [2]. The microstructural analysis demonstrates that well-distributed TiB₂ particles within the matrix contribute to a threefold increase in hardness while enhancing elastic modulus. The interfacial interactions between TiB₂ and the surrounding matrix material develop during high-temperature deposition, creating strong bonds that impede crack propagation during service.

Advanced manufacturing techniques like selective laser melting (SLM) further expand the formation possibilities for TiB₂-reinforced wear-resistant coatings, particularly in complex high-entropy composites. During SLM processing, the rapid melting and solidification promote microstructural refinement, with TiB₂ particles serving as nucleation sites that facilitate a more uniform phase distribution [3]. The resulting microstructure exhibits enhanced interfacial bonding between TiB₂ particles and the matrix, significantly improving wear resistance through dispersion-strengthening mechanisms. The formation temperature and cooling rate during SLM processing directly influence the interaction between TiB₂ and matrix phases, creating synergistic effects that substantially increase microhardness while reducing material degradation under sliding wear conditions.

The wear resistance mechanisms of TiB₂-based coatings correlate strongly with their formation pathways and resulting microstructure. The crystalline TiB₂

structure in CVD-produced coatings provides extraordinary hardness while minimizing adhesive interactions between the tool surface and workpiece materials. For composite coatings created through HVOF and SLM processes, the wear mechanisms shift with operating conditions, with adhesive wear dominating at lower speeds and oxidation-induced wear becoming more prominent at higher speeds [4]. The fundamental property improvements stem from the unique combination of hardness, chemical stability, and interfacial strength achieved during formation, which collectively enhances machining efficiency across diverse applications, including aerospace components, automotive manufacturing, and other high-performance sectors.

The ongoing investigation of formation mechanisms for TiB₂-based wear-resistant coatings continues to reveal critical insights for optimizing performance in specific operational contexts. By understanding the complex relationships between synthesis parameters, microstructural evolution, and tribological behavior, engineers can strategically design coatings with tailored properties for particular applications. This approach significantly extends tool lifespans, improves operational reliability, and promotes sustainability through reduced material waste and enhanced energy efficiency, highlighting the substantial industrial value of advanced TiB₂-based coating technologies.

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