Backscattered electron imaging versus specimen thickness in Scanning Electron Microscopy

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The Backscattering Electron (BSE) imaging mode in Scanning Electron Microscopy (SEM) is a technique normally applied to the investigation of bulk specimens providing a compositional contrast. The possibility to apply this investigation methodology also to thinned specimens has been recently envisaged [1].

Following this approach, in this work we will investigate the relation between compositional contrast, resolution and sample thickness, by comparing BSE and Transmitted Electrons (TE) images in the SEM (STEM). Moreover, we will show that BSE imaging mode can be applied to the observation of specimens with a thickness which allows STEM observations at the same time, and that the image formation in both methods is governed by the same rules.

In Fig. 1 a) is reported a scheme of the experimental set-up used for STEM imaging in the SEM [2], while in Fig. 1 b) and c) respectively the observed specimens: a scheme of the AlAs/GaAs multilayer and a High Energy STEM image, obtained with a Tecnai F20 operating at 200 keV, of a cross-sectioned Sb Si implanted specimen annealed at 1000 °C for 2 secs, and showing a precipitation of metallic Sb nanoparticles [3].

According to the rules defining the incoherent imaging mode, a specimen detail will be visible if its features, having a location determined by the probe, will give rise to a number of collected electrons sufficiently different from that of the surrounding region. The difference between these collected signals allows us to compute the contrast, and from the contrast it is possible to deduce the threshold current J, i.e. the minimum beam current which must be employed to detect a definite contrast between two points in an image, for a specific pixel time [4]. The threshold current is the quantity which will guide us trough the discussion of the results. In fact its trend versus specimen thickness t, for the investigation of compositional details with BSE is rather general and shows a constant value, for sample thicker than the electron range. In the small thickness region, J present a minimum giving rise to the mentioned possibility of simultaneous observation of thinned specimens with TE and BSE.

Fig. 2 a) shows for E = 20 keV the simulated threshold currents J_{BSE} and J_{STEM} versus t, for BSE and STEM (collection angular range [0°, 5°]) observations respectively. The critical currents are comparable for t about 250 nm and the experimental images obtained with a specimen thickness of t ~ 250 nm operating at 20 keV in BSE (b) and STEM (c) imaging modes on the same specimen area confirm these conclusions, therefore showing a comparable resolution, as pointed out by the contrast profiles.

The experimental data support the theoretical conclusions and at the same time point out interesting aspects of the image formation process. The beam spreading in AlAs and GaAs at 20 keV (for t = 250 nm) are about 250 nm and 350 nm respectively. It means that only a small fraction of the AlAs layers crossing the specimen gives rise to the image. The information about the presence of the AlAs layers is related to the scattering events occurring when the half width of the beam is of the order of the AlAs layer sizes.

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Therefore a similar behavior should be shown by small particles on a substrate, as reported in Fig. 3, where STEM ([20°, 60°]) (a), and BSE (b)-(d) images of the Sb doped specimen are shown. Fig. 3 a) and b) refer to the same specimen region with *t* ~ 100 nm. The resolution is the same but the BSE image shows a smaller number of nanoparticles as only the ones close to the specimen surface are visible. Fig 3 c) refers to a specimen region of *t* ~ 250 nm, while (d) to the bulk region. The increase of *t* doesn't affect the contrast, but the single particles tend to disappear merging in a continuous bright line.

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5. This work is dedicated to the memory of Pier Giorgio Merli.

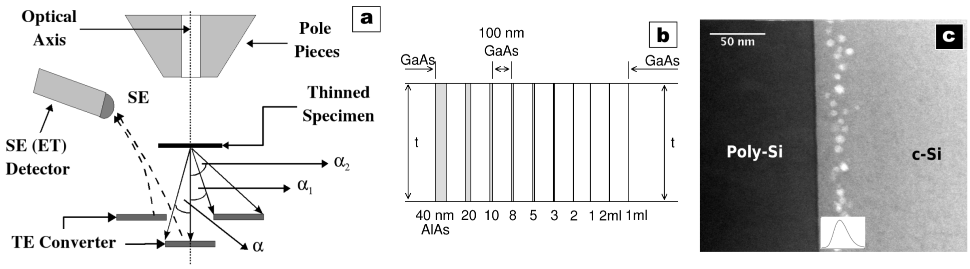

Figure 1. (a) Scheme of the SEM-STEM set-up. (b) Scheme of the observed AlAs/GaAs multilayer. (c) High Energy STEM image of the Sb implanted Si specimen showing the precipitation of Sb nanoparticles. In the inset the as-implanted Sb concentration profile.

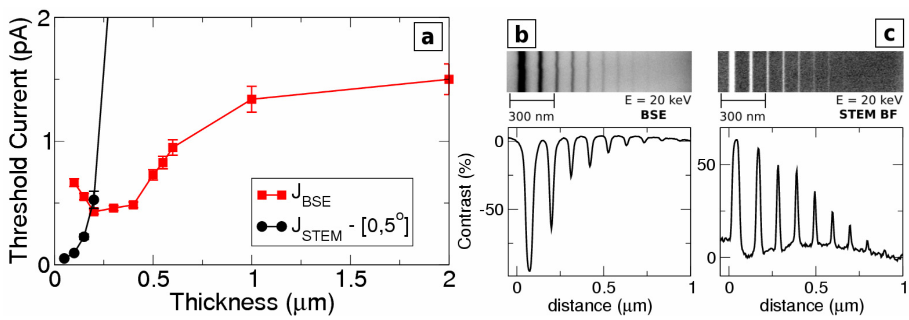

Figure 2. (a) Simulated threshold currents vs thickness for the BSE and STEM ([0°, 5°]) observations at 20 keV for the 10 nm AlAs layer of the multilayer. (b) BSE and (c) STEM images, and corresponding contrast profiles, of the same specimen region with *t* ~ 250 nm.

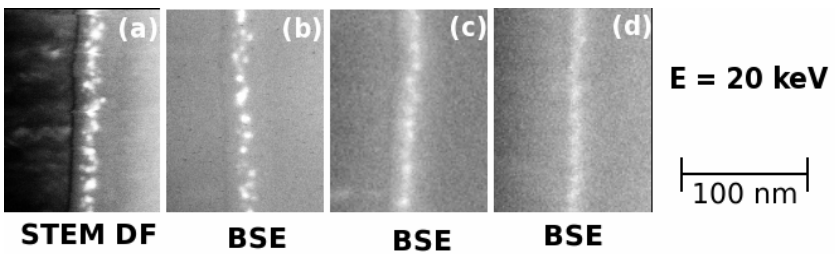

Figure 3. (a) STEM ([20°, 60°]) of the cross sectioned Sb implanted Si specimen having a *t* of about 100 nm; (b) BSE image of a specimen region with the same *t*; (c) BSE image of a specimen region having *t* about 250 nm; (d) BSE image of a bulk region of the specimen.

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