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Electron Tomography of Microelectronic Devices

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Transmission electron microscopy (TEM) has been used in the diverse fields of science, engineering and industry over the decades. However, one of the fundamental limitations is that the image obtained using a TEM is a two dimensional slice of a three dimensional structure, which can introduce difficulty in interpreting the 3-dimensional structure of the feature being analyzed. Electron tomography is one way to overcome these restrictions by reconstructing a three dimensional structure from numerous projections of one sample taken over a wide angular range [1].

Electron tomography is mainly explored and used in life science, which deals with the complicated molecular structures from an order of a micrometer down to a nanometer in size. Owing to the aggressive scaling of microelectronic devices, the size of the devices is now suitable for electron tomography and it has begun to draw attention [2]. For example, an entire submicron size via can be imaged using a conventional mid-voltage TEM, which makes the tomographic reconstruction of the whole device possible and practical. Furthermore, the small size of complex features of current devices often results in tightly curved interfaces within the thickness of a normal TEM specimen, resulting in significant geometrical blurring of image details in conventional cross-section images.

One of the practical problems we encounter is that sample thickness increases drastically with the tilt angle. Since the fidelity of tomographic reconstruction is related to the angular range from which the projection images are obtained, getting good images over a relatively wide angular range is crucial [1]. We prepared various device samples one of which is the post-type via sample prepared by focused ion beam (FIB) as shown in Fig. 1. The advantage of the post-type sample over a conventional sliver-type TEM sample is that the sample thickness along the electron path remains constant at all tilt angles while that of a sliver-type sample doubles at 60˚ tilt and triples at about 70˚ tilt. Thus, the maximum tilt angle for the sample is now limited not by the sample thickness but by the sample holder geometry. In addition, the images at high tilt angles possess the same quality as the ones obtained at low tilt angles. We obtained the images of the sample over the range of ±70˚ at every 2˚ using a 200 kV TEM. The images were reconstructed and rendered by using software developed at UCSF [3]. The examples of the reconstructed results are shown in Fig. 2. They reveal the detailed structures of the via such as the hump at the bottom and the morphology of the sidewall, which are almost unobtainable with conventional TEM imaging techniques.

We demonstrated the application of electron tomography to the microelectronic device. This approach has not yet matured but we expect that it will be one of the most important 3D imaging techniques for electronic devices in the near future.

References

[1] J. Frank, Electron tomography: three-dimensional imaging with the transmission electron microscope, Plenum Press, New York, 1992.
[2] C. Kübel et al, *Microsc. Microanl. 8 (suppl. 2)* (2002) 1104CD.

[3] We gratefully appreciate the help and support of Dr. Agard's group at UCSF.

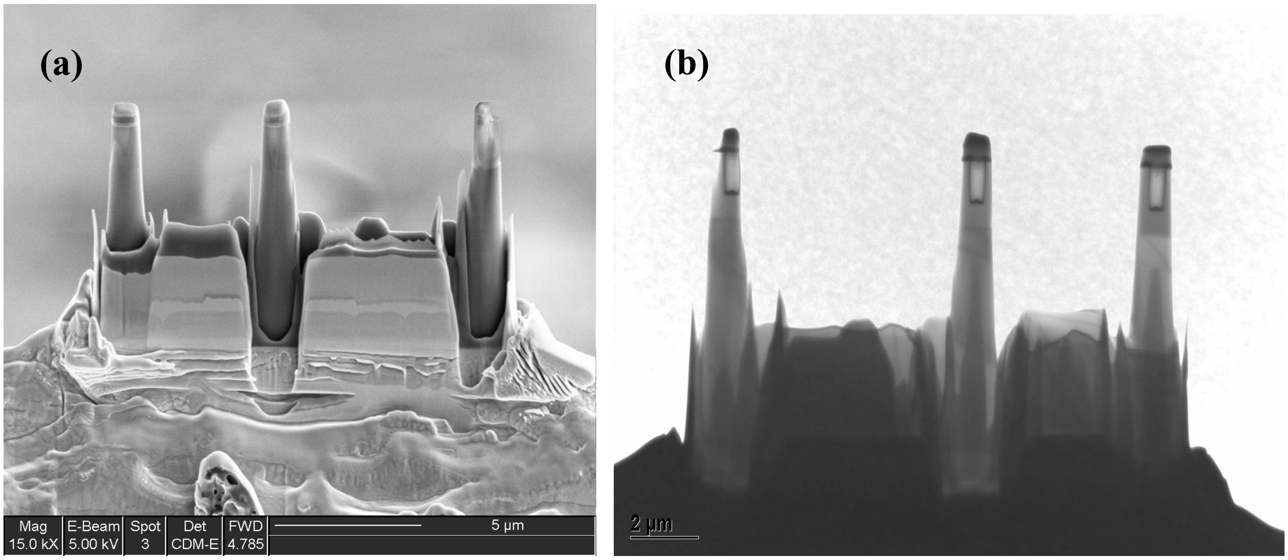

FIG. 1 (a) SEM and (b) TEM BF image of the via post-type sample prepared by FIB

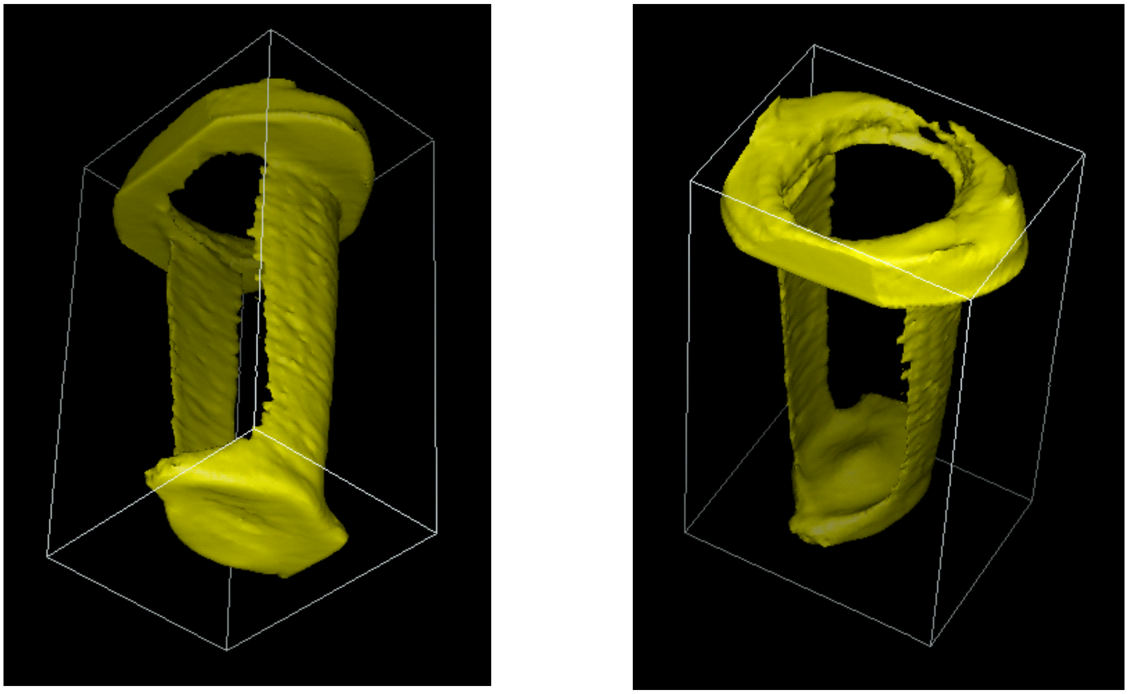

FIG. 2 Three dimensional reconstruction of the via from the sample in FIG. 1