X-ray Rocking-Curve Analysis of Crystals with Buried Amorphous Layers. Case of Ion-Implanted Silicon

BY S. MILITA AND M. SERVIDORI

CNR–Istituto LAMEL, Via Gobetti 101, I-40129 Bologna, Italy

(Received 21 September 1994; accepted 26 May 1995)

Abstract

X-ray rocking-curve analysis of implanted silicon is commonly used to investigate damage accumulation with increasing ion dose. The damage build-up is observed by the trends of either the maximum of the lattice strain normal to the surface ($\varepsilon_{\perp}$) or the depth integral of the $\varepsilon_{\perp}$ profile. However, for doses high enough to produce a buried amorphous layer, the determination of the peak value of the $\varepsilon_{\perp}$ depth profile, and hence of its integral, is not possible. This is demonstrated by means of a simple diffraction model which describes the amorphous layer as a material for which the structure factor is reduced to zero by sufficiently high values of the static Debye–Waller factor and for which the expansion $a$ normal to the surface is given by the product of the fractional change of the interplanar spacing of the perfect crystal ($\varepsilon_{\perp0}$) and the thickness of the amorphous layer ($t_a$). Since this expansion can be written as $u = \varepsilon_{\perp0} t_a = (n + x)d$, where $n$ is an integer ($n = 0, 1, 2, \ldots$), $0 \leq x < 1$ and $d$ is the spacing of the diffraction planes of the perfect crystal, the diffraction model shows that, for given thickness $t_a$ and fraction $x$ of $d$, there exists a discrete, in principle infinite, set of $u$ values able to give identical rocking curves. This prevents the rigid outward displacement of the damaged surface crystalline region with respect to the substrate from being determined.

1. Introduction

Studies of ion–target interaction, the observation of defect formation of different types and the modeling of damage accumulation in crystals are relevant activities to understand the physical aspects of the ion-implantation process. X-ray diffraction techniques, mainly in the multicrystal configuration, are recognized as a powerful tool for such investigations, owing to their high sensitivity to weak strain fields associated with lattice defects. Several papers have been published in the literature in the last two decades and many of them were devoted to the analysis of the damage growth with increase in the incident ion dose in implanted silicon (see e.g. Bai & Nicolet, 1991; Cellini, Carnera, Berti, Gasparotto, Steer, Servidori & Milita, 1995; Sealy, Barklie, Lulli, Nipoti, Milita & Servidori, 1995). The trends with dose of the peak value of the $\varepsilon_{\perp}$ depth distribution or the value of the depth integral of $\varepsilon_{\perp}$, as determined by the best fit of experimental rocking curves (RCs), provide evidence of different phenomena, such as dynamical recovery of point defects inside each cascade or produced by different ion tracks, clustering of point defects under bombardment and formation of amorphous islands in the crystalline matrix. However, this type of analysis is limited to the upper threshold of ion dose at which a buried amorphous layer begins to form. In fact, if the expansion in this layer is described, like the case of a crystalline lamina, in terms of thickness ($t_a$) and strain ($\varepsilon_{\perp0}$) with respect to the perfect substrate, a definite value of $\varepsilon_{\perp0}$ cannot be determined for the amorphous layer.

This ambiguity is demonstrated by the semi-kinematical diffraction model previously reported by Kyutt, Petrashe & Sorokin (1980). This model, whose formalism is particularly suitable for an easy mathematical treatment, shows that, if the deformation parameter is written to the first-order approximation as $\varepsilon_{\perp} = -\Delta \theta / \tan(\theta_B)$, for a given thickness of amorphous layer $t_a$, there exists a discrete, in principle infinite, set of $\varepsilon_{\perp0}$ values able to produce identical RCs. However, the dynamical model and more exact expressions for the incidence and deformation parameters will be shown not to remove this uncertainty.

Here, preliminary theoretical remarks are reported on the interference effects of the wave fields coming from the substrate and the surface crystalline region, whose lattices are spatially separated by an amorphous layer. It will be shown that, for interference phenomena to appear, the two lattices must not necessarily be displaced (dephased) with respect to one another along the normal to the sample surface.

2. Experiment

(001)-oriented silicon single crystals were implanted at room temperature and at random incidence with doses of $5 \times 10^{14} \text{Si}^+ \text{cm}^{-2}$ and $1.5 \times 10^{15} \text{Si}^+ \text{cm}^{-2}$ at 1.5 MeV energy and $5 \times 10^{14} \text{Si}^+ \text{cm}^{-2}$ at 180 keV energy. As shown in the following, the last two implants are able to produce buried amorphous layers. The structural characterization of such sandwiched layers is relevant from the technological point of view, if reference is made to the rather wide recent literature dealing with silicon-on-insulator (SOI) structures obtained by,
The X-ray measurements were made with a double-crystal diffractometer arranged in parallel (non-dispersive) Bragg-Bragg \((n,-n)\) geometry. Cu \(K_{\alpha1}\) radiation was used from the \(0.15 \times 0.8 \text{ mm}^{-2}\) point focus of a sealed tube, the size \(0.15 \text{ mm}\) being in the scattering plane. The collimator was a silicon single crystal asymmetrically cut for grazing-incidence 004 reflection, giving a probe beam on the sample with a divergence in the scattering plane as low as about 2 \(\mu \text{rad}\). This value is ten times smaller than the intrinsic width of the symmetric 004 RC of an infinitely thick silicon crystal and therefore enables convolution to be neglected when minimization routines are used to best fit the experimental X-ray intensity profiles. Hence, the calculated RC of the sample was obtained by simply averaging its \(\sigma\)- and \(\pi\)-polarization profiles over the weights of the \(\sigma\) and \(\pi\) integrated intensities from the collimator.

### 3. Rocking-curve analysis

Fig. 1 reports the experimental symmetric 004 RC (open circles) obtained from the sample implanted with \(1.5 \times 10^{-15} \text{ } ^{28}\text{Si}^+ \text{ cm}^{-2}\) at 1.5 MeV energy. The inset evidences the complex interference pattern of wave fields produced inside the sample. The best fit (line) resulted from a dynamical recursion expression (Wie, Tombrello & Vreeland, 1986) applied to a multilamina description of the deformed sample. This formalism assumes \(\varepsilon_1\) and the exponent of the static Debye-Waller factor \([\exp(-L_H)]\) to be constant within each lamina. In the approximation of a spherically symmetric Gaussian distribution of atomic displacements from the deformed lattice sites, \(L_H = 8[\pi \sin(\theta_B)/\lambda]^2(w^2)\), where \((w^2)\) is the mean square displacement. The initial damage distribution was tailored on the basis of the implant parameters by using a model for which the strain values in the laminae are to some extent constrained to follow a physically plausible depth profile. This precaution is necessary to reduce strongly the probability that unreasonable saw-toothed profiles are obtained when the lamina strains are free to vary independently of one another. This starting profile was then optimized automatically by means of a simplex-type routine (Press, Teukolsky, Vetterling & Flannery, 1992), which minimizes the differences between experimental \((I_i^{\text{exp}})\) and calculated \((I_i^{\text{calc}})\) intensities. The criterion

\[
\chi^2 = \frac{1}{k} \sum_{i=1}^{k} [\log(I_i^{\text{calc}}/I_i^{\text{exp}})]^2
\]

was used, where \(k\) is the number of experimental points. The optimization of the parameters describing the \(\varepsilon_1\) and \(L_H\) distributions led to the profiles of Fig. 2. At first sight, the \(\varepsilon_1\) profile in Fig. 2(a) appears meaningless, since a random implantation of monoenergetic ions in silicon cannot create a doubly peaked damage distribution. However, it becomes understandable if the extremely large values of \(L_H\) at a depth of 1.5 \(\mu \text{m}\) (Fig. 2b) are considered and the following diffraction model is referred to.
4. Semikinematical diffraction from crystals with a buried amorphous layer

4.1. Outline of the model

According to the semi-kinematical model (Kyutt et al., 1980), the diffraction curve of a perfect crystal capped with a thin surface deformed layer of the same material is given by the expression

\[ R(\eta^o) = R_p(\eta^o)|1 + 2i\eta^o \int_0^{\lambda_o} \exp[2i \int_0^A (\eta - f) \, dA'] \, dA|^2, \]

(1)

where \( R_p(\eta^o) \) is the reflectivity curve of the perfect substrate of infinite thickness,

\[ \eta = \frac{\psi_0 + \Delta \theta \sin(2\theta_B)}{|K||\psi_H| \exp(-L_H)} = \eta^o/\exp(-L_H) \]

(2)

is the incidence parameter on the crystal,

\[ f = -\frac{2 \sin^2(\theta_B)e_\perp}{|K||\psi_H| \exp(-L_H)} = f^o/\exp(-L_H) \]

(3)

is the term including the normal component of the lattice strain and

\[ A = \frac{\pi|K||\psi_H| \exp(-L_H)}{\lambda \sin(\theta_B)} \]

is the dimensionless depth in the sample. Here, \( \psi_{0,H} \) are the Fourier coefficients of the crystal polarizability (\( \psi_H \) is the real part of \( \psi_H \)), \( \theta_B \) is the Bragg angle of the perfect crystal, \( \Delta \theta \) is the departure from \( \theta_B \), \( K \) is the polarization factor, \( \exp(-L_H) \) is the static Debye–Waller factor lowering the structure factor (polarizability) when \( L_H > 0 \), \( \lambda \) is the X-ray wavelength, \( z \) is the depth coordinate in the sample and \( A_0 \) is the interface depth separating the deformed surface region from the perfect substrate. In (2), \( \eta \) is written for symmetrical reflection and \( \eta^o \) is for \( L_H = 0 \) (in all quantities the superscript \( o \) means absence of static disorder). \( \eta^o \) is assumed complex only for \( R_p(\eta^o) \), i.e. absorption is neglected in the thin deformed surface region.

Let us consider, for simplicity, that \( \eta \) does not depend on \( A \) (flat sample) and that the crystal region above the substrate consists of two laminae (Fig. 3), of which only lamina 1 is perfect \( \varepsilon_{\perp,1} = L_{H1} = 0 \), \( \eta_1 = \eta^o \), \( \eta_2 = \eta^o/\exp(-L_{H2}) \), \( f_2 = f_2^o/\exp(-L_{H2}) \). Moreover, let \( \varepsilon_{\perp,2} \) and \( L_{H2} \) be constant in lamina 2. Equation (1) then becomes

\[ R(\eta^o) = R_p(\eta^o)|1 + \eta^o B + C|^2, \]

(4)

where

\[ B = \left( \{ \exp[2i(\eta^o - f_2^o)T_2^o] - 1 \}/(\eta^o - f_2^o) \right) \exp(-L_{H2}) \]

and

\[ C = \exp[2i(\eta^o - f_2^o)T_2^o][\exp(2i\eta^o T_1^o) - 1], \]

where \( T_1^o = A_1^o \) and \( T_2^o = A_2^o - A_1^o \).

If \( L_{H2} \) is so large that diffraction does not occur in lamina 2 (buried amorphous layer with thickness \( t_o \) and strain \( \varepsilon_{\perp,o} \)), then (4) gives the solution

\[ R(\eta^o) = R_p(\eta^o)|3 + 2 \cos F(\cos D - \cos E) + 2 \sin F(\sin D - \sin E) - 2 \cos(D - E)|, \]

(5)

where

\[ F = 2f_0^o T_0^o = 2\pi\varepsilon_{\perp,o} t_o/d, \]

(6)

\[ D = 2\eta^o(T_1^o + T_2^o) = \{2[\psi_0 + \Delta \theta \sin(2\theta_B)]/\lambda \sin(\theta_B)\}\{t_1 + t_o\}, \]

\[ E = 2\eta^o T_2^o = \{2[\psi_0 + \Delta \theta \sin(2\theta_B)]/\lambda \sin(\theta_B)\}t_o, \]

\( t_{1,o} \) are the thicknesses of the two laminae, \( \varepsilon_{\perp,o} \) is the strain in the amorphous layer and \( d \) is the spacing of the diffracting planes in the perfect crystal. We see that (5) reduces to \( R(\eta^o) = R_p(\eta^o) \), the reflectivity curve of the perfect crystal, for \( T_2^o = 0 \) or \( T_1^o = 0 \). This is expected because in the first case the buried amorphous layer is removed, while in the second the perfect crystal is capped with non-diffracting material.

4.2. Interpretation of the strain profile

In a previous paper (Fabbri, Servidori & Zani, 1989), it was shown that the surface of a silicon single crystal undergoes a vertical shift after an amorphizing implant and that this shift, as measured mechanically by alphastep, can attain some nanometres. According to this result, the depth integral strain in lamina 2 is the measurement of the vertical expansion and can be written from (6) as

\[ \varepsilon_{\perp,o} t_o = u = (n + x)d, \]

(7)

where \( n \) is an integer (0, 1, 2, . . .) and \( 0 \leq x < 1 \). This means that the outward rigid translation \( u \) of lamina 1

Fig. 3. Sketch of a crystal consisting of two layers on a substrate. Layer numbers, thicknesses (T) and interface positions (A) are indicated.
given by the buried amorphous layer can be divided into a multiple of the interplanar spacing in the perfect crystal plus a fraction between 0 and 1 of this distance. In this case, since in (5) \( \cos F = \cos[2\pi(n + x)] = \cos(2\pi x) \) and \( \sin F = \sin[2\pi(n + x)] = \sin(2\pi x) \), for given thickness \( t_n \) and fraction \( x \) there will exist a discrete, in principle infinite, set due to \( n \) of \( u \) values for which the corresponding RCs [(5)] are identical. Equation (7) implies that, in the presence of a buried amorphous layer, a definite value of \( \varepsilon_{\perp n} \) (and hence of \( u \)) cannot be determined.

Let us now evaluate for the amorphous layer the threshold of \( L_H \) above which the model holds. Several RCs were calculated for the sample of Fig. 1 and compared with the experimental one by the above \( \chi^2 \) criterion. The \( \varepsilon_{\perp} \) profile of Fig. 2(a) was kept fixed, while the \( L_H \) values in the peak region of the lattice strain, originally greater than 100 (Fig. 2b), were increased in steps of 0.5 starting from the value of 0.5. The trend of \( \chi^2 \) vs \( L_H \) is reported in Fig. 4 and shows that the threshold value of \( L_H \) can reasonably be set at 5, a value for which \( \chi^2 \) is essentially zero. According to the \( L_H \) expression, for \( L_H = 5 \) and the 004 diffraction spectrum, we obtain the credible value for amorphous silicon of \( (w^2)^{1/2} = 0.068 \text{ nm} \), approximately ten times larger than the thermal displacement at 300 K.

On the basis of these arguments, the \( \varepsilon_{\perp} \) profile of Fig. 2(a) can be replaced with an equivalent one as follows. Each of the amorphous laminae for which \( L_H \) in Fig. 2(b) is at least 5 contributes to the overall vertical expansion by their own \( \varepsilon_{\perp,i} \) and \( t_{n,i} \). This total rigid outward translation is

\[
u = \sum_{i=8}^{12} \varepsilon_{\perp,i} t_{n,i} = (n + x)d,
\]

where 8 and 12 are the numbers of the upper and lower highly disordered laminae from the surface, respectively.

in Fig. 2b. The obtained value \( u = 0.81998 \text{ nm} \) leads to \( n + x = 6.03931 \) and to the average \( \varepsilon_{\perp,n} = 2.083 \times 10^{-3} \text{ nm} \). If these \( \varepsilon_{\perp,n} \) and \( t_n \) values are used for all the amorphous layer from lamina 8 to lamina 12, the calculated RC does not differ from that in Fig. 1. According to (7), this \( \varepsilon_{\perp,n} \) is one of the possible values that imply the same RC. However, the value of \( \varepsilon_{\perp,n} = 1.356 \times 10^{-5} \text{ relative to n = 0} \) was reported in Fig. 5(a). The lowest value was chosen for the shift of the sample surface because it corresponds to the actual dephasing of the lattices adjacent to the amorphous layer [strictly, dephasing implies that these lattices have the same spacing; however, Fig. 2(a) shows that these spacings are not very different from one another]. We have also to consider that an upper threshold to the discrete, in principle infinite, set due to \( n \) is de facto imposed by \( \varepsilon_{\perp,n} \) values, for which, for implanted silicon, do not exceed a few percent. Then, for \( t_n = 394 \text{ nm} \) and \( \varepsilon_{\perp,n} \) equal to e.g. 4%, the limit of \( n \) amounts to about 100. The corresponding highest \( nd \) is comparable with the errors associated with the thickness values obtained by the RC best fit. Consequently, for \( u = xd \), the thickness \( t_n \) will include the integer part (\( nd \)) of the vertical expansion. A study of the errors in parameter determination is in progress and will be reported in the near future.

As to \( L_H \), its depth profile in Fig. 5(b) differs from that in Fig. 2(b) only for the constant value of \( L_H = 5 \) within \( t_n \). The complex interference pattern is then the result of the interaction between the wave fields

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Fig. 4. Decrease of \( \chi^2 \) with the increase of the static disorder in the buried amorphous layer.

Fig. 5. (a) Strain and (b) static disorder profiles giving the same best-fitted RC as in Fig. 1.
associated with the deformed crystalline regions whose lattices are separated by \( t_\alpha \) and displaced (dephased) from one another by the amount

\[ u = \varepsilon_{\perp \alpha} t_\alpha = xd \quad (8) \]

parallel to the surface normal.

From (5), written for a bi-lamina structure on a thick substrate, and (8), it comes out that intensity oscillations are observed for any thickness of the amorphous layer \( t_\alpha > 0 \), regardless of the value of the rigid translation \( u \). For \( x \neq 0 \), the interference pattern is due, besides the thicknesses of the surface crystalline laminae, to both \( t_\alpha \) and \( \varepsilon_{\perp \alpha} t_\alpha \). When the lattices of the crystalline layers adjacent to the amorphous layer are not dephased (\( x = 0 \)) but only spatially separated by \( t_\alpha \), the interference pattern is sensitive to this thickness.

These interesting phenomena occur independently of the thickness of the buried layer and, for a very thin buried layer, of its nature. In fact, thin crystalline laminae sandwiched between thick layers give negligible contribution to the overall diffraction and hence behave like amorphous materials. The above arguments describe quite general conditions for the appearance of Bragg-case X-ray interference phenomena associated with buried layers and then apply also to III–V and IV–IV heterostructures in which an ultrathin crystalline lamina is grown between thick crystalline layers or a contaminant amorphous layer accidentally forms during growth (Tapfer & Ploog, 1989; Holloway, 1990).

To conclude this section, we underline that the outward shift of the surface occurring when a buried amorphous layer is formed by ion implantation cannot be determined by X-ray diffraction. This is due to neither the approximations in the semi-kinematical model nor those in the incidence and deformation parameters [(2) and (3)].

5. Comparison between approximate and more exact expressions

For this comparison, the expression for \( \eta \), recently reported by Zaus (1993), was used, which proved more effective than (2) for large deviations from the Bragg condition. Moreover, the above \( f \) parameter [(3)], suitable only for \( \varepsilon_{\perp \alpha} \) values below 1%, was replaced by the exact expression already used in a previous study (Servidori, Cembali, Fabbri & Zani, 1992) for the general case of an asymmetric reflection. The new expression for the incidence parameter for symmetric reflection, which includes the exact deformation term, is

\[ \eta' = \{\psi_0 + 2 \sin(\theta) [\sin(\theta) - \sin(\theta_B)]\} \times [K|\psi_H^*| \exp(-L_H)]^{-1}, \]

where \( \theta \) is the incidence angle and \( \theta_B = \sin^{-1}[\sin(\theta_B)/(1 + \varepsilon_{\perp \alpha})] \) is the Bragg angle of the deformed material. If the incidence angle is written as \( \theta = \theta_B + \Delta \theta \), it can be shown that, for sufficiently low \( \varepsilon_{\perp \alpha} \) and \( \Delta \theta \) values, the expression for \( \eta' \) reduces to that of \( \eta - f \) in §3.

The comparison of the 004 experimental RC with those calculated by the two models was done for the silicon wafer implanted with \(^{28}\text{Si}^+\) ions at \( 5 \times 10^{14} \) cm\(^{-2}\) dose and 180 keV energy. The following procedure was adopted. The experimental RC was best fitted with the approximate expressions of §3 and the output data were taken as input data for the more exact model. A further parameter optimization was then done, as the differences in the two models involve differences in the corresponding \( \chi^2 \) values.

Fig. 6 reports the two best fits and the resulting \( \varepsilon_{\perp \alpha} \) profiles (the \( L_H \) profiles are not included because they are analogous to those of the previous sample) obtained with the minimum value of \( \varepsilon_{\perp \alpha} \) \( [n = 0 \text{ in (7)}] \) in \( t_\alpha \). The two calculated RCs are indistinguishable from one another, while vanishingly small deviations are seen in the corresponding \( \varepsilon_{\perp \alpha} \) profiles.

Another comparison is shown in Fig. 7, where the calculations were performed for an \( \varepsilon_{\perp \alpha} \) value corresponding to \( n = 12 \) in (7). In this case, while the two best fitted RCs cannot again be distinguished from one another, some difference is appreciable in the \( \varepsilon_{\perp \alpha} \) profiles.

Fig. 6. (a) Experimental and best-fitted RCs of a silicon sample implanted with \(^{28}\text{Si}^+\) ions at \( 5 \times 10^{14} \) cm\(^{-2}\) dose and 180 keV energy. (b) Strain profiles relative to the minimum strain value in the buried amorphous layer \( (n = 0) \). The approximate and more exact diffraction models are compared.
profiles. This of course comes from the fact that the greater the strain the larger is the discrepancy between the two models. However, for a best fit with more exact expressions, also, the determination of the rigid translation of the crystal portion above the amorphous layer is ambiguous.

6. Crystal without a buried amorphous layer

This section is introduced here to underline that the cycling of RCs on varying \( n \) is a feature related to the presence of a buried amorphous layer. In fact, for a deformed crystalline lamina sandwiched between a perfect cap and a perfect substrate, \( (4) \) becomes

\[
R(\eta'') = R_p(\eta'') [1 + 2G^2 - 2G \cos F(\cos D + G \cos E) \\
- 2G \sin F(\sin D + G \sin E) \\
+ 2G \cos (D - E)],
\]

(9)

where \( G = [\eta'' \exp(-L_{H2}) - \eta'' + f_2^2]/(\eta'' - f_2^2) \) and the other quantities are the same as in (5). Equation (9), which reduces to (5) for \( L_{H2} \) tending to infinity \( (G = -1) \), shows that, unlike the case of an amorphous layer where the \( f \) parameter (and hence \( \varepsilon_\perp \)) enters only periodic functions, \( \varepsilon_\perp \) is included also in term \( G \). Therefore, the determination of the strain in this crystalline layer will be possible. This result is of course not surprising, but some remarks will help in the understanding of the difference from the case of a buried amorphous layer.

Figs. 8(a) and (b) show the RC best fit and the \( \varepsilon_\perp \) and \( L_H \) profiles in the sample implanted with \( ^{28}\text{Si}^+ \) ions at \( 5 \times 10^{13} \text{ cm}^{-2} \) dose and 1.5 MeV energy. Here, all laminae defining the strain profile are crystalline and the one corresponding to the damage peak has \( \varepsilon_{\perp p} = 8.779 \times 10^{-4} \) and \( t_p = 196.2 \text{ nm} \). This lamina contributes to the overall surface shift \( \sum \varepsilon \tau = 0.7952 \text{ nm} \) with \( \varepsilon_{\perp p} = 0.1722 \text{ nm} \). This shift corresponds to \( (n + x) = 1.2686 \). If we follow the same procedure as for an amorphous layer, for \( t_p = 196.2 \text{ nm} \) and \( x = 2.686 \times 10^{-1} \), we will have \( \varepsilon_{\perp p} = 1.859 \times 10^{-4} \) and \( \varepsilon_{\perp p} = 1.570 \times 10^{-3} \) for \( n = 0 \) and \( n = 2 \), respectively. These strain values do not modify the term \( F \) in (9) but introduce severe variations in term \( G \). Fig. 9 evidences the corresponding severe changes in the RCs. Therefore, for crystalline laminae, different RCs are obtained for different \( n \) values and then, for a given lamina thickness, the determination of \( \varepsilon_\perp \) is not ambiguous.

7. Concluding remarks

This paper shows that there is an upper limit for the X-ray technique to follow the growth of damage with the increase of dose in ion-implanted silicon. This limit is associated with the dose at which a buried amorphous
layer begins to form. In fact, when this occurs the value of $\varepsilon_{\perp_0}$ and hence the depth integral of $\varepsilon_{\perp}$ cannot be determined. In both approximate and more exact models, the interfaces between the amorphous layer and the adjacent crystal regions were assumed to be sharp and this assumption did not affect the goodness of the best fits between theory and experiment. Rough interfaces were actually observed by high-resolution transmission electron microscopy, particularly in samples kept at liquid-helium temperature during implant (Narayan, Fathy, Oen & Holland, 1984). Therefore, as our implants were made nominally at room tempera-

ture, some heating effect under bombardment cannot be excluded.

A more extended paper including further experiments and theoretical remarks on Bragg-case X-ray interferometry will be reported in the near future.

The authors thank R. Fabbri, F. Cembali, A. Parisini, R. Balboni and L. Zazzetti (Istituto LAMEL) for their valuable cooperation.

References


