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Nanostructured protective coatings for harsh environments: from design to manufacture

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Materials exposed to extremely demanding environments in applications such as aerospace, automotive, mining and petroleum continue to face increased technological, environmental and economical challenges, especially since the performance of modern equipment, systems and components is pushed to and beyond their limits. This frequently leads to materials deterioration accelerated by excessive wear, erosion, tribo-corrosion, and other mechanisms related to the surface damage, resulting in increased operation and maintenance costs, decreased efficiency, premature failure, and compromised safety in the case of critical applications.

Good understanding of materials deterioration processes allows one to develop appropriate strategies to protect technologically relevant substrates taking into account the complete life cycle of the component. Advanced nanostructured coatings call for an "ideal" combination of the mechanical, elasto-plastic, tribological, corrosion, thermal and other characteristics. Such requirements can only be satisfied by using specifically tailored coating architectures, while considering nanocomposite, nanolaminate, multilayer and graded layer systems. Specifically, combination of multiple coating types obtained by different complementary processes (called "hybrid" coatings) provide much promise for combined functional characteristics including multifunction, adaptive or smart performance.

Finite element modeling of the coating architecture, in combination with the tailored mechanical properties of individual materials of the coating systems including appropriate stress management, opens new opportunities as a predictive tool for developing high performance nanostructured protective coatings.

Development of new in situ real time techniques to characterize materials deterioration mechanisms includes examples such as (i) assessment of the progression of solid particle erosion; (ii) stress measurements; (iii) micro-scratch and nano-wear testing to study defect initiation and propagation; and finally, (iv) tribo-corrosion testing to assess the synergistic effects involved in different wear and corrosive environments.

Throughout the talk, we will illustrate the relationships that exist between the microstructure, the mechanical properties and the tribological performance of protective coatings by presenting different examples. Emphasis will be on (i) material's damage caused by solid particle erosion in aeronautical engines (compressor components, heat exchangers, pumps, piping systems); and (ii) mechanical and tribological performance of optical films (e.g., antireflective coatings and optical interference filters) on glass and on plastics for their use in touch screens, corrective glasses, low emissivity or smart windows, and others.