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Cross-sectioning of plan-view samples and artifacts of TEM sample preparation

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In semiconductor failure analysis it is often desirable to look at a certain defect in two perpendicular directions. Usually, to achieve this, two TEM samples are prepared – a plan-view sample of the defect area and a cross-section of a *similar* defect. To have a view of the *same* defect at different angles one can employ electron tomography. However, electron tomography is still a very experimental technique requiring substantial amounts of time and producing results with limited resolution and reliability. Another solution would be to section the defect in two perpendicular directions. This can be achieved by using dual-beam FIB instruments [1, 2].

In our lab we developed a simple technique which allows to reliably section samples in two perpendicular directions. While providing important failure analysis information such samples, as an added bonus, also allow to obtain a valuable information about artifacts introduced during TEM sample preparation.

The plan-view sample can be prepared by any suitable technique (FIB, ion-mill, chemical, etc.). It is beneficial to make this sample somewhat thicker than usual to allow for more material in the cross-section. Once the plan-view sample is prepared and investigated in TEM the sample is mounted flat on a FIB holder with a small amount of glue (M-Bond, Superglue, etc.). After the sample is mounted it is very helpful to mark the feature of interest either in the FIB or with a laser marker. If the feature of interest is located close to the top surface of the sample a protective layer has to be deposited to make sure the feature is not damaged during the subsequent fibbing.

Figure 1a shows a TEM image of a plan-view sample prepared by FIB. The sample was cut close to the substrate to contain the contacts, the poly-silicon lines and some of the substrate. The dashed line in the image indicates the position of the FIB cross-section (shown in Figure 1b) prepared from this plan-view sample. A higher magnification TEM image of the cross-section is shown in Figure 1c. In this image one can measure the thickness of the initial plan-view sample to be 475 nm, the FIB-damaged layer on the Si side – 19 nm and on the W side – 10 nm.

Figure 2a shows a dark field STEM image of a plan-view sample prepared by mechanical dimpling followed by 4 kV Ar ion milling at a shallow angle [3]. In this case, a small defect in less than 100 nm wide poly silicon line was successfully cross-sectioned and analyzed (Figure 2b). In the cross-section one can see that the damage for the Ar ion beam is significantly smaller and amounts to 4 nm (c). The substrate side of the sample (Figure 2d) shows a much larger amount of damage (36 nm) since it was exposed to the FIB Ga 30 kV ion beam without any protection.

More details will be provided in the presentation.

References

[1] Max Sidorov. Unpublished results (2002-2005).
[2] R.B. Irwin, A. Anciso, P.J. Jones, C. Patton, Microscopy Today 1 (2005) 26
[3] Thanks to Liliana Thompson for providing the plan-view sample

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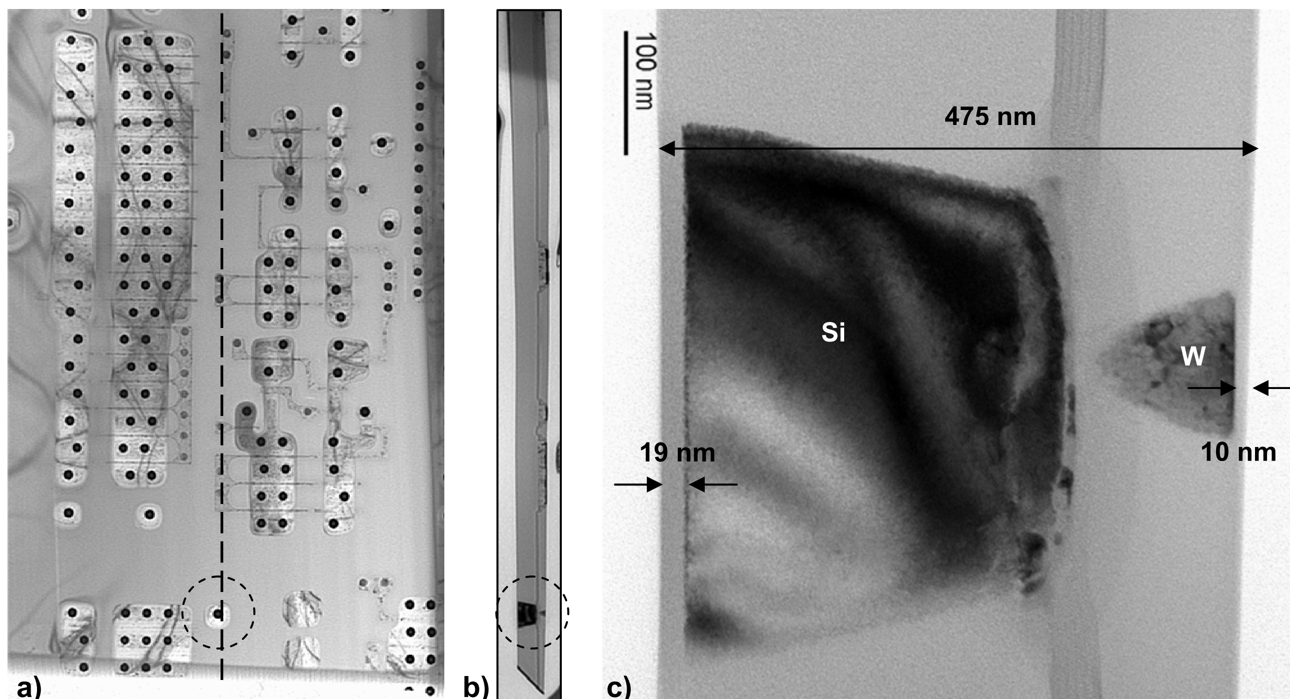

Fig. 1 (a) TEM of plan view sample with position of cross-section indicated by dashed line;
(b) TEM of cross-section sample; (c) Magnified image of feature circled in a) and b).
The thickness and the FIB damage of the initial plan-view sample can be easily measured (indicated).
Note: FIB damage is for shallow angle incidence of 30 kV Ga ion beam. W suffers less damage than Si.

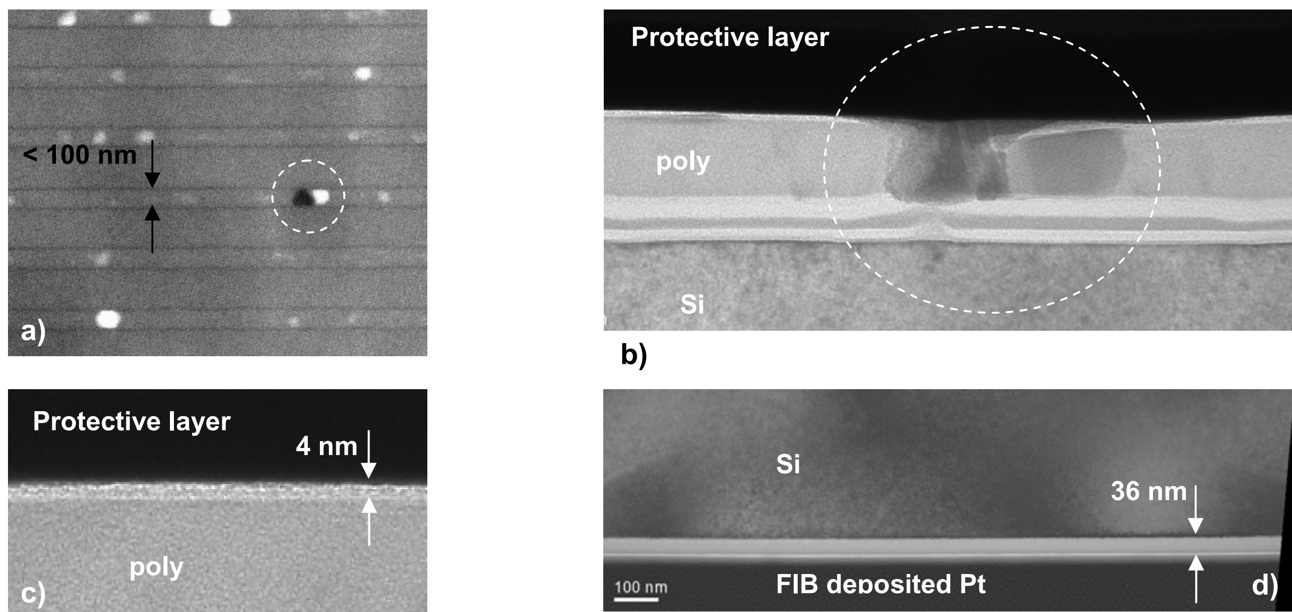

Fig. 2 (a) Z-contrast STEM of plan-view sample. Defect in less than 100 nm poly-silicon line is circled;
(b) Cross-section of the plan-view sample showing the same defect;
(c) 4 nm damaged layer from 4 kV Ar ion milling; (d) Substrate side of the sample showing 36 nm damaged layer from 30 kV Ga FIB ion beam (normal incidence).

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