Modeling the composite hardness of coated systems involving multilayer coatings

E. S. Puchi-Cabrera[1, 2, 3], M. H. Staia[1, 2, 4], A. Iost[4]

1. School of Metallurgical Engineering and Materials Science, Faculty of Engineering, Universidad Central de Venezuela, Postal address 47885, Los Chaguaramos, Caracas, 1040, Venezuela.
2. Venezuelan National Academy for Engineering and Habitat, Palacio de las Academias, Postal Address 1723, Caracas 1010, Venezuela.
3. Université Lille Nord de France, USTL, LML, CNRS, UMR 8107, F-59650 Villeneuve d´Ascq, France.
4. Arts et Métiers ParisTech – Centre de Lille, MSMP, 8, Boulevard Louis XIV, 59000 Lille Cedex, France.

ABSTRACT

The change in the composite hardness with penetration depth derived from nanoindentation tests conducted on coated systems, which involve the deposition of multilayer coatings, in general exhibit a complex shape, as a consequence of the sequential contribution of each coating layer to the composite hardness during indentation loading. In spite that there are a number of models, which have been proposed for describing the change of the composite hardness with penetration depth for monolayer coatings, as well as for determining the coating and substrate hardness, very few research works have addressed the problem of describing this kind of data for multilayer coatings. In the present communication, a rational approach is proposed for extending two models widely used for the analysis of monolayer coatings, in order to describe the composite hardness data of multilayer coatings, as well as for determining the hardness of each individual layer and that of the substrate. Thus, a modified form of the models earlier advanced by Korsunsky *et al*. [1] and Puchi-Cabrera [2], as well as their computational instrumentation, are proposed. The extension of both models to deal with multilayer coatings is conducted on the basis of the model developed by Iost *et al*. [3], in order to adapt the Jönsson-Hogmark [4] model to the analysis of indentation data of multilayer coatings. The proposed models are validated employing nanoindentation results obtained from a 2024-T6 aluminum alloy coated with a DLC film, employing electroless NiP as intermediate layer (Fig. 1-2), as well as the results obtained for a ZrN/MoN bilayer deposited onto a 316L stainless steel substrate. The advantages and disadvantages of the different models employed in the analysis are thoroughly discussed.

Keywords

Hardness modeling, multilayer coatings, indentation loading response, nanoindentation testing

References

[1] J. R. Tuck, A. M. Korsunsky, D. G. Bhat, S. J. Bull (2001) "*On the application of the work-of-indentation approach to depth-sensing indentation experiments in coated systems*" Surf. Coat. Technol., **139** pp.63-74.
[2] E. S. Puchi-Cabrera, (2002) "*A new model for the computation of the composite hardness of coated systems*" Surf. Coat. Technol., **160** pp.177-186
[3] K. Rahmoun, A. Iost, V. Keryvin, G. Guillemot, N. E. Chabane Sari (2009) "*A multilayer model for describing hardness variations of aged porous silicon low-dielectric-constant thin films*" Thin Solid Films **518** pp.213–221.
[4] B. Jönsson, S. Hogmark (1984) "*Hardness measurements of thin films"* Thin Solid Films **114** pp.257-269

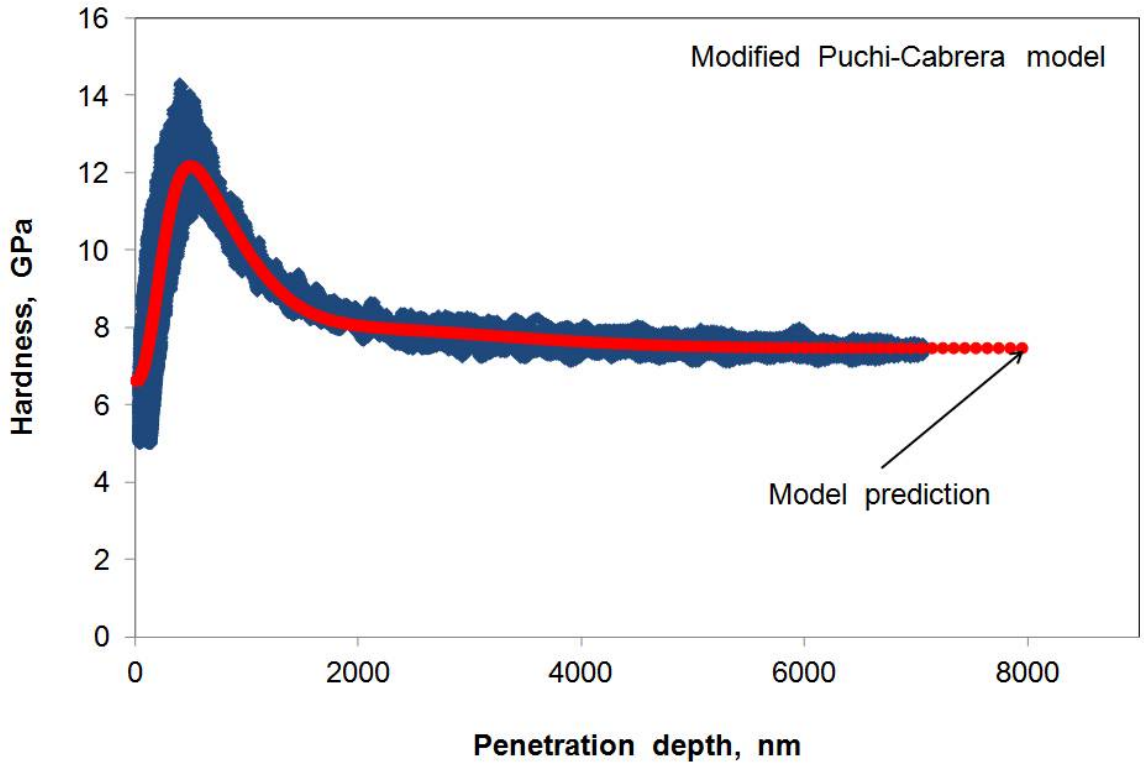

Figure 1: Change in the experimental values of the composite hardness as a function of penetration depth for the coated system under investigation. The description of the experimental data has been conducted with the modified PC model.

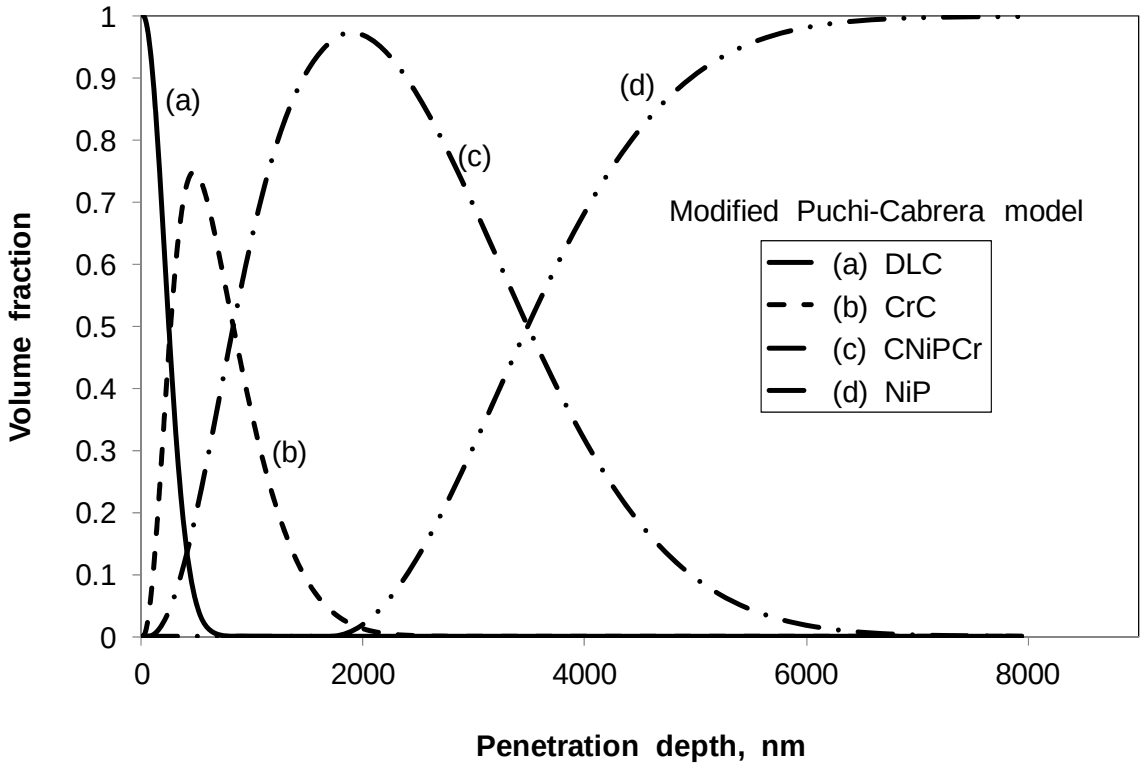

Figure 2: Change in the volume fraction of each coating contributing to the composite hardness, according to the PC model, as a function of penetration depth.