Multi-location TEM Failure Analysis from the Same Planar View Sample for Precise Localization of 28nm Soft Fail

Qianqian Yu*, JH Lee, Haibo Dai, Qihua Zhang, Kary Chien
Semiconductor Manufacturing International (Beijing) Corp., Beijing, P.R.China 100176
*E-mail –Cathy_YQQ@smics.com, Tel: +86-10-67855000-21854

Abstract and Summary- **In this paper, we report a novel method of multi-location cross-section sample preparation for TEM failure analysis from the same planar view TEM sample, which is a large soft fail area. With the development of semiconductor technology, the sizes of devices are smaller and smaller, and the complexity of their structures is increasing. Though a test may show that a large area including multiple devices suffers a soft fail, there is a big risk if we simply use traditional cross- section TEM analysis to solve the problem. In this way, it is easy to miss or over-mill the failed device. Firstly, a large plan-view TEM sample will be prepared, which covers the whole soft fail area. By this means, we can search the precise failed location to determine the root cause failure. Secondly, based on plan-view TEM analysis, multi-location cross-section sample preparation can be completed. The minimum distance between two cross-section samples must be at least 5µm by traditional sample preparation. However, using this technique, we can prepare cross-section samples from distance separation of 1 µm or smaller between two samples. In this way, we are able to point out all soft fail devices from the plan view TEM sample due to its larger field of view. Further, more information can be obtained on the fail devices from multi-location cross-section samples by Transmission Electron Microscope (TEM), Scanning Transmission Electron Microscope (STEM), or Energy Dispersive X-ray (EDX) analysis.**

I. INTRODUCTION

The focused ion beam (FIB) microscope and transmission electron microscope (TEM) have played an outstanding role in silicon process evaluation and semiconductor failure analysis. On the one hand, FIB is usually used for TEM sample preparation because of its high precision milling. On the other hand, most of physical and chemical characterization such as high resolution imaging, nano beam diffraction (NBD) measurement, and Energy Dispersive X-ray (EDX)/Electron Energy-Loss spectrometry (EELS) elemental analysis can be completed by TEM. Conventionally, we can prepare two types of TEM samples, i.e., plan-view and cross-section samples to analyze defects from at least two locations in a wafer. However, with the shrinking of the critical dimension (CD) of semiconductor technology nodes and increased complexity of structure, TEM analysis from two perpendicular directions on the same target are required by FIB technique, in order to obtain more information on defects, as shown in Figure 1. First, a plan-view TEM sample parallel to the wafer surface was prepared [1], which covers the whole soft fail area using in-situ lift-out FIB milling. In this way, there is a greater chance to catch any abnormity as compared with cross-sectional sample due to its larger-scale view (10µm x 10µm). After TEM analysis, the planar sample was further milled to multi-location cross-section samples along the vertical direction. Based on this method of sample preparation, we are able to analyze a defect from two different perpendicular directions and therefore obtain more information for failure analysis.

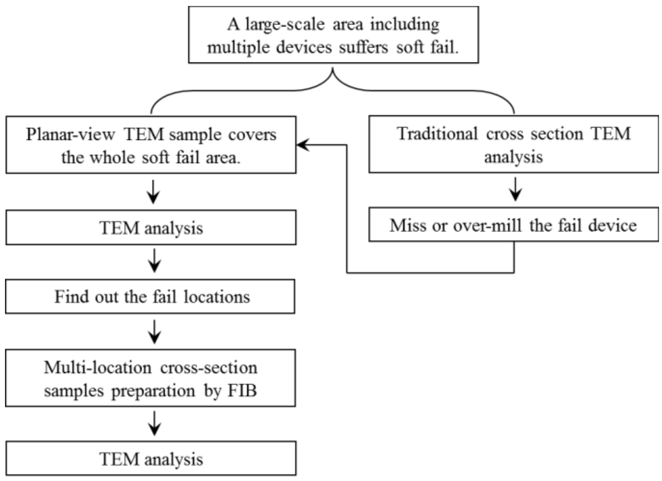

Fig. 1 Schematic drawing of process flow to prepare sample for TEM analysis.

II. EXPERIMENTS

A dual-beam FIB machine equipped with easy lift was used to prepare TEM samples. Samples are then analyzed by TEM operating at 200 kV electron beam acceleration voltage. Scanning-TEM EDX is used for elemental analysis. Some detailed description of sample preparation procedures are not described here, due to their proprietary nature. Figures 2 and 3 show the schematic process flow of sample preparation for multi-location cross-section samples from a plan view TEM sample. A plan-view TEM sample parallel to the wafer surface was prepared including the whole soft fail area using in-situ lift-out FIB milling. Further, the planar sample was further milled to multi-location cross-section samples along the vertical direction separately.

In general, the procedure is as follows:

1) Locate the large–scale area of interest by electrical test.
2) A plan-view TEM sample is prepared using in-situ lift-out method. Using our technique, we prepared a 10µm x10µm plan view TEM sample including all suspect locations.
3) Using easylift tips to in-situ lift-out the lamella and place on copper grid.

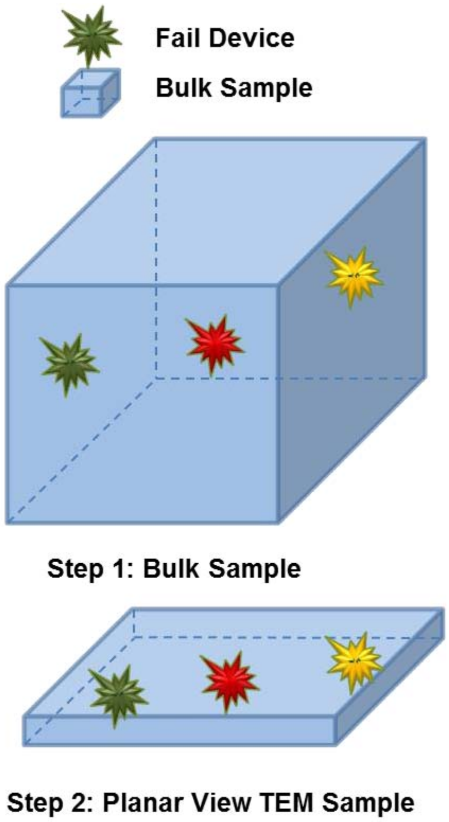

Fig. 2 Schematic drawing of process flow to prepare planar view TEM sample.

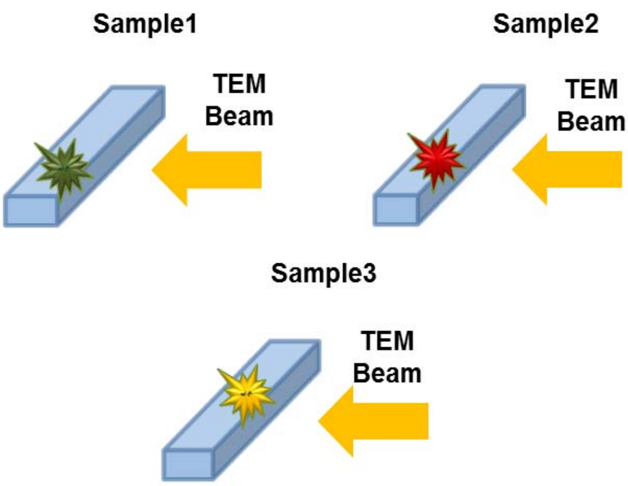

Fig. 3 Multi-cross-section samples process flow.

4) Do TEM analysis and find out the failed locations by plan view TEM observation. From the TEM and STEM images, abnormal and discontinuous silicide profile was found, as shown in Figure 4. Silicide abnormity was observed in three failed locations (S1, S2 and S3) in the same plan view sample. In this way, we have located the precise failed locations.
5) The special marks near the targets are made by FIB milling to identify the locations, as shown in Figure 5a.

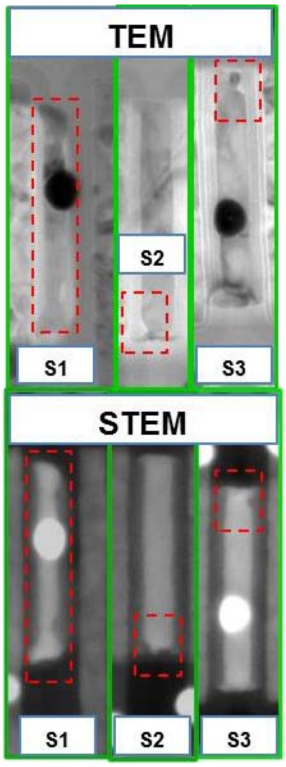

Fig. 4 Planar-view TEM and STEM images from suspect sites.

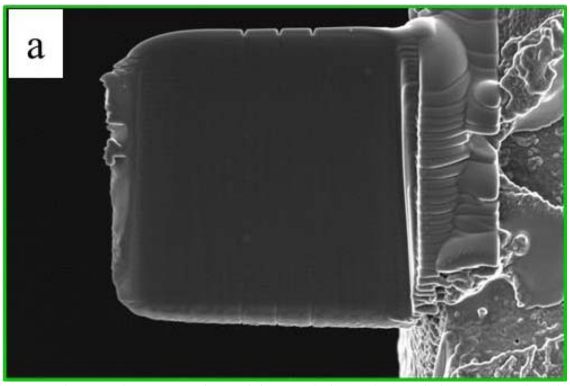

Fig. 5a Planar view samples with special marks and the protective layers on top side.

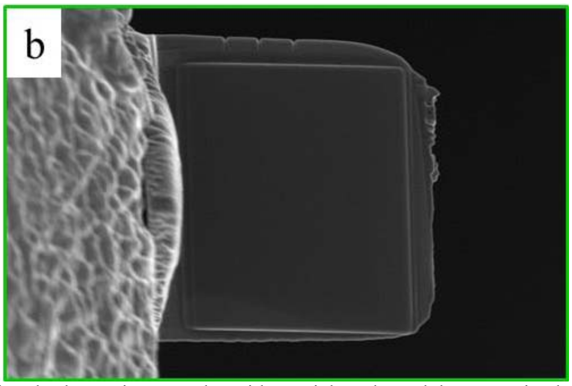

Fig. 5b Planar view samples with special marks and the protective layers on back side.