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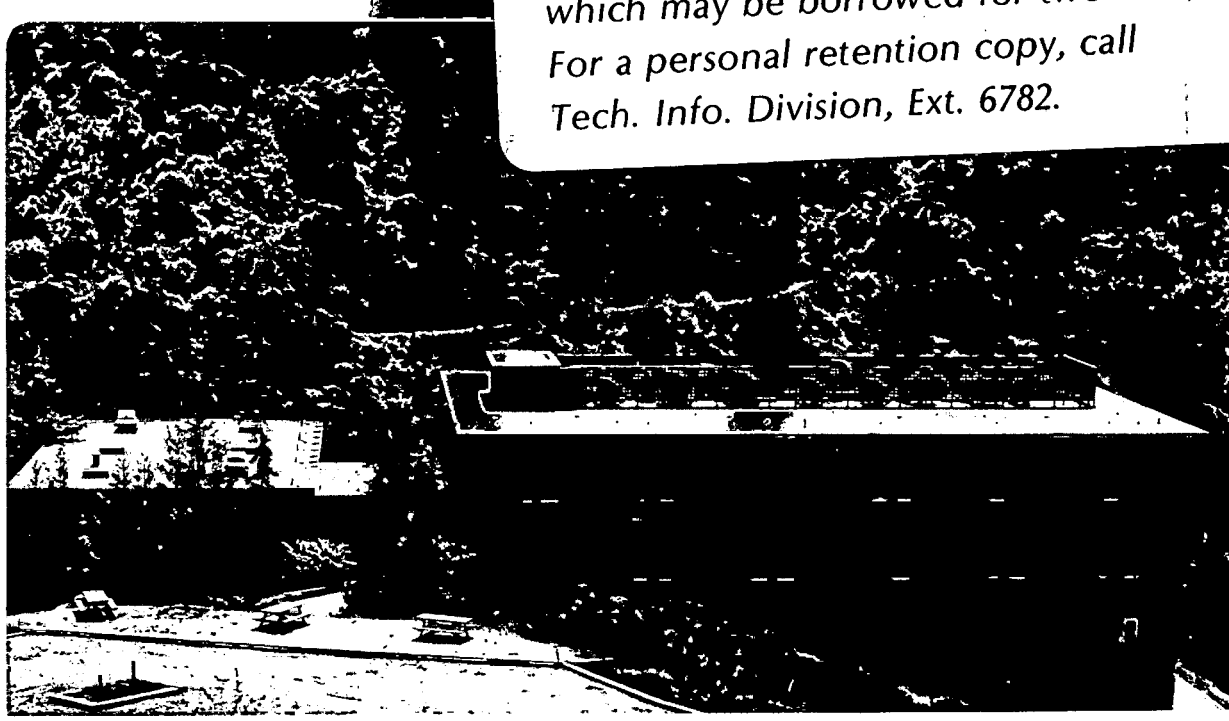

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MeV Electron Irradiation Induced Regrowth of Amorphous Zones in Silicon

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ABSTRACT

Deep buried amorphous layers were created in (100) Si by 11 MeV As implantation. The effect of 1.2 MeV electron irradiation at the upper and lower interfaces of the buried layer was investigated on thin cross-section specimens prepared for transmission electron microscopy. It was found that in partially amorphous silicon amorphous zones ($\leq$100Å) imbedded in crystalline matrix shrank during the irradiation. On the basis of these results and earlier published data, the mechanism of the crystal to amorphous transformation has been discussed.

The sequence of structural changes that occur during conversion of crystalline silicon to an amorphous state when subjected to radiation damage by particles with sufficient energy to be above the displacement threshold is still not well understood. The eventual loss of all long range order must take place either by a) the gradual increase in elementary point defects and/or their clusters and complexes to a density at which a transformation to the amorphous state occurs or to a density where it is just no longer possible to recognize a lattice site[1,2] or b) by accumulation of small amorphous zones that are formed directly and almost instantaneously near the end of the track of an energetic heavy ion.[3] In the latter case it is clear that amorphous and crystalline material will coexist before the material becomes entirely amorphous. Even in the former case it is likely that a nonuniform distribution of point defect complexes will develop particularly at temperatures where the elementary point defects are mobile so that some zones become amorphous before others. If this is the case, an interesting question arises. How stable should small amorphous zones surrounded by still crystalline material be under the irradiation environment? It is known that amorphous silicon regrows at about 500°C by migration of the crystal-amorphous interface with an activation energy of about 2.4 eV.[4,5] It seems likely that migration of these interfaces should take place at lower temperatures with the aid of radiation induced transfers of energy to atoms at the interface and the energy emitted by recombination of vacancies and interstitial atoms at the interface.

To test this idea the effect of high energy electron irradiation on partially amorphous silicon was investigated. A cross section electron microscope specimen of a silicon wafer implanted at room temperature (RT) to a dose of 10^{15} As ions cm^{-2} at 11 MeV provides two different kinds of crystal to amorphous interface at the edges of a buried amorphous layer.(6) At the edge nearest to the surface the displacement damage varies only slowly with depth so that a wide region of partially amorphous material is formed. At the deeper edge there is a much sharper transition from crystal to amorphous material.(6) Figure 1 shows these two interfaces as observed in a cross-section transmission electron micrograph.

Figure 2 shows the effect of 1.2 MeV electron irradiation for increasing times when the beam was placed near each of these interfaces. Amorphous zones shrank at both interfaces but the effect was most pronounced at the near surface interface where amorphous zones would have been expected to be surrounded by crystalline material over a wider region. The experiment was repeated at high and low beam current in order to estimate the effect of beam heating. The result was almost the same for the two beam currents for comparable total electron fluence which shows that the shrinkage of amorphous zones was not due to specimen heating. Previous experience also suggests that the rise in temperature of the specimen could not have approached the 450°C necessary to get thermal regrowth of amorphous regions.(7)

The experiment clearly shows that the formation of amorphous material during ion damage can involve a competition between two processes: 1) formation of new amorphous zones and 2) shrinkage of amorphous zones that are still surrounded by crystalline material. At low temperatures ($\leq$RT) the first process is dominant and the ion implated material eventually becomes 100 percent amorphous. However, at higher temperatures the second process becomes important and it is increasingly difficult to produce amorphous layers in silicon.

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FIGURE LEGENDS

Figure 1. Transmission electron micrograph from the cross-section specimen of a Si wafer implanted with As at RT to a dose of 10^{15} cm^{-2} at 11 MeV.

Figure 2. Effect of 1.2 MeV electron irradiation on partially amorphous region produced by 11 MeV As implant.

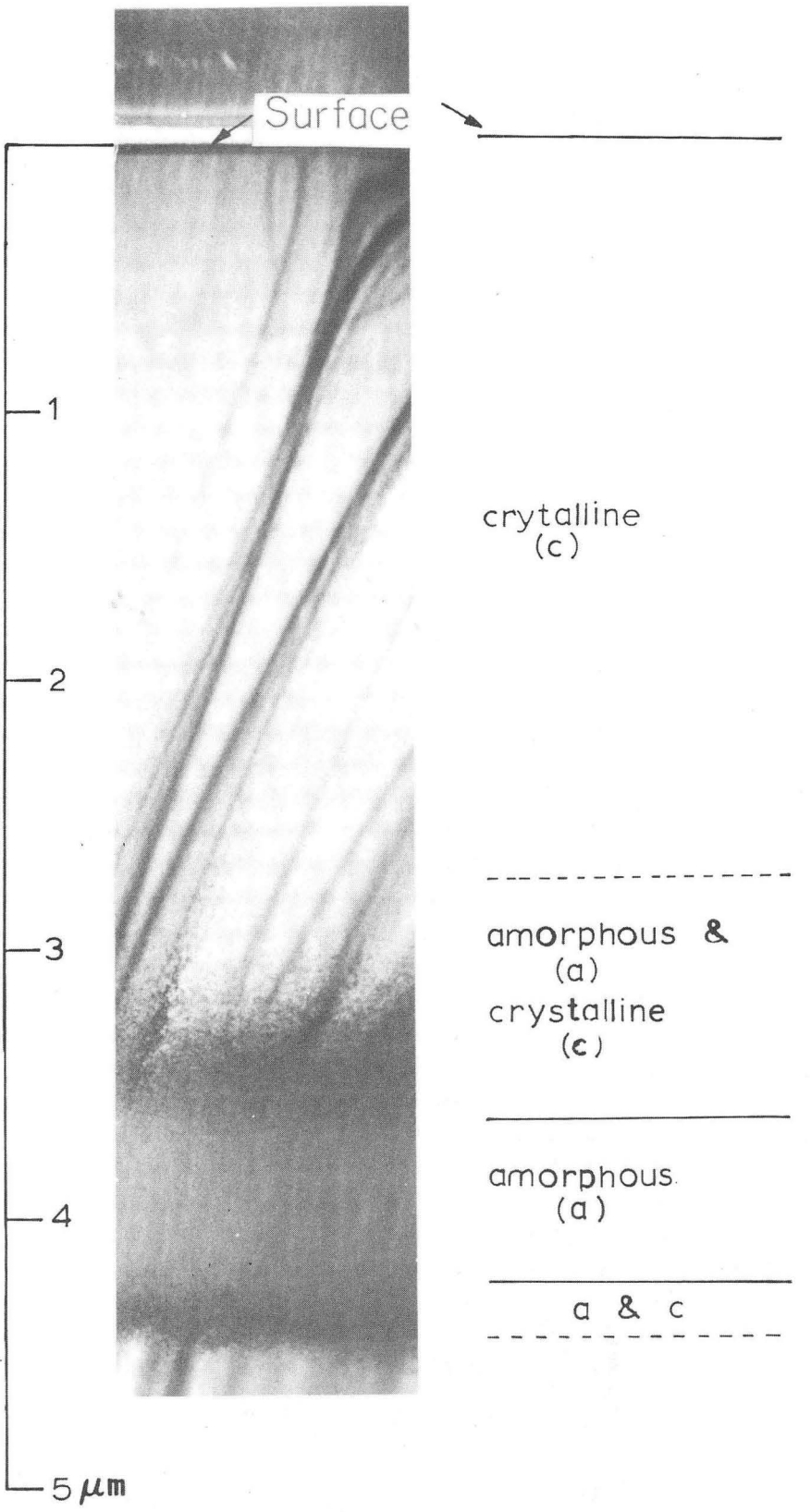

Figure 1

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ELECTRON IRRADIATION INDUCED MIGRATION OF AN AMORPHOUS/CRYSTALLINE INTERFACE

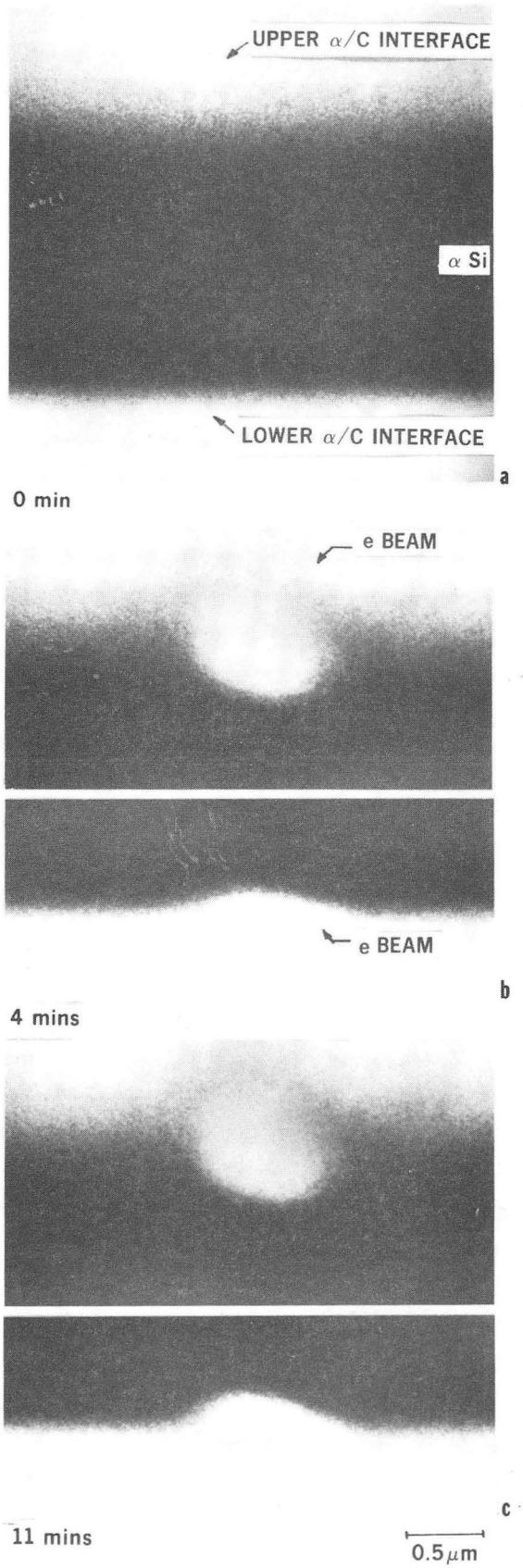

Figure 2 XBB 828-7366

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