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Cross-sectional nanoprobing sample preparation on sub-micron device with fast laser grooving technique

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ABSTRACT

Cross-sectional sample preparation is one of the most important failure analysis (FA) techniques in the semiconductor industry. It was commonly used for film stack critical dimension measurement, defect identification, electrical fault isolation and etc. However, cross-sectional sample preparation to a specific target location on a sub-micron device is very challenging and time-consuming. This is because of mechanical polishing easily caused metal smear, delamination, film peel-off, micro-cracked and etc. This paper focused on cross-sectional nanoprobing (XNP) sample preparation improvement in quality and quantity. A laser blast to deprocess or create a groove at near to target location before conventional mechanical polishing and focus ion beam (FIB) fine milling. The proposed technique not only reduces the sample preparation time to the sub-micron target location but also prevent mechanical damages that caused by mechanical polishing technique.

1. Introduction

Cross-sectional sample preparation by mechanical polishing technique is one of the most important areas in semiconductor failure analysis (FA). Many wafer fab requires this for film stack critical dimension (CD) measurement, defect identification, electrical fault isolation and etc. However, cross-sectional sample preparation to a specific target location for a sub-micron device is very challenging and time-consuming, especially on 45° rotated lithography wafer. This is because of mechanical polishing easily caused metal smear, delamination, and micro-cracked. To avoid this, it is often required to reduce the polishing rotation speed resulting time-consuming.

Previously, we reported a novel cross-sectional nanoprobing (XNP) technique on a sub-micron device to performed fault isolation [1]. The sample preparation technique used is conventional cross-sectional polishing technique, which is time-consuming. In this paper, we proposed Fast Laser Grooving (FLG) technique to prepare XNP sample on sub-micron devices. Laser deprocessing for FA top-down delayering application is reported in 2013 [2,3]. The laser deprocessing technique is further explored and applies to large area Cross-sectioning imaging with Scanning Electron Microscopy (XSEM) [4]. A cross-sectional nanoprobing (XNP) sample requires a large area for nanoprobe landing (Fig. 7), in order to achieve this, we have combined the Fast Laser Deprocess Technique (FLDT) with the conventional cross-sectional polishing method to reduce the sample preparation time. The technique not only reduces the sample preparation time to the sub-micron target location but also able to avoid mechanical damage, delamination, and micro-cracked that may be caused by mechanical polishing technique. An alternative technique that has very high speed to create large cross-sectional area will be using plasma Focused Ion Beam (Plasma-FIB) [5]. However, it is very costly and not all wafer fab can afford it [4].

2. FA technique and experiment

A 40 nm Non-Volatile Memory (NVM) device was selected for the experiment. This device is in 45° rotated lithography wafer, which will have 45° crack toward wafer notch when cleaving with commercial micro-cleaving tool such as SELA. Therefore, a normal 0/90 degree cleaving method is not applicable for this kind of sample. Two samples were used in this experiment, one sample was polished using a conventional cross-sectional polishing technique, another sample use Fast Laser Deprocess Technique (FLDT) to create groove follow by the same

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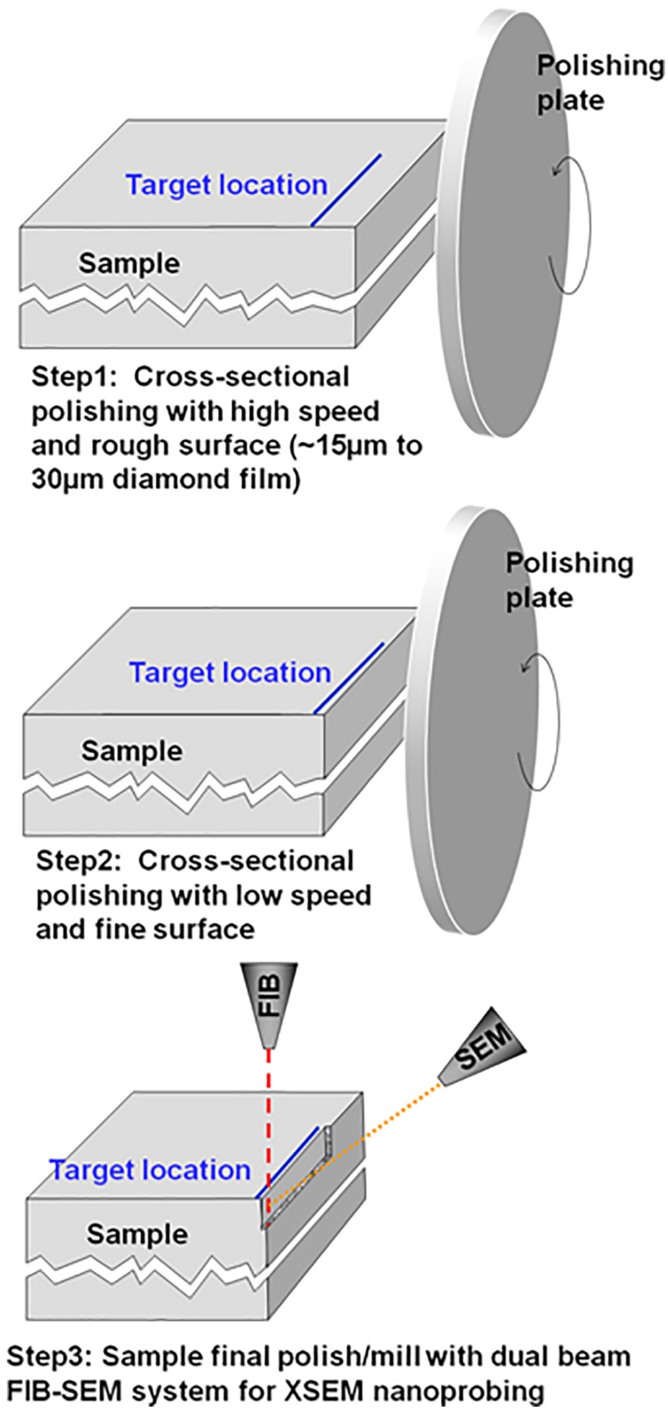

Fig. 1. Cross-sectional nanoprobing (XNP) sample preparation steps by conventional polishing and dual beam FIB technique.

rough polishing technique.

Fig. 1 shows the previously reported sample preparation technique [1]. A sample was rough mechanical polished, normally diamond lapping film with 30 μm roughness so that can reach target location faster.

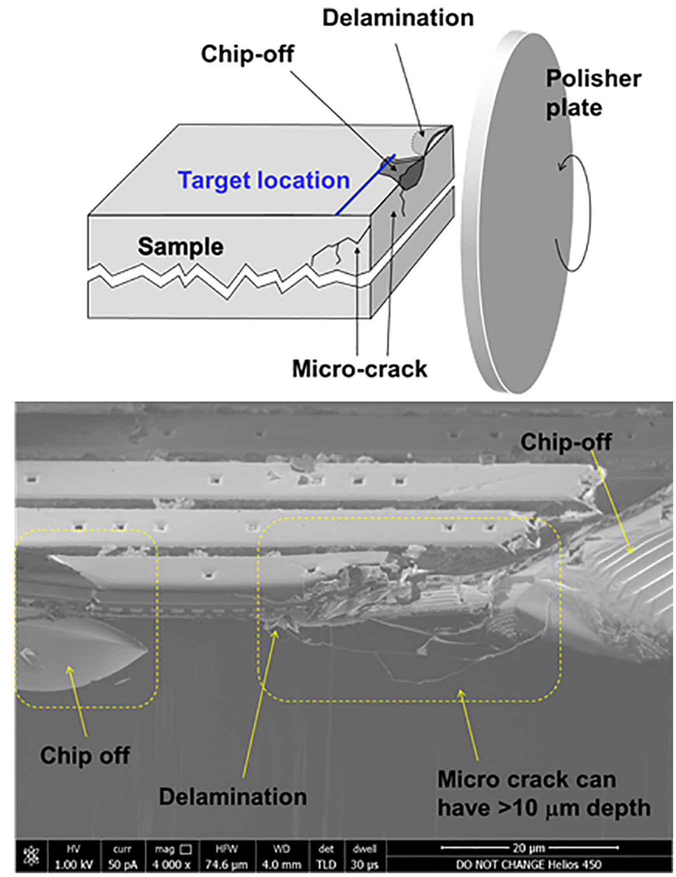

Fig. 2. Damaged that usually caused by cross-sectional mechanical polishing technique.

After polished near to the target location, polishing plate switch to finer diamond lapping film (normally from 6 μm to minimum 1 μm) to fine polish with low rotation speed to a few ten microns away from the target location. After fine polished, the sample will fine mill polish with Dual Beam Focus Ion Beam (FIB). In this experiment, we only use fast polishing speed of 60 rpm and 3 μm lapping film for fine polishing. Fig. 2 shows the possible damaged that can cause by cross-sectional mechanical polishing technique. Mechanical Cross-sectional polishing easily caused micro-crack, delamination, chip-off, and damages on the sample, especially at the higher polishing speed. In order to avoid damages with fast polishing speed, sample 2 used the proposed FLG technique as shown in Fig. 3. The laser deprocessed groove can prevent further delamination or micro-crack into the target location.

To study the groove depth that created by FLG technique, a different number of 50×, 100×, 150×, 200× laser pulses were used to deprocess near to target area on sample 2. The laser system that used is this experiment is from New Wave Research, model Ezlaze3. The laser has a wavelength of 532 nm and was integrated into a model PM5 Cascade probe station. The laser energy used in this experiment is 0.5 mJ with a 50× objective lens. Finally, the sample will be FIB fine polished the surface for nanoprobe. The FIB used in this experiment is Helios 450S from ThermoFisher. The nanoprobing system used for electrical measurement is NProber system from ThermoFisher.