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A.A. Voevodin, C. Muratore, S.M. Aouadi

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Hard Coatings with High Temperature Adaptive Lubrication and Contact Thermal Management: Review of Recent Progress

A.A.Voevodin^{1*}, C. Muratore², S.M.Aouadi³

¹*Materials and Manufacturing Directorate, Air Force Research Laboratory, Wright-Patterson Air Force Base, OH 45433, USA*

²*Department of Chemical and Materials Engineering, University of Dayton, Dayton, OH 45469, USA*

³*Department of Materials Science and Engineering, University of North Texas, Denton, TX 76207, USA*

Abstract

Progress in the design and exploration of hard coatings with high temperature adaptive behavior in tribological contacts is reviewed. When coupled with most recent surface engineering strategies for high temperature contact thermal management, this progress opens a huge opportunity for adaptive coating applications on machine parts, where oils and coolants are commonly used. The adaptive mechanisms discussed here include metal diffusion and formation of lubricant phases at worn surfaces, thermally- and mechanically-induced phase transitions in hexagonal solids, contact surface tribo-chemical evolutions to form phases with low melting point, formation of easy to shear solid oxides, and others. All of these adaptive mechanisms are combined in nanocomposite coatings with synergistic self-adaptation of surface structure and chemistry to lubricate from ambient temperatures to 1000 °C and provide surface chemical and structural reversibility during temperature cycling to maintain low friction coefficients. The review also highlights emerging surface adaptive concepts, where advances with *ab initio* modeling of intrinsically layered solids point to new compositions for thermally stable, easy to shear ceramic coatings, load- and temperature-adaptive surfaces with arrays of compliant carbon and boron nitride nanotubes as well as low friction two-dimensional structures. Approaches for self-regulation of coating thermal conductivity, heat flow, and thermal spike mitigations are discussed in the context of surface structure evolution and phase transitions. Future progress is linked to the development of *in situ* exploration techniques, capable of identifying adaptive surface chemistry and structural evolutions in broad temperature regimes. When combined with predictive modeling, such approaches drastically accelerate adaptive coating developments. The review identifies opportunities, strategies, and challenges for designs and applications of hard coatings with high temperature adaptive lubrication and contact thermal management.

Key words: hard coating; high temperature; solid lubrication; thermal management; adaptive; tribology

* Corresponding author – andrey.voevodin@us.af.mil; +1-937-255-4651 phone; +1-937-255-2176 fax

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