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Full Length Research Paper

Effect of an electric field within microscopy focused ion beam (FIB) between manipulator sharp and the ion trap of the electron detector

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The manipulation of samples with micro manipulators sharps in the normal axis to the observation plane is practically blind in microscopy focused ion beam (FIB) mono beam. The application of a negative potential to the manipulator sharp has been considered, which causes differences of electrical potential between the detector and the sample holder, generating an electric field between the sharp and the sample. This makes the electrons, aside the sample, undergo a greater deflection, reflecting in poorer contrast image. This deflection depends on a great extension of the sample holder height between the micromanipulator sharp, voltage deflector, q/m electron factor and electron acceleration.

Key words: Focused ion beam (FIB) mono beam*,* contrast effects, electric fields, height.

INTRODUCTION

SEM microscope has been a very useful tool for nanometric characterization materials (Sene et al., 2009; Behdani et al., 2009; Mopoung, 2011; Martinez-Valencia et al., 2011). Very interesting, microscopy focused ion beam (FIB) is also an excellent tool for realizing microscopic sculpts nowadays (McMahon et al., 2009; Roussel, 2009). In this way, the use of micro manipulating sharps for transporting and maneuvering the pieces to be carved is required. Several types of sharps exist in the market, with the advantage of being electrically isolated. On the other hand, the use of these manipulators has the disadvantage of not knowing the approach to use for the sample. There is also the risk of the specimen or the micro manipulator sharp resulting in damage by crashing during their operation. The FIB/SEM does not present this problem because the FIB column is 52^o in respect to the SEM column. Therefore, it can be considered switching between the both to control the depth without difficulty. In the mono beam FIB, the problem is well-known- lack of ability to contact another reference point. The manipulation and displacement in the normal axis to the observation plane is practically blind.

In observation of this disadvantage, the application of a negative potential to the micro manipulator sharp was considered. In this way, a difference of potential between the electric field of the secondary electron detector and the sample will exist. It means that electrons aside the sample when attracted towards the detector will be deflected by the action of the negative potential applied to the sharp, decreasing the image contrast.

The objective of this report is to provide an option to determine the height between the micro manipulator sharp and the sample to avoid damages by dangerous collisions.

EXPERIMENTAL DETAILS

The FIB equipment consists of vacuum camera, ion source, ionic column, sample holder, electrons detector and a computer to control instruments (Giannuzzi**,** 2005). FIB system is very similar to SEM microscope. Usually other terms like SEM-FIB column, Spectroscopy Auger TEM or a secondary spectrometer of masses are added. The gallium ions leave the column and interact with the

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specimen. The inelastic scattering of incident Ga+ produces secondary electrons, phonons and X-rays (Wirth, 2009). The ion-induced secondary electrons, ion-induced secondary ion are used to generate the image in FIB by electron collection with a dynode electron multiplier (CDEM) (Davies and Khamserhpour, 1996).

All experiments were carried out in a mono beam FIB model JEM 9320 FIB with a typical current of 10 pA of gallium ions, Ion source current 2 mA, Ion acceleration voltage 30 kV, and magnification image x300.

RESULTS AND DISCUSSION

Microscopy FIB is used for micro modeling; this implies the necessity of an element for micro manipulation. Several options exist for micro manipulating sharps with three degrees of freedom X, Y, Z used for such aim. In order to avoid a possible damage by collision between the sample and this type of sharp, it is necessary to have a good control of their movement.

For the control of the movement on the plane of the image, it is sufficient to use normal image mode. For the control of the movement in direction to normal plane of the visual area, the FIB double beam can be changed between SEM to FIB mode. These equipment count on column SEM to 90° and column FIB to 52° with respect to column SEM. With the only switch image option, a 52° of tilt could occur in this way. However, the FIB mono beam is practically blind in normal direction of the viewing area. In other way, when the ion beam of Ga interacts with the sample, secondary electrons and ions are generated. The electrons are used in the image formation in the equipment, and are attracted by the +400 V potential applied to the detector (Gamo, 1996) and Campbell et al. (1995). Figure 1A shows an image of mono beam FIB (JEM-9320FIB), where the micro manipulator sharp is observed in greater brightness with a potential of -25 V. The sample observed with little brightness is a TEM grid with some carbon nanotubes forming a membrane. In this image, there is a small dark halo projected on the sample surrounding a small region in the neighborhoods of the micromanipulator sharp generated by potential by -25V, which deflected the secondary electrons. These electrons, aside the specimen, form a dark halo, which causes a poorer contrast than in the image. Figure 1B shows an image where the sharp touches some carbon nanotubes ropes. The brightness is now uniformed because the deflector electric field in the sharp is grounded; and an image with the same brightness is observed, because the electrons do not have any impediments to arrival at the detector.

In SEM microscope, the topographic contrast depends on the number of trajectories of dispersed electrons. In each point where the scanning electrons have impact, the number of backscattered electrons has direct information of the tilts of the specimen (Goldstein et al., 1992) and Gert (2007). The secondary electrons generated in the FIB (Roussel, 2009) are attracted towards the electron detector in the same way like the microscopy SEM. In principle if a topographic tilts affect the contrast of the image, an external electric field carries out the same task to expel the electrons in the neighborhoods (Campbell et al. (1995).

Figure 2A shows a representation of an electrical simulation model (COMSOL 3.3) of the FIB vacuum camera, which includes a micro manipulator sharp with a potential of -25V. The electron detector is a greater distance with a +400V potential applied to the Faraday cage of the detector.

The micro manipulation sharp without charge is (Figure 2A) in the neighborhoods of the specimen. It is observed the lines of the electric field aside the sharp and the specimen area where the electrons do not have any impediments to allow arrival in the detector.

Figure 2B shows the deformation of the electric field around the manipulator sharp. When the sharp has a lower potential than the grounded level of the sample holder, an electric field is generated between both, deflecting the secondary electron. This, aside the sample, forms a dark halo (Figures 1A and 1B). In Figure 2C, there is a less deformation effect of electric field due to a major distance between a specimen and a manipulator sharp which causes a minor deflection of the secondary electron and minor contrast difference.

Basic analytical model

With the electric field in plates (Jackson, 1988) and a first Newton law:

$$\vec{a} = \frac{Vq}{dm} \qquad 1$$

where $\vec{a}$ is the acceleration of secondary electron, V is voltage applied between the sharp and simple holder, q, m is the electron charge and mass respectively and d is the distance between the sharp and entire simple holder. Figure 3 shows a representation of the interaction of gallium ions and the sample when the sharp with charge is surrounding the neighborhoods of the sample. There exists two electron currents: the electron deflected and the deflection in which the algebraic adds result to the total number of electron; where it arrives at the detector as normal image mode (without sharp charge).

Conclusion

In this article, the electric fields have been modeled as the cause of deviations in the secondary electrons that form the images in FIB. The effect of changes of contrast has been observed experimentally based on the changes of the electric field between the micromanipulator sharp and the sample, which depends as well on the distance

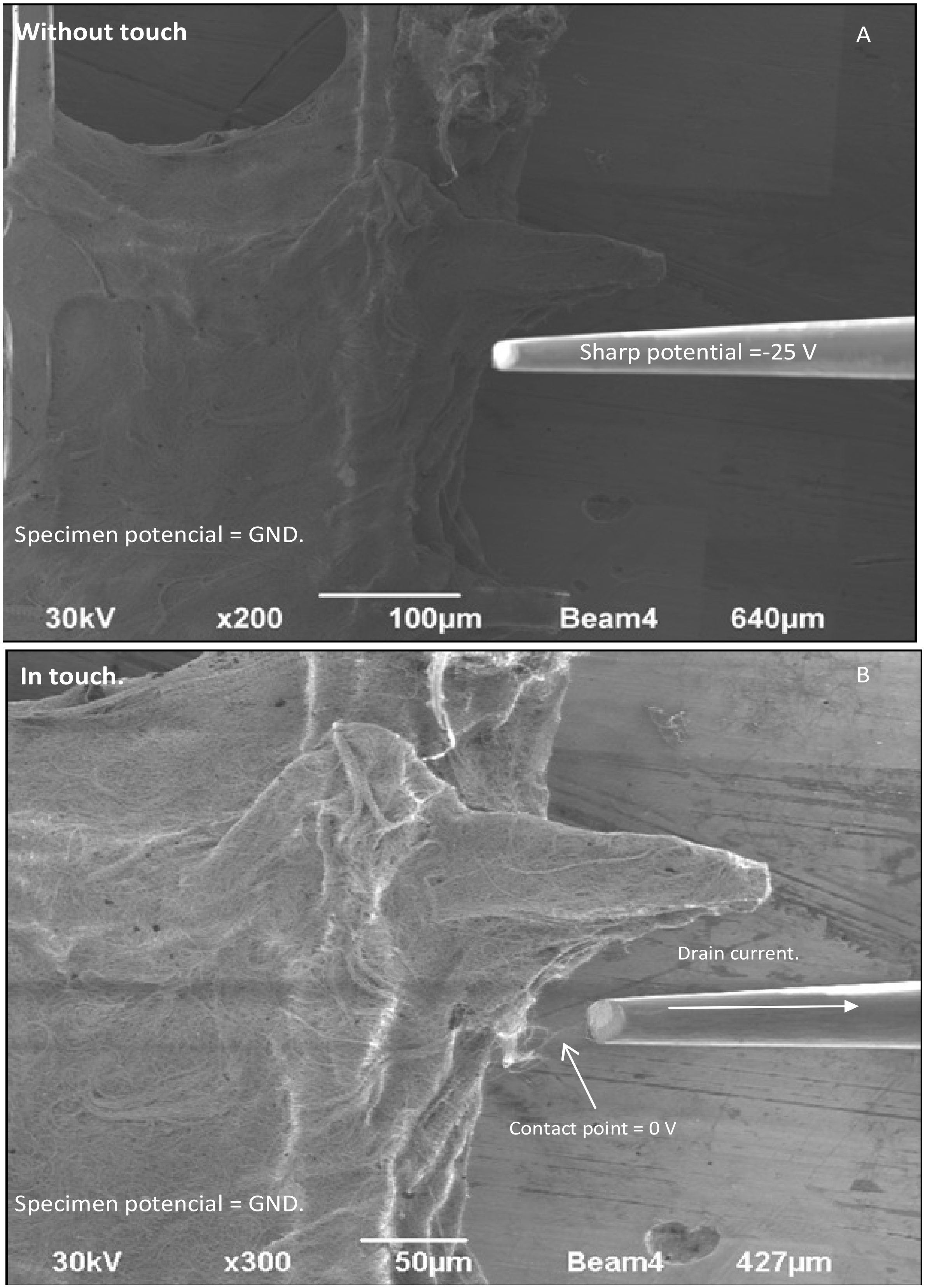

Figure 1. Image of TEM grid with carbon nanotubes and a micro manipulator sharp with -25 V potential. (A) Sharp not touching the sample, a dark halo appears in the sample surface; (B) Sharp is touching a carbon nanotubes rope. The sharp potential stop and a normal image obtained.

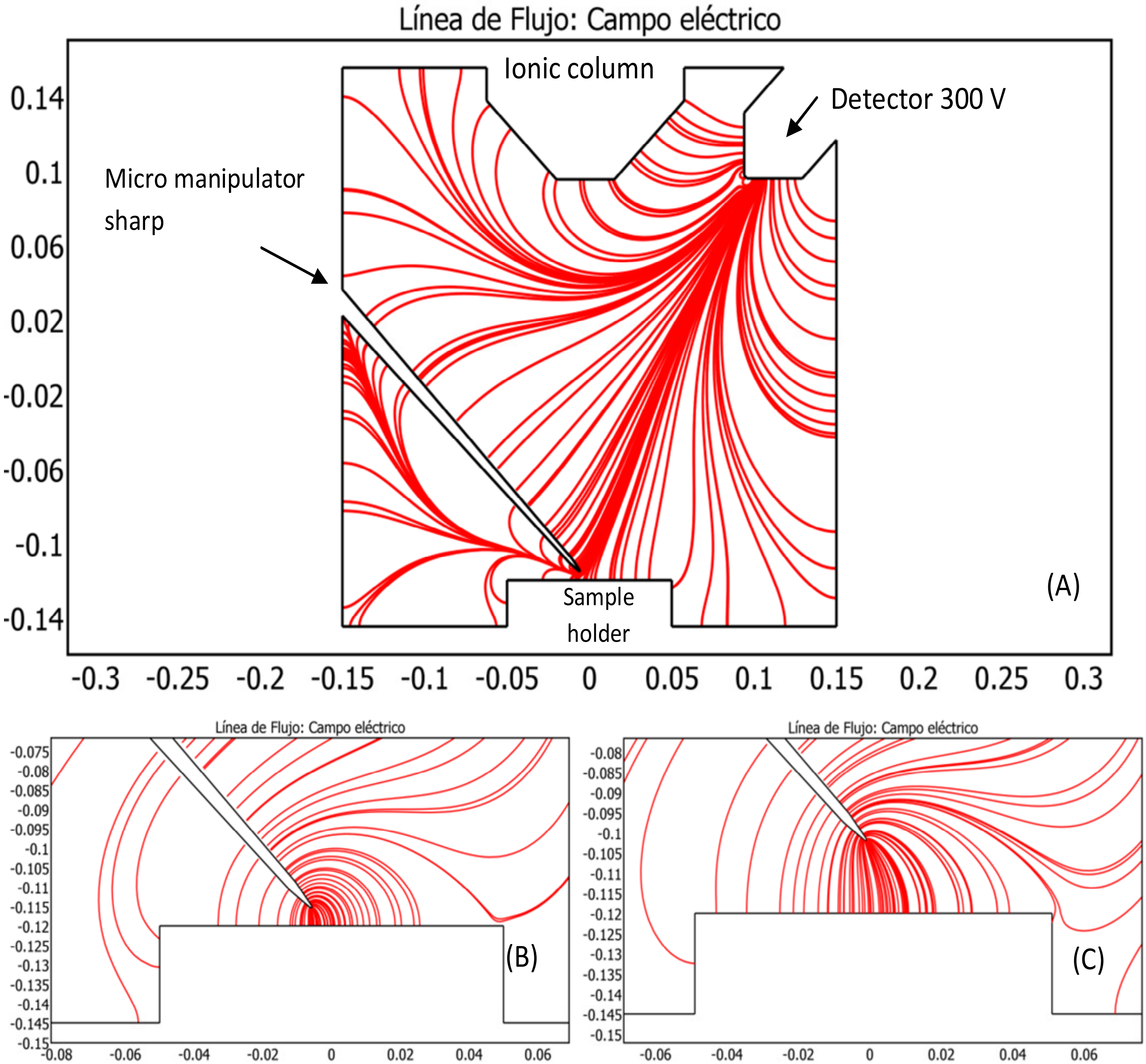

Figure 2. Finite element model (COMSOL 3.4) of the FIB vacuum system. (A) Image without a sharp potential (normal operation); (B) Image with a sharp potential, a minor distance of the sample, (C) A major distance of the sample.

between both. However, when the potential of the sharp touches the sample (ground level or reference) or by elimination of the potential applied, the brightness becomes uniformed in all the image. This is because the electrons do not have any impediments to free arrival in the detector. Besides, a simple analytic model was determined to know the dependency of the distance between the micromanipulator sharp and the sample. This is to enable one to know the height by the difference of the dispersed electrons that arrive at the detector. This is through the action of the sharp potential against which it should have to arrive in the detector in normal operation.

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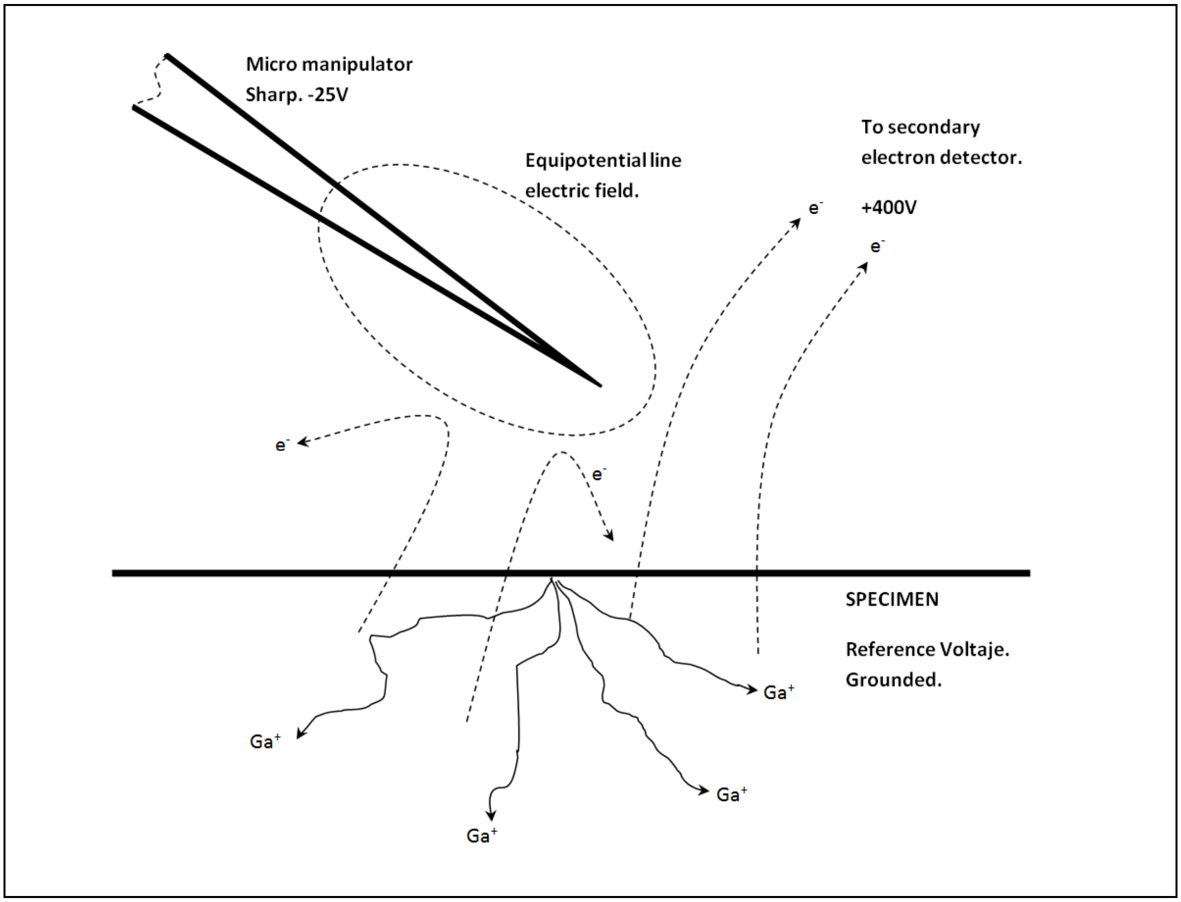

Figure 3. Illustration of the electron currents when a sharp potential is applied.

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