Project No./(Center No.) E-18-634    P6272-OAO

Project Director: Dr. Stuart R. Stock

Sponsor: Universal Energy Systems

Agreement No.: P.O. No. S-760-6MG-103 under Gov't Prime No. F49620-85-C-0013

Award Period: From 12/1/86 To 12/31/87 (Performance) 12/31/87 Reports

Sponsor Amount:

Contract Value: $ 19,995
Funded: $ 19,995 (fixed price)

Cost Sharing No./(Center No.) E-18-315/(F6272-OAO) Cost Sharing: $ 1,999

Title: Synchrotron X-ray Topography of Striations and Strain Fields in GaAs and Si
Synchrotron White Beam Topography of Striations and Interface Breakdown in GaAs and of Strain Fields in Si

RESTRICTIONS
See Attached Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval — Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with (none proposed)

COMMENTS:
Project No. E-18-634  
Includes Subproject No.(s) n/a  
Project Director(s) S. R. Stock  
GTRC/GHx  
Sponsor Universal Energy Systems  
Title X-Ray Synchrotron Topography of Striations and Strain in GaAs and Strain Fields in Sn  
Effective Completion Date: 12/31/87  
Grant/Contract Closeout Actions Remaining:  
☐ None  
☒ Final Invoice or Copy of Last Invoice Serving as Final  
☒ Release and Assignment  
☐ Final Report of Inventions and/or Subcontract: Already Submitted Patent and Subcontract Questionnaire sent to Project Director  
☒ Govt. Property Inventory & Related Certificate  
☐ Classified Material Certificate  
☐ Other  
Continues Project No.  
Continued by Project No.  
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Facilities Management - ERB  
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FINAL REPORT FOR

1986 USAF-UES SRFP/GSSP CONTINUATION GRANT

Synchrotron White Beam Topography of Striations
and Interface Breakdown in GaAs
and of Strain Fields in Si

by

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January 15, 1988
Abstract

The primary focus of this project was the characterization of striations and of interface breakdown in LEC GaAs(In) by synchrotron white beam topography. Wafers grown for the Air Force by Texas Instruments and by Rockwell and wafers provided by Hewlett-Packard OED were studied. Whenever possible wafers cut from adjacent parts of the boule were examined. Synchrotron microbeam diffraction was also applied to the study of In concentration gradients in wafers with striations.

The secondary object was to develop techniques for the mapping of long-range strain fields in silicon. Synchrotron white beam section topography was employed, and the extra Pendellosung fringes introduced by the varying strain gradients provided the data for this analysis. Strain fields around laser-drilled holes and around simulated and actual devices were studied.

Significant progress was made toward developing these new techniques and toward understanding striation formation and interface breakdown morphology. Analysis of the microbeam diffraction experiments is still underway.
I. Introduction

Characterization of growth defects in GaAs alloyed with In and with other elements and in Si containing long-range strain fields was the goal of this one-year research program. The specific areas of research were: identification of anomalous electrical regions in ion-implanted Si, elucidation of striation structure in GaAs (In) and characterization of interface breakdown morphology in GaAs (In). Little effort was devoted to studying CVD Si(Ga) layers on Si because no new specimens were available.

Synchrotron white beam x-ray diffraction topography was the technique used for studying the semiconductor crystals. Much of the research was straight-forward characterization using projection and reflection topography. In addition, section topography was used to examine strain gradients between implanted and un-implanted regions of extrinsic Si detector materials. Development of novel x-ray topographic techniques was also an important part of the program. Section topographic strain mapping was further refined. Topographic EXAFS was investigated for use in identifying changes in stoichiometry in doped and undoped GaAs. Finally, microbeam diffraction mapping was used to investigate changes in composition across striations in GaAs(In).

The importance of the materials under study and a description of synchrotron radiation and white beam topography are outlined in the proposal and will not be reiterated. Where it is necessary to the interpretation of results, additional
explanations will be furnished in the appropriate section.

II. Results

All of the synchrotron white beam topography was performed at the Stanford Synchrotron Research Laboratory (SSRL) during the following periods: December 15-23, 1986; March 27-April 8, 1987; October 30 - November 4, 1987; November 28 - December 9, 1987 and December 18-21, 1987. All of the experiments at SSRL were with white radiation and were performed in collaboration with Dr. Z.U. Rek of SSRL. Mr. Y.H. Chung (the author's student) helped during the last three periods; Mr. P.C. Huang (the author's student) and Professor T. Gross of the University of Kentucky assisted during the experiments of December 18-21, 1987. Table 1 lists the Si specimens from AFWAL/MLPO and UDRI which were studied at SSRL; Table 2 lists the GaAs samples examined.

Topographic EXAFS experiments were performed at SSRL during April 1987 in collaboration with Dr. D.K. Bowen and Ms. L. Hart of the University of Warwick, England; Dr. Bowen's group is undertaking the complex image processing required to detect contrast changes due to the topographic EXAFS effect. Some preliminary synchrotron monochromatic topographic imaging was performed at the National Synchrotron Light Source (NSLS) in collaboration with Dr. M. Kuriyama's group (National Bureau of Standards); little relevant information was obtained during the short run (February 4-6, 1987), and no further discussions is included in this report. Microbeam diffraction mapping of the spatial variation of lattice parameter in a striated GaAs(In)
wafer was performed at Line X14C, NSLS during January 5-12, 1987. This experiment by the author and Mr. Y.H. Chung was in collaboration with Drs. G.E. Ice and C.J. Sparks, Jr. of Oak Ridge National Laboratory and Dr. A. Habenschuss of Oak Ridge Associated Universities; due to a lack of manpower these results are only now being analyzed, and discussion will, therefore, be limited.

IIa. Study of anomalous electrical regions in ion-implanted Si

This portion of the project centered on identification of the mechanism(s) of performance degradation in extrinsic Si detector materials. Current fabrication requires Si amorphotization followed by Ga implantation. Certain areas of the specimens exhibited anomalous electrical behavior, and it is unclear whether impurity content or damage/strain is the primary factor in degraded performance. X-ray diffraction topography (white beam projection, section and reflection methods) was used to investigate whether damage was associated with these areas. Table 1 lists the samples studied in this part of the project.

Projection topographs of samples G0319-1416 and G0319-1438 are shown in Figure 1. The horizontal lines at top and bottom of these topographs represent the borders of different implantations. The strain gradient is quite severe in this region: diffracted intensity is much greater than background. In the topographs of the former sample there are several, somewhat irregular borders, indicating that the masking procedure probably
could be improved. Considerable damage is visible on both samples (small and large spots and lines in the center part of the specimen) and appears to be associated with surface flaws introduced during handling or testing.

Transmission projection topographs were recorded from G0343-2411-b,-c,-B and -C which had been implanted with different doses of silicon ions (Figure 2).* The incident x-ray beam was normal to the surface, and symmetrical Laue patterns were obtained. Contrast at the interface between implanted and unimplanted material was clearly visible in topographs from all four samples. As different reflections are sensitive to different components of the strain gradient at the interface, one expects different contrast in different diffraction spots. This was observed: the interface had contrast above and below background and in certain hkl it was invisible. The contrast of the interface definitely was greater at larger implantation doses (for the same hkl), which is a qualitative indication of higher strain gradients (e.g. higher stress). The visibility of the border was directly related to the orientation of the diffraction vector \( \mathbf{h} = [hkl] \) relative to the edge of the implanted region. When the projection of \( \mathbf{h} \) was parallel to or nearly parallel to the border, minimum contrast was observed. The converse was also true: \( \mathbf{h} \) perpendicular to the border gave greatest contrast. This result

*The lower-case letters denote (100) wafers while the capital letters denote (111) orientations. The samples labeled by the same letter received the same implantation treatment, and the alphabetical order of samples indicated decreasing dose.
is consistent with the expected variation in strain field.

The diffracted intensity was also greater on the implanted side than on the unimplanted side of the crystal. This was most visible in section topographs (Figure 2b). With the slit oriented perpendicular to the border, a few reflections showed a change in Pendellosung fringe pattern on either side of the boundary. An extra half period was introduced on the ion implanted side, indicating significant strain was present (Figure 2c). The maximum strain from the rapidly varying strain field normal to the substrates' surface can be calculated from this result, but as it involves numerical solution of the dynamical diffraction equations for hypothetical strain distributions, the calculation of strain is beyond the scope of this project.

Section topographs recorded with the slit parallel to the implantation border were much more sensitive to the strains present (Figure 2d). A large number of extra fringes were introduced, indicating that the strain gradients extended much farther and were much more intense normal to the border than perpendicular to it. We note this result is similar to our results for devices on silicon obtained from an identical geometry (see Section II.c). Quantification of the strain is quite beyond the scope of this project as outlined above. We believe that a reasonably small effort in this area would pay enormous dividends in terms of understanding of the strains associated with implanted layers.
IIb. Striation structure and interface breakdown morphology in GaAs(In)

The structure of striations and the morphology of interface breakdown were studied for wafers and longitudinal slabs of GaAs(X), where X represents various atomic species. As In is the most commonly used isovalent dopant, the majority of samples examined were GaAs(In) and contained on the order of 1 at % In. Sets of wafers spanning the initiation and development of interface breakdown were studied with projection (transmission) and reflection settings (Table 2). Wafers from two Hewlett-Packard boules* and from two Texas Instruments boules** provided the bulk of data.

Topographs from pairs of wafers from the seed and tail ends of boules doped with different elements*** showed well-defined striations in some cases. Both tail and seed-end wafers doped with In showed striation structure as did the seed-end wafer doped with P. The striation structure was very similar in both cases (Figure 3) although there were many more dislocations visible in the P-doped material -- which may be an artefact of the growers' process. We note, however, that the tail end of the P-doped boule had a structure identical to that of undoped GaAs: cellular dislocation walls. The P in this boule was less

* Grown in a low thermal gradient, fully encapsulated, low-pressure LEC process. The nominal boule diameter was 65 mm.

** Grown by low pressure, LEC process. The diameters of the wafers examined were 3.0 in.

*** These wafers comprise the first group of Run 12/86 in Table 2.
successful than In in suppressing dislocation generation; without data on the different concentrations and growth processes, nothing further can be concluded.

Our first observation of interface breakdown was in the tail-end of the In-doped boule (G0508-2416), and the boundary of the breakdown region is shown in Figure 3c. The breakdown cells had a very uniform diameter throughout, unlike those observed in the HP and TI wafers. The cells tended to be aligned in rows, but there were numerous faults in the "stacking," and the arrays were not closed-packed. A feature common to all of the In-doped material was the presence of alternating light and dark streaks extending from the cells. This structure was evidently a precursor to cell formation.

Similar breakdown structures were observed in wafers from HP (H276, H287 and H288) and from TI (EB46). Unfortunately wafers from TI EB48 were not available from the interface breakdown region. The morphology of the breakdown zones in the other boules were very similar and only the data from H276 will be presented in detail. Figure 4 shows transmission white beam topographs from H276 which allow one to trace the spread of the cellular region*. Most of the figures are mosaics of several topographs: the areas of interest were much larger than the x-ray beam. The Burgers vectors of the dislocations observed in GaAs(In) wafers could not be identified because they were never

*The left hand edge of the topographs is the edge of the half wafer which was available to us. The topographs of Figure 4 were from the center of the boule.
out of contrast. This may be due to In decoration.

Just prior to interface breakdown, the normal concentric striation rings had given way to a very distorted pattern (Figure 4a). The swirling pattern of striations was reminiscent of turbulence and probably reflected local instabilities in the rate of solidification. The area of the topograph labeled S showed contrast similar to the light and dark alternating streaks noted in Figure 3c, and it is believed that the two topographs showed slightly different stages in the nucleation of the cellular structure. The dislocation density was very low in this wafer.

Slice 58 was the next available wafer and the cellular structure was well-advanced and not quite circular, covering an area of about 12 mm² (Figure 4b). The cell size was reasonably uniform, about 0.4 mm diameter, and few dislocations were observed. Some substructure was visible, but well-defined facets (such as observed in Figure 4e or Figure 6b,c) could not be resolved.

A few dislocations were observed in slice 59, and the morphology of the breakdown zone was similar to that observed in slice 58 (Figure 4c). The zone diameter was approximately 7 mm, and the average cell diameter was somewhat larger (0.6 mm). As was seen in slice 60 which had a length of 10 mm (Figure 4d), the shape of the breakdown region was not circular, and slice 59 probably had a similar shape. Striations were faintly visible in both, and some of the cells in the lower part of the zone in
slice 60 resembled the faceted cells observed in optical micrographs. The 90° bends in the dislocations in the lower part of the slice 60 topograph were a very unusual feature in GaAs, and one could perhaps explain them by invoking dislocation motion and intersection while the temperature of the boule was near the melting point.

Figure 4e was from slice 63 and showed a wide range of cell sizes. The prism structure was very clear in the middle of the breakdown volume. The diameter was about 21 mm, and the zone was more radially symmetric. Another interesting feature was the a lobe of the interface breakdown region which almost surrounded a region of material in which constitution supercooling had not reached the initial value for interfacial instability.

Figure 5 shows topographs from wafers 32 and 42 of boule H287. Well-defined striations and interface breakdown are shown. Along the edge of the breakdown region in wafer 42, alternating light and dark streaks were observed as were jogs in the striations nearby. These features were identical to those shown above. Very few dislocations were present, indicating that the dislocations observed in wafers from boule 276 were incidental to the breakdown process.

Figure 6 shows two topographs and one optical micrograph from various cellular structures. Figure 6a was from boule H288 and was recorded in transmission. Figure 6b was recorded in reflection from TI boule EB46, wafer 66. Note that this wafer was not etched: the images exhibit diffraction contrast and not
contrast from surface topology. This wafer was not thinned so transmission topography yielded little information. The images of prismatic cells was remarkably similar to optical micrographs provided by HP (Figure 6c).

Some longitudinal slices were also studied with topography. The only well-defined interface breakdown was observed in the slab provided by Rockwell, R162 (Figure 6d). Diffraction contrast from the cell boundaries was visible. There were quite a number of breaks in the cells (horizontal boundaries) which might be related to growth interruptions.

We are currently attempting to obtain more wafers from boules exhibiting interface breakdown. A complete series of wafers, spanning the ~1cm length of the boule in which breakdown spreads, would add significantly to the understanding of the breakdown phenomena. Continued progress depends on the availability of Air Force funding, the possibility of which appears quite good.

IIc. Section Topographic Strain Mapping

In section topography a narrow, ribbon-like beam of x-rays is used to illuminate a triangular prison of material in the specimen. A parallel-sided, low absorption crystal such as Si produces section topographs containing fringes parallel to the sides of the topograph. The maxima and minima in the fringe pattern are loci of constant phase between Bloch waves at the exit surface of the crystal. Strain gradients increase the number of fringes, and spatially varying gradients are imaged in
a single section topograph as sections through hyperboloids. The approximation of geometric optics to dynamical diffraction theory allows one to relate the magnitude of the gradient to the number of addition fringes introduced in the section topograph. While this equation does not have an analytic solution, it is fairly simple to solve iteratively.

In most cases the strain gradient is not as useful as the strain itself, and Mr. Chung and the author have developed a simple method of extracting elements of the strain tensor \( \varepsilon_{ij}(x,y) \) from the elements of the gradient tensor as a function of position around a stress concentrator. Note that \( \varepsilon_{ij} \) is an average over the thickness of the specimen. The method relies on the fact that the gradient is the first derivative of strain and that the strain and strain gradient tensors are zero far from the concentrator. Strain is therefore obtained by integrating the gradient over the direction parallel to the projection of the diffraction vector.

The strain fields in silicon crystals around laser-drilled holes and around simulated and actual devices were studied using white beam section topography. Normally narrow adjustable slits are used, but only one section topograph can be recorded at any time. The large, parallel beam of synchrotron radiation made possible recording several section patterns simultaneously. A set of narrow, parallel slits were drilled in a Ta foil for this purpose and up to six section patterns could be recorded simultaneously at SSRL using the multiple slit. A set of section
topographs around a laser-drilled hole is shown in Figure 7 for this specimen. Also shown are the contours of constant dilational strain.

Simulated and actual devices have been studied with projection and section topography. Section topographs seemed to be most sensitive to strain gradients when the slit was oriented parallel to the edge of the oxide layer or device. A typical example was an (001)Si wafer with stripes of silicon nitride on a uniform oxide layer. In white beam projection topography one could always observe the location of the borders. In section topographs with the diffraction vector and slit normal to the stripe borders, however, the position of the borders were not evident. When the section patterns were recorded with the slit at 45° from the stripe border, the location of successive edges were clearly evident (Figure 8). Images of successive edges showed contrast alternating above and below the background of Pendellosung fringes. This is easily explained by noting that the strain gradients have the same magnitudes but opposite signs; channeling of x-rays is expected and will produce this type of contrast. In some section patterns, an additional half-Pendellosung period was observed indicating that there was a significant difference in strain underneath the two types of layers.

The highest sensitivity to strain appeared when the section slit was parallel to the edge of the device or layer (Figure 9). In this orientation at least nine extra fringe periods were
observed. Analysis of the local strain gradient is beyond the scope of the geometric optical approximation to the dynamical diffraction described above. Considerable numerical analysis is necessary before anything other than a qualitative understanding can be advanced. The qualitative understanding is sufficient, however, for optimizing processing conditions and will thus have a major impact.

We note that it has been a major accomplishment for the device fabricators to make samples which are perfect enough for Pendellosung fringes to be resolved. We also note that the section topograph of the extra Pendellosung fringes introduced by the devices strain field is the first ever obtained from an actual device. This major advance should lead rapidly to improved processing and to a deeper understanding of influence of layer parameters on the stress introduced.

IIId. Topographic EXAFS examination of stoichiometry variation in a longitudinal GaAs crystal

Topographic EXAFS refers to x-ray topographic contrast due to fluctuations in absorption (e.g. EXAFS—extended x-ray absorption fine structure) of a specimen diffracting wavelengths near that of the absorption edge of an element in the sample. Even if the sample is unbent, the intrinsic divergence of the white radiation beam is sufficient for diffraction of energies spanning at least a single absorption oscillation. On bent crystals the contrast takes the form of parallel fringes.

*This research was partially supported through NSF grant INT-8513629.
Disturbances in the fringe pattern indicate anomalous regions of the sample; the strain and chemical contributions, however, must be separated. If this can be done, one will be able to simultaneously probe the spatial distribution of chemical and crystallographic defects.

Considerable effort was devoted to detecting topographic EXAFS contrast during the April 1987 run at SSRL. The facilities available at that time were not optimum for detecting this effect. The vertical beam size was limited to about 4 or 5 mm and thus the accessible energy range was less than optimum. The goniometer's angular rotation was rather coarse, given the above constraint, and thus was a great hinderance. The experiment requires locating a favorable transmission Laue spot and orienting to diffract wavelengths at the absorption edge; a real-time x-ray video camera is vital for rapid orientation. The detector available proved to be unsatisfactory, and we were forced to do the alignment using a large number of Polaroid exposures (at least 52 exposures were required).

The absorption edge for a <110> reflection of an undoped GaAs crystal was obtained, and numerous topographs were recorded (75 high resolution SR5 films) as the specimen was rotated across the edge. Between top and bottom of the longitudinal wafer, a 1% difference in Ga concentration was known to exist, and the absorption edge was "scanned" at either end of the crystal. The large change in contrast associated with the edge was clearly visible, but it was impossible to detect the presence of
topographic EXAFS contrast by eye. Detailed image analysis is required to determine whether topographic EXAFS was present. Our collaborators from Britain have considerable expertise in this area and are about to begin this phase of the study.

IIe. Synchrotron X-Ray microbeam diffraction mapping of lattice parameter variation in striated GaAs(In)

The spatial variation of lattice parameter in a striated crystal of GaAs(In) (G04265-2042) was measured using monochromatic x-rays. Rocking curves from each position were recorded in reflection using the symmetric (004) planes and a fundamental wavelength of 1.786 Å. A nominal beam diameter of 10 μm was obtained using a laser-drilled Pd collimator. The collimator was positioned perpendicular to and within two centimeters of the sample using translation and rotation axes of the collimator mount. The small beam divergence led to little broadening of the beam footprint, and any small misalignment of the collimator would tend to compensate for this broadening. At diffraction angles of θ=39.20° the beam irradiates an elliptical area with diameters of 10 and 15 μm.

Figure 10 shows a topograph of the area studied with microbeam diffraction and the projections of the incident beam and scan directions. The longer axis of the beam's footprint was approximately tangential to the striations, and the beam was

*This research was partially supported by the NSLS/HFBR Faculty Student Support Program of Brookhaven National Laboratory.
scanned in both X and Y directions in the specimen's surface (Figure 10). The topograph shows that the striation spacing was about 175 μm in this part of the crystal. Scan steps were 20, 40 or 80 μm, depending on the direction of the scan. Figure 11 shows a rocking curve from the specimen. The full width at half maximum (FWHM) is about 36 arc sec which is much larger than the expected width of about 15 arc sec; this is due primarily to the focusing optics used in Beam Line X14-C.

Analysis of the variation of lattice parameter with position is underway. Cursory examinations of the data revealed that any variation would be subtle. Therefore, the peak positions were defined in terms of the centroid. Analysis is also complicated by the macroscopic curvature of the 250 μm thick specimen: its radius of curvature was approximately 4 m. Our preliminary conclusion is that further experiments are necessary, with double crystal contour mapping required for precise determination of the variation of lattice parameter and hence In concentration.

III. Recommendations

A great deal has been accomplished in many areas during the year of research supported by the UES-USAF SFRP/GSSP. Conclusions are included within the sections of the report (IIa-IIe) and are not repeated here.

A large amount of characterization activity can be supported at very modest annual levels on the order of $50,000. It is the author's strong recommendation, therefore, that work of this kind be continued until such time as the Materials Laboratory can
justify internal development of x-ray diffraction topography capabilities. The specialized topography and rocking curve support for laboratories studying electronic and optoelectronic materials is absolutely essential for credibility in that community.
Table 1: Silicon samples from AFWAL/MLPO and UDRI examined with synchrotron white beam topography at SSRL during the months indicated. Unless otherwise noted samples were examined in transmission and with projection topography. [R] denotes that the reflection setting was used instead of transmission, and [S] denotes section topography instead of projection.
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Table 2: Gallium Arsenide samples examined with synchrotron while beam topography at SSRL during the months indicated. The samples were LEC wafers cut perpendicular to the growth direction unless otherwise indicated ([L] denotes a longitudinal slab, and [HB] denotes horizontal Bridgman crystals). Sources of the crystals are labeled when known: HP for Hewlett-Packard OED, TI for Texas Instruments, R for Rockwell, St for Spectrum Technologies CS for Crystal Specialties, MAC for M/A-Com and CMC for Cominco. Virtually all specimens were examined in transmission with the beam direction approximately along <100>. Other beam directions are noted as are topographs recorded using the reflection geometry ([R]). In many cases, multiple topographs were recorded to cover a larger area of the sample than the beam cross-sectional area ([AS]).

*indicates that these two samples may have been interchanged prior to delivery to the author.

** The USAF identification number has been deleted in order to save space.
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Figure 1. Projection topographs of ion-implanted Si samples G0319-1416 and G0319-1438 (a. and b., respectively). The dark lines at the top and bottom of the topographs are the borders between regions with different dosage levels. Damage is imaged as the fuzzy spots and lines, some of which is labeled by the letter D. The damage appears to be associated with surface flaws.
Figure 2. Section topographs from samples G0343-2411 -b, -c, -B and -C. Samples identified by lower-case letters are (001), and those given by capital letters are (111). Each letter denotes a given implantation dose, and the alphabetical order indicates decreasing dose. Part of the specimen surface was implanted, and the topographs spanned the interface between un-implanted and implanted material.

a. Section topograph of -b with the slit normal to the implantation border. Note the change in diffracted intensity from the two sides.

b. Section topograph of -b with the slit normal to the edge and showing the addition of an extra Pendellosung half-period on the implanted side.

c. Section topograph of -b with the slit parallel to edge of the implanted region. Many additional fringes are introduced, and differences in diffracted intensity are clear.
Figure 3. Topographs of wafers of GaAs doped with In and P and showing striations and interface breakdown structure.

a. GaAs(P) wafer G0520-2478, from the seed end of the boule.
b. GaAs(In) wafer G0508-2413, from the boule's seed end.
c. GaAs(In) wafer G0508-2416, from the boule's tail end.

Note the cellular zone on the left side (wafer center).
Figure 4. Topographs from a set of GaAs(In) wafers from boule H276 of Hewlett-Packard. These topographs illustrate the perturbation of striations just before the interface broke down and the subsequent development and spread of the cellular structure. The center of the left edge of each topograph is the center of the wafer, and topographs of wafers 56, 58, 59, 60 and 63 are shown in a.-e., respectively.
Figure 6. Comparison of cellular structures observed in a transmission topograph of a sample grown by H-P (a.), in a reflection topograph of a sample grown by T.I. (b.), in an optical micrograph of an H-P wafer (c.) and in a longitudinal slab of boule R162 provided by Rockwell (d.).
Figure 7. Section topographs and contour maps of strain gradients and of dilational strains around a laser-drilled hole in (001)Si.
Figure 8. Section topograph of the silicon substrate when the nitride stripes were oriented at 45 deg. from the slit axis. A projection topograph recorded with the same diffraction vector is shown for reference.
Figure 9. Section topograph of the silicon substrate with the edge of the device parallel to the slit axis and lying in the middle of the exit side of the Borrmann triangle. At least nine extra fringes have been introduced.
Figure 10. The area of the GaAs(In) wafer studied by microbeam diffraction is indicated on the topograph as are the two scanning directions X and Y.
Figure 11. Rocking curve recorded with a 0.01 mm diameter beam from the sample shown in Figure 10.