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Nanomechanical Properties of Lamellar Materials

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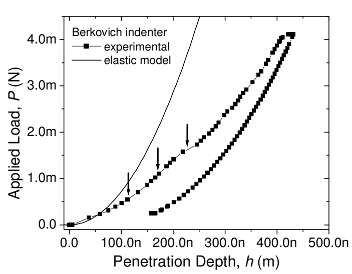
Abstract – Lamellar materials are employed as solid lubricants, in batteries and recently some of these materials, principally clay, are used as reinforcement in polymer nanocomposites. The anisotropy in the mechanical properties of lamellar materials is very high due to the strong atomic bonds in the basal plane compared to the weak forces between the lamellas. The nanoindentation tests on this kind of material present a very specific behavior since the tip penetration is ruled more by fracture than plastic and/or elastic deformation.

The crystallographic structure of lamellar materials shows strong cohesion in the basal geometry but weak Van der Waals forces between the lamellas. Several lamellar materials where subjected previously to nanoindentation tests. A review of the nanomechanical properties of Lead iodide [1], niobium disulfide intercalated with hydrated sodium [2], InSe and GaSe single crystals [3], kaolinite 'macrocrystals' [4] lamellar materials and kyanite [5], a pseudolamellar material, investigated by nanoindentation technique is presented. The behavior of these materials show very similar aspects, with a consistent occurrence of pop-ins related to fracture of lamellas that rules the indenter penetration. Highly ordered pyrolytic graphite, that is a well known material, was investigated to understand the behavior of this kind of materials under indentation. Typical instrumented indentation on graphite show pop-ins at loads between 0.1 to 4 mN using Berkovich as shown in Figure 1. At higher loads large pop-ins are observed in all kind of lamellar materials. The decrease in indentation hardness as load increases is due to fracture events on lamellas. The measured elastic modulus decrease by increasing the indentation loads, due to fracture under pyramidal indentation. In graphite an elastic load-unload behavior is observed during spherical indentations until loads of 500 mN for indenters with radius of 48 μm and 117 μm. In addition, the load versus displacement curves can not be fitted by a hertzian model for spherical indentation [6]. The results those are similar to other lamellar materials indicating that the behavior is typical for lamellar structures [1-6]. The concept of hardness for lamellar materials is not properly defined since the indentation energy is related more to fracture of lamellas than to plastic deformation. Elastic modulus can not be properly determined by instrumented indentation for lamellar materials. The fracture patterns with the different indenters were investigated to understand the tip penetration during indentation. The behavior of scratch tests of graphite with pyramidal indenter is also discussed.



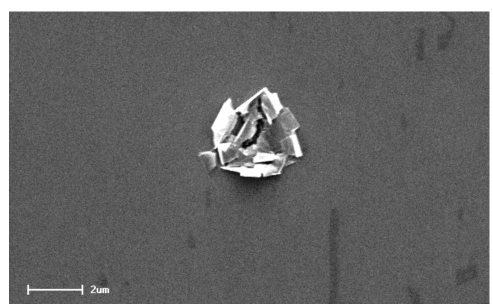


Figure 1 Typical load versus penetration curve for a Berkovich indenter, showing pop-ins, and the image of the respective indentation of graphite.

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