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Low Damage Sample Preparation of Semiconductor Materials Using Low Energy Ion Milling

S. Roberts*, D. Flatoff*, W. Chiou**

*South Bay Technology, Inc., San Clemente, CA 92673
**UC Irvine, Dept of Chemical, Biochemical & Materials Science, Materials Characterization Center, Irvine, CA 92697

Ion beam milling has become a widespread specimen preparation technique for non-biological materials over the last two decades, particularly for cross-sectional and plan-view transmission electron microscope (TEM) specimens. The basic principle of ion milling involves bombarding a specimen with energetic ions or neutral atoms accelerated and formed into a tightly focused ion beam. Material is sputtered from the specimen resulting in electron transparent areas around the area of interest. Geometrical arrangements from system to system vary, but typically the specimen is rotated or oscillated relative to the ion beam during the milling process. The ion beam is tilted at a given angle with respect to the specimen surface during the ion beam milling process and is adjusted from 0 to 15 degrees.

The disadvantage of ion beam milling specimens for TEM is the artifacts produced during the process. Artifacts include preferential sputtering (one material sputtering at a different rate than another), specimen heating, and radiation damage. Minimizing the incident ion angle to the surface of the sample has been found to be one of the most effective techniques for reducing these effects on the specimen. However, the major artifact that still remains directly resulting from ion milling is the amorphous damage created due to high energy ion bombardment. It has been well known that this process of ion bombardment (typically from 2 – 10 keV) causes damage in the crystalline structure [1]. In the case of semiconductor crystals (such as Si and GaAs), this damage appears mostly as amorphous material on the surfaces of the thinned sample. Reducing the incident ion energy used during the milling process has been found to dramatically reduce and eliminate the amorphous damage produced by traditional ion milling techniques [2].

This paper illustrates the ability of the low energy ion milling system to produce virtually damage free samples free of artifacts typically found in ion beam milled samples. Semiconductors that are susceptible to ion beam damage, such as GaAs and ZnSe, have been somewhat difficult to prepare in the past without inducing a large amount of crystalline damage. Using low energy milling techniques combined with Tripod Polishing and dimpling sample preparation methods, successful sample preparation with a minimum amount of ion damage were produced.

Samples were prepared using two different mechanical preparation methods: Tripod polishing and dimpling. Both methods are well characterized and are widely used for sample preparation. Following preparation samples were prepared using low energy ion milling techniques and examined using the TEM. Figure 1 shows the state of the samples prior to insertion into the ion milling system. Samples were either mounted to a copper grid or inserted directly into the sample holder.

Figure 2 shows the improved sample resulting from low energy ion mill sample preparation. The reduced ion damage is a direct result of low energy ion bombardment and illustrates the effectiveness of this technique, eliminating the need for cooling stage requirements often associated with other systems.

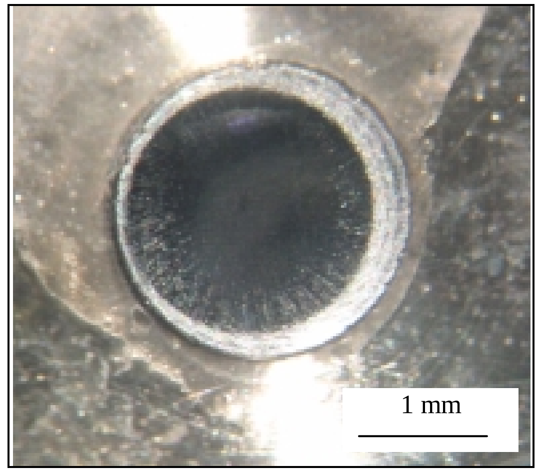

FIG.1. Optical micrograph showing a tripod polished sample (left) and a dimpled sample (right) following mechanical preparation. Both cross sectional and plan view samples can be prepared with these methods.

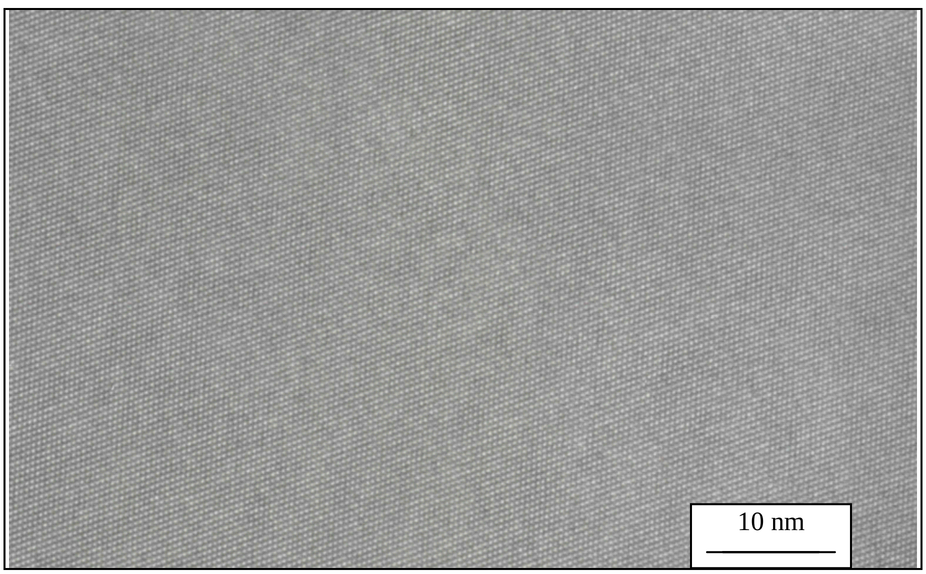

FIG. 2. TEM image showing the GaAs sample processed using low energy ion milling.

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