11th International Conference on Advanced Materials
ICAM 2009
Rio de Janeiro Brazil
September 20 - 25

Effect of the native oxide mechanical deformation on GaAs nanoindentation

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Abstract - The native oxide has been found to have a noticeable effect on the mechanical deformation of GaAs during nanoindentation. It has been observed that in the early stages of mechanical deformation, plastic flow occurs in the oxide layer while the gallium arsenide is still in the elastic regime. The deformed native oxide layer results in a pile-up formation that causes an increase in the contact area between the tip and the surface during the nanoindentation process. This increase in the projected contact area is determinant to the apparent high pressure sustained by the crystal before the onset of plastic deformation.

It is now evident that alterations of the near-surface crystal structure can be used for growth of semiconductor nanostructures at specific surface sites. Atomic force microscope [1-3] and nanoindentation [4] tips have recently been used to produce surface patterns in order to control the site nucleation of quantum dots. The patterns were created by shallow indentation of small pits on the semiconductor surface, which resulted in mechanical deformation of the semiconductor with the introduction of dislocations. Since the indentation procedure typically occurs in air, native oxide layers on the semiconductor cannot be avoided. In a previews work, it was observed that the native oxide present on the InP surface plays an important role on the early stages of mechanical deformation of InP during nanoindentation tests [5]. In this work, a study of the role of the native oxide on the mechanical deformation of a (100) GaAs surface is presented. The early stages of deformation of a native oxide layer on (100) GaAs were studied by nanoindentation. The residual indentation impressions were observed with an atomic force microscope (AFM). It was found that residual impressions with pile up at the surface have been observed for indentations in the elastic regime for GaAs, as shown in figure 1. These are attributed to plastic deformation of the native oxide layer. The observed pile up is formed by the flow of oxide out from the pit during the indentation. Due to broken bonds in the oxide layer, some oxide adheres to the diamond tip, leading to the formation of a pit with rough pile up rim. This unexpected plastic deformation on the native oxide layer causes an increase in the real contact area between the tip and the surface under pressure. As a consequence, the maximum mean contact pressure (MCP) values are underestimated in the elastic range for GaAs. In this work we show that measurements of the MCP supported before the beginning of plastic deformation must take into account plastic deformation of the native oxide layer. In practice, the MCP supported by GaAs before plastic deformation is overestimated if the contact depth is not corrected due to the native oxide layer contribution (figure 2).

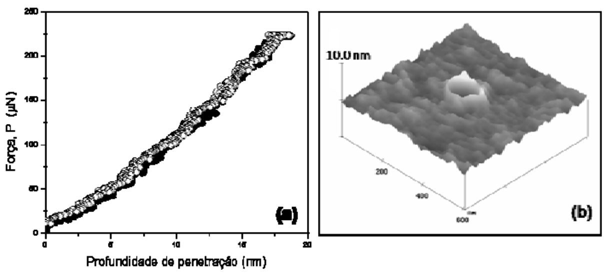

Figure 1. (a) Nanoindentation curve in the elastic regime for GaAs and (b) the residual impression of the indentation showing the plastic deformation of the native oxide.

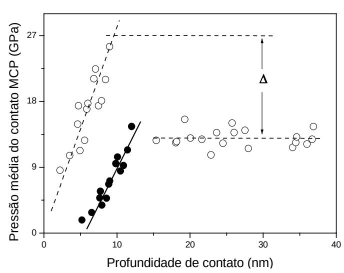

Figure 2. The MCP versus the contact depth. The closed circles were obtained after a correction in the contact area due to the unexpected oxide deformation.

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