Diagnostic test for ion implantation dosimetry

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A diagnostic technique is discussed and illustrated by experiment, which reveals sources of error in current integration dosimetry. The technique uses simple, specially prepared samples and an oscilloscope display of the measured current versus time.

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I. INTRODUCTION

Ion implantation has become an accepted tool in the fabrication of solid-state devices. Two reasons for the widespread use of ion implantation are its potential for precise doping control and for reproducibility. However, effects peculiar to ion impact on solids can interfere with accurate dosimetry and thereby jeopardize these primary advantages of ion implantation. Diagnostic techniques are therefore needed to determine the presence and origin of dosimetry errors. The most straightforward method of dosimetry is the integration of the ion current falling on the sample. We present here a simple test that diagnoses errors in such an integration system.

From the total charge deposited on the target, one can easily calculate the total number of incident ions that have been implanted if the average charge state of the ions is known. Complications arise, however, because secondary electrons and ions, which are generated by the primary particles impacting the sample and other surfaces, can cause spurious currents which are also integrated. The number and type of secondary particles depends on the incident ions’ species, the sample material, and on the surface condition of the sample. The problem may be complicated further by the action of suppression biases applied to various electrodes in the vicinity of the target. Frequently, these suppression biases are only partially effective in suppressing the various secondary particles.

A diagnostic procedure should reveal the presence and magnitude of spurious current. The test should permit immediate evaluation of modifications and adjustments of suppression biases, and the procedure should require very little in the way of ancillary equipment or ion implantation modification. These criteria are met in our test by preparing target samples which generate a higher yield of secondary particles. The current in the sample is monitored by an oscilloscope synchronized to the beam scan area and a second electrode biased at −500 V dc (labeled “suppressor”) is located in the shadow of the window and suppresses the emission of secondary electrons from the edge of the window into the Faraday cup. Figures 1 and 2 show photographs of the oscilloscope trace for the three bias arrangements labeled (a), (b), and (c) sketched in the corresponding schematics. The traces represent the measured current versus time or, equivalently, versus position. The incident ion was 100 kV Kr⁺ in all cases.

The bias arrangements were chosen to illustrate common sources of error in current integration and their identification by the present diagnostic test. As can be seen in the trace (a), there is a 15% or 50% increase in the current when the beam impinges on the Au or on the inclined section of the target. This spurious increase can be explained by a loss of secondary electrons generated within the Faraday cup (A) to the vacuum vessel walls.

In part (b) the polarity of the Faraday cup (A) bias is reversed and the target is positive with respect to electrode B which is held near earth potential via the oscilloscope input. Now the escape of secondary electrons from the target is suppressed electrostatically and the error current is reduced, but a new complication arises. Secondary positive ions or energetic neutral particles which leave the Faraday cup will produce electrons (which we shall call “tertiary electrons”) at any solid surface which they encounter. The measured current will reflect both the loss of positive ions and the col-
collection of tertiary electrons by a decrease in relative magnitude during the time the beam is incident on the Au or inclined part of the test samples. The presence of tertiary electrons and their role in ion beam measurement is discussed at length in a paper by Matteson et al. The traces labeled (b) show this change in the current as a decrease of about 5% and 10%.

In (c) the two electrodes A and B have the same bias with respect to each other as in (b), but a change in their potential with respect to the ground (i.e., the vacuum chamber walls) was made. The result is good suppression of secondary electrons and negative ions with an improvement in the collection of secondary positive ions by the electrode B. In the case of the Si–Au sample (Fig. 1), no detectable change is noted to within an experimental error of about 2%. In the other case (Fig. 2), the current increases by 5% which is opposite to the change observed in part (b). This increase could be caused by the loss to the vacuum chamber wall of secondary electrons produced by sputtered Ta atoms impacting on electrode B. Taking into account the strong enhancement of sputtering at slanted angles of beam incidence (proportional to \( \cos^{-1} \)), this increase corresponds to less than a 2% error for a Ta target at normal incidence. We have applied this test on a commercial target assembly, and found that errors of more than 20% easily occur.

### III. CONCLUSION

The diagnostic technique described can be easily used to test the effectiveness of a conventional charge integration system employed in ion implantation systems. The test samples are simple to prepare. Spurious currents of a few percent can be detected, depending on the actual geometry of A and B and the ground wall. Thus, the test procedure provides a simple, prompt, and accurate way to check ion implantation dosimetry for errors due to secondary emission effects.

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