Slicing Off-Axis Si, SiGe, and Ge Wafers

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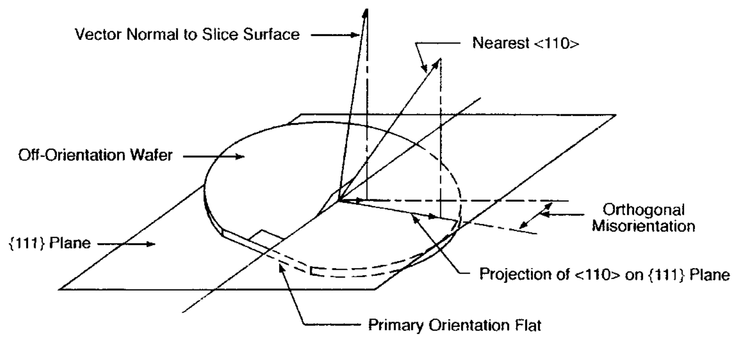
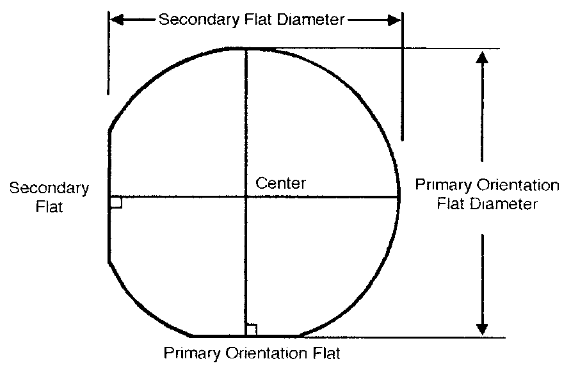
A. Introduction

Many engineers and device designers that are fabricating microelectronic, photonic, and Microelectromechanical devices and circuits require silicon wafers cut off-axis to a primary surface. Surfaces vicinal to the {100}, {111}, and {110} are most common and produced by cutting an on-axis crystal at the appropriate angle. Virginia Semiconductor Incorporated (VSI) can grow crystals of the {111}, {100}, {110}, {211}, {311} crystallographic planes. Also, VSI can slice the ingot along any axis to produce wafers with surfaces at any position on the stereographic projection. This paper describes the basic process and descriptions used to cut off-axis wafers.

The typical Integrated Circuit (IC) industry uses off-axis {111} wafers for certain applications in device and circuit fabrication. There exist SEMI Standards for this classification of {111} wafers, and the related, general, SEMI diagrams for these wafers are given below (Figure 1). This paper, and VSI customers in general, are not as concerned with specifics of the off-axis {111} wafer, but various specification wafers that are off-axis to any primary surface. One should refer to SEMI M1-0298 if the details of off-axis {111} wafers are of interest. A general description of the Miller {hkl} planes and Miller <hkl> directions is given in reference [1].



Orthogonal Misorientation



Primary Orientation Flat Diameter

17 SEMI M1-0298 © SEMI 1978, 1998

Figure 1- Figure from SEMI Standards, SEMI M1-0298 that describe Industry conventions for cutting off-axis (111) wafers.

When VSI slices off-axis wafers from any primary surface, and to the customer specifications the general process described below is used.

B. General Process for Cutting Off-Axis Wafers

Before an off-axis Si, SiGe, or Ge wafer can be produced a stereographic projection is created and,

1. the direction to tilt the wafer is shown on the diagram with an arrow, and
2. the degrees of tilt are shown on the diagram.

Figure 2 is an example stereographic projection used in production for cutting a silicon {100} slice 2 degrees toward the <110> and the flat (note the proper use the generalized bracket notation {}, and <>).

Stereographic Projection
<100>

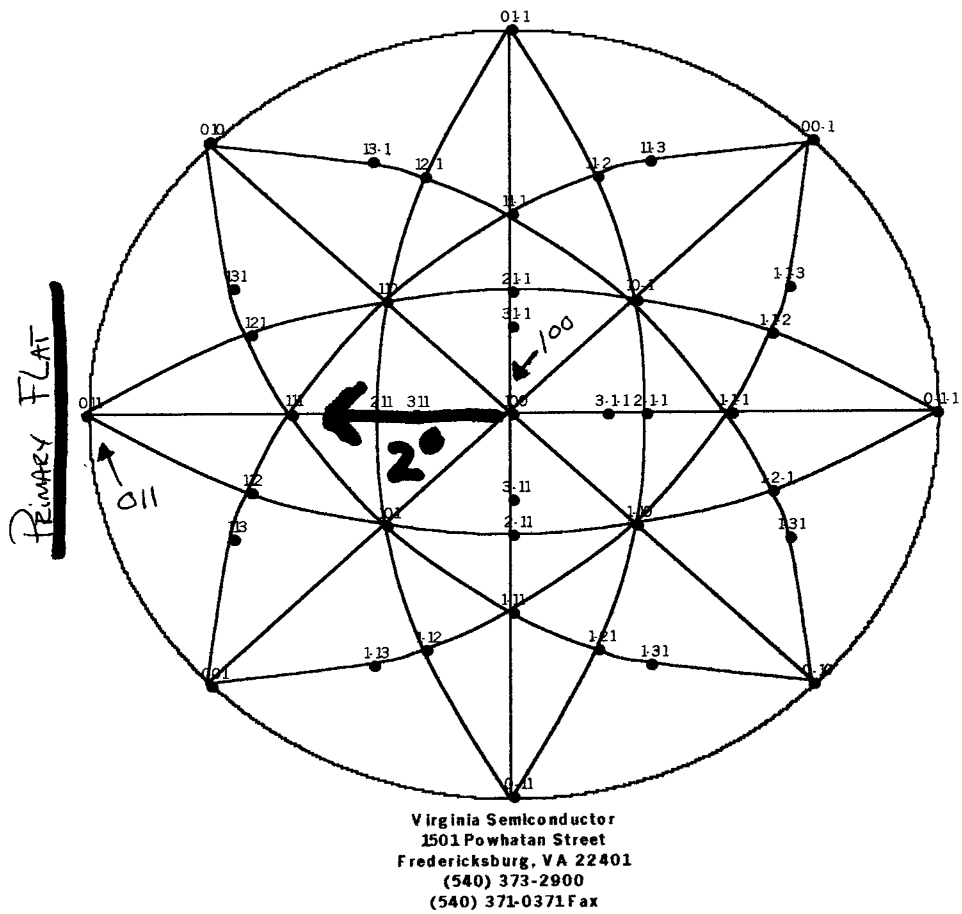


Figure 2 Stereographic projection for the {100} with the direction of tilt indicated by a bold arrow,
and the 2 degree tilt identified.

A crystal is grown using the CZ or FZ technique, and to the closest possible primary orientation shown on the center of the stereographic projection. For this example, the

(100) orientation crystal is grown. After the flats have been properly ground onto the crystal ingot, the saw-operator mounts the ingot on a wafer slicing mounting beam. For this example the primary flat is at the (011). Flat orientation is verified and recorded using an XRAY diffraction Rocking Curve. Figure 3 is a top view showing the ingot and the orientation of the flat as well as wafer surface. The positioning of the saw-blade is also shown in Figure 3.

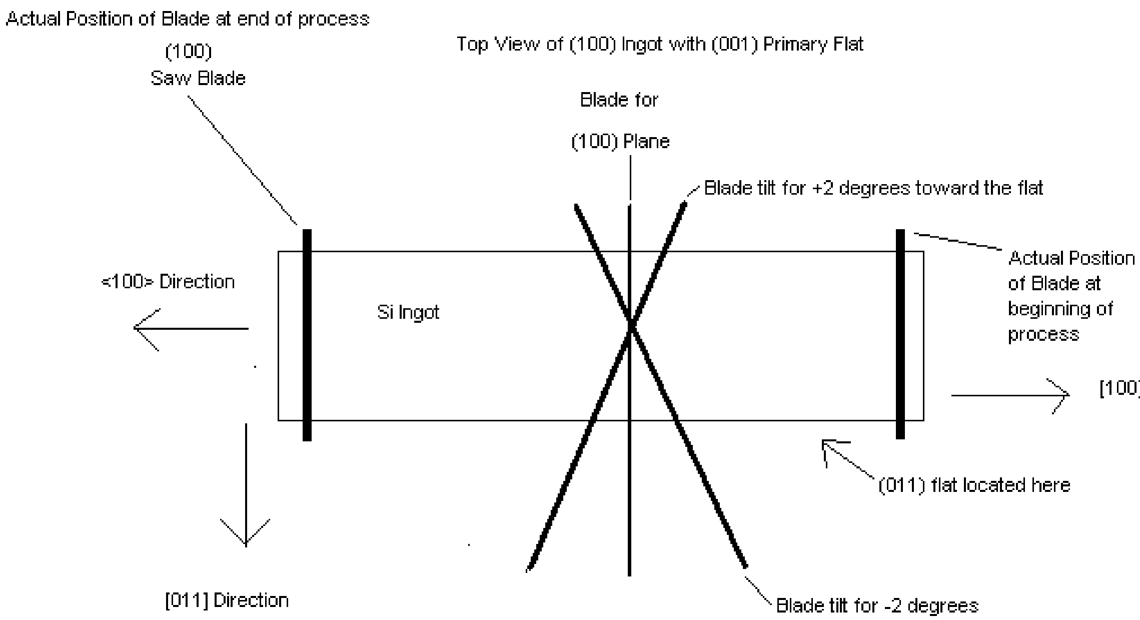


Figure 3 Position of Ingot and Saw-Blade During off-axis cutting of a (100) +2 degrees toward the <110> flat (not drawn to scale).

First, the operator cuts a (100) slice that is (100) +/- the customer tolerance specification (so called orientation slice). SEMI Standards Specifications are +/- 1 degree, but VSI often will slice wafers with +/- 0.1 degree of tolerance. The saw-operator verifies the {100} orientation using an XRAY diffractometer to measure the orientation slice; an XRAY rocking curve is produced for the orientation slice.
Then, as shown above, the crystal is rotated on the inner-diameter saw +2 degrees such that the fixed-location blade slices the crystal +2 degrees toward the (011) flat. Again, the operator measures the degree of miss-cut using and XRAY Rocking Curve. If the off-axis slice meets customer specification, then the remainder of the crystal is cut. For tight tolerance slices, several slices may be monitored for proper orientation using the XRAY Rocking Curve. The same general procedure is used for different primary orientations and off-axis wafer slices.

C. Results and Discussion for Off-Axis (100) Wafers
A set of silicon wafers were cut according to the above general procedure and then measured using the XRAY Diffractometer. The XRAY Rocking Curves for each slice are shown below (Figures 4-6). Note that the Orientation Slice is cut precisely to the (100) before the crystal is rotated and cut at either +.25 degrees and toward the flat, or –.25 degrees and away from the flat (as described in Figure 3).

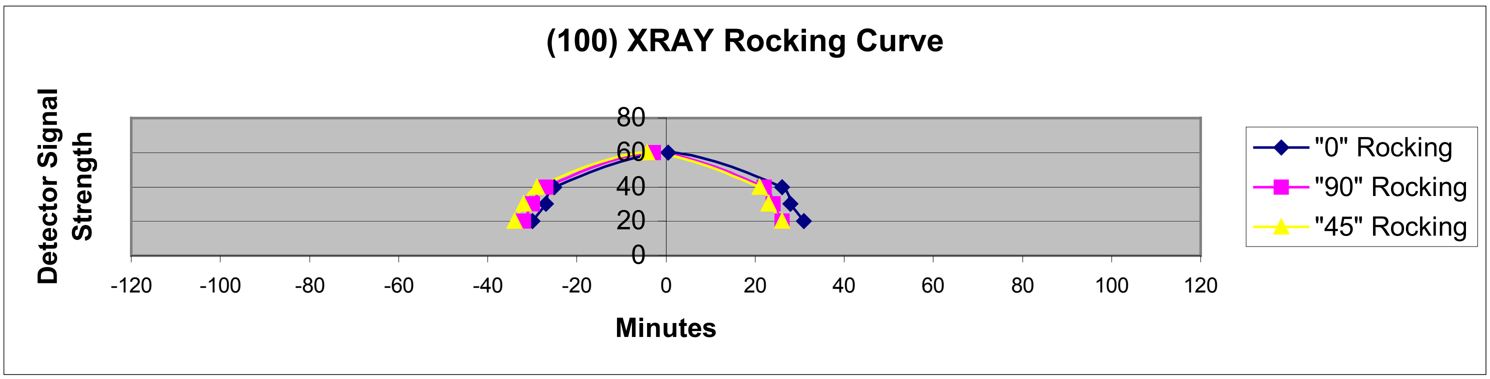


Figure 4 XRAY Rocking Curve for (100) Si slice.

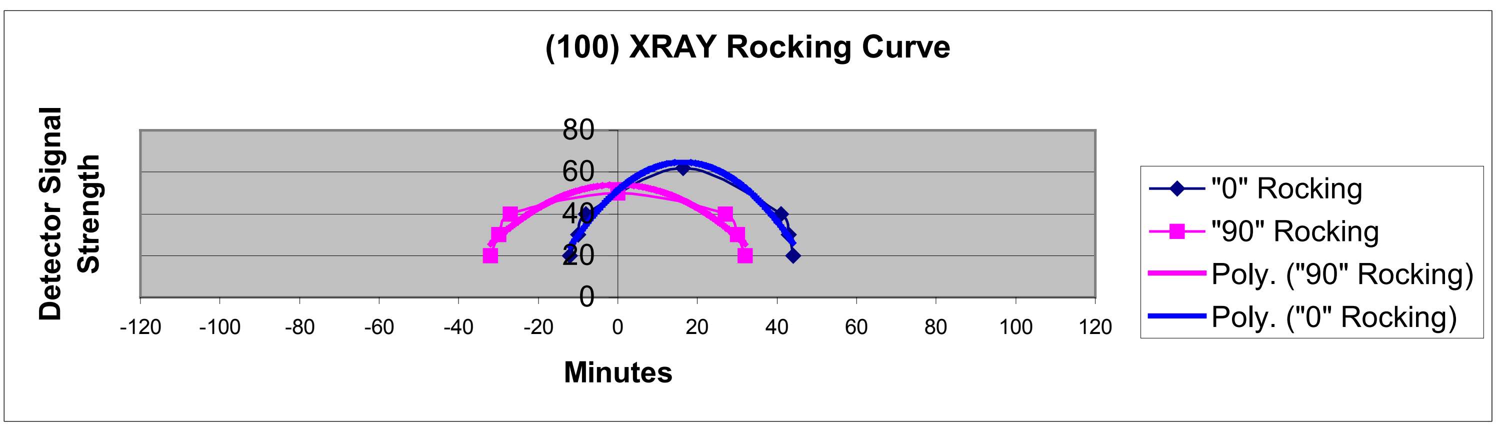


Figure 5 XRAY Rocking Curve for (100) +.25 degrees toward the (011) Flat Si slice.

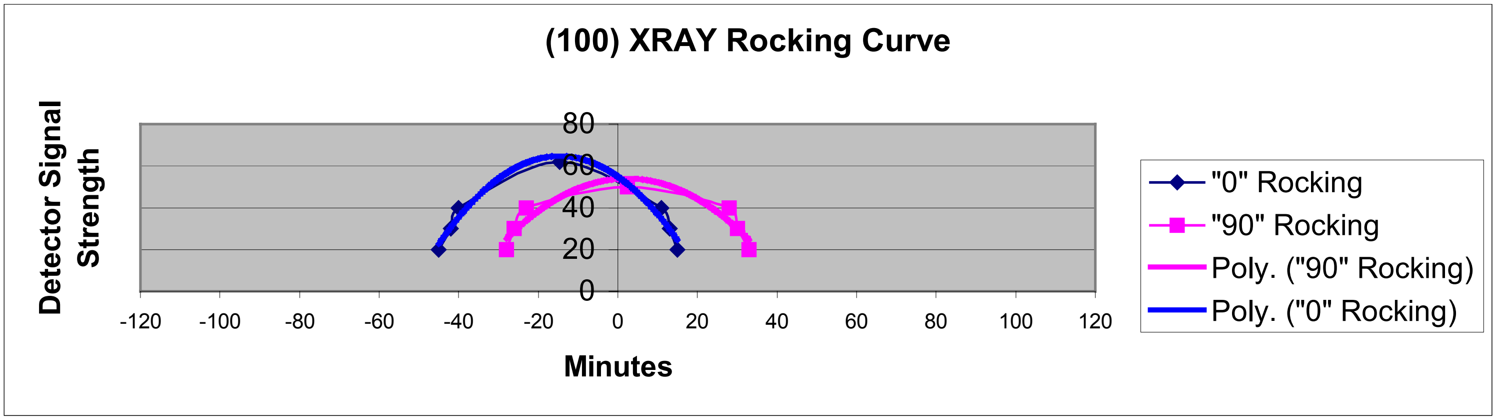


Figure 6 XRAY Rocking Curve for (100) -.25 degrees away from the (011) Flat Si Slice.

D. Summary

A general description of how to slice Si, SiGe, and Ge off-axis has been given. The information given in this paper should be sufficiently accurate for the specification of wafers used in a variety of microelectronic and MEMS applications.

E. References

[1] B.G. Streetman, Solid State Electronics, Third Edition, Chapter 1, Prentice Hall, 1990, ISBN 0-13-822941-4