CROSS-SECTIONAL TRANSMISSION ELECTRON MICROSCOPY OF SEMICONDUCTORS

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ABSTRACT

A method to prepare cross-sectional (X) semiconductor specimens for transmission electron microscopy (TEM) has been described. The power and utility of XTEM has been demonstrated. It has been shown that accuracy and interpretation of indirect structural-defects profiling techniques, namely, MeV He+ channeling and secondary ion mass spectrometry (SIMS) can be greatly enhanced by comparing their results with those obtained by XTEM from the same set of samples.

INTRODUCTION

For a 100 keV microscope, the maximum thickness of silicon that can be imaged under the bright-field condition is ~1 micron. Therefore, good quality specimen preparation for the TEM studies is one of the essential requirements. The specimens can be prepared in three ways so that either top or edge-on (90° cross-section) or low-angle (1-3°) beveled view of the specimen can be seen. For the top view and low angle beveled view specimens, the thinning is performed by a chemical jet that ejects an HF:HNO₃ solution or by low energy (6-10 keV) ion milling. However, for cross-section type specimens, especially from the ion implanted samples where the surface layers of thicknesses of only a few 1000 Å are to be viewed, the preparation method involves mechanical thinning followed by ion beam milling. It is nearly impossible to prepare such specimens by chemical thinning.

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The cross-sectional TEM (XTEM) is a very powerful method because the buried damage regions and the defects at the sub-surface interfaces can be directly viewed with very high resolution.

PREPARATION TECHNIQUE FOR CROSS-SECTION SPECIMENS

The first stage for specimen preparation is to mechanically prepare a cross-section specimen ~25 \mu m thick. This is schematically illustrated in Fig. 1a. Two pieces of specimen of dimensions 5 mm x 1 mm are glued together face-to-face with contact adhesive, and then mounted on a glass disc with wax with a piece of silicon slice ~6 mm x 9mm on either side for support. Then, the surface is polished flat with 240 grit SiC paper followed by another 600 grit SiC paper and 6 \mu m diamond paste. With some of the III-V compounds, such as InAs, a final 1 \mu m polish is given to improve the surface finish. Then the specimens are turned over, remounted with wax, and the polishing sequence repeated to give a final specimen less than 25 \mu m thick.

Subsequent thinning is done by a 6 kV, 50 \mu A Ar\(^+\) ion-beam. The specimen is mounted with the mechanically polished surface making an angle of ~20° with the ion-beam. It is thinned from one side only at a time, and the specimen is not rotated. The specimen is orientated with the edge of interest furthest from the ion-beam. After ~1 hr it is turned over and then the other side is thinned until a semi-circular shaped hole occurs at the edge. This procedure preserves the specimen edge without the need for an added protective coating, but occasionally gives rise to some readily recognizable ion beam thinning surface structure. On the other hand, if a protective coating is used, the specimen can be rotated during ion-beam thinning, and such surface structure is markedly reduced.

![Schematic diagram illustrating mechanical polishing](image)

Fig. 1. A schematic diagram illustrating mechanical polishing: (a) initial mounting of the specimens, (b) after the first side has been polished flat.