Title
ON PRECIPITATION OF PHOSPHOROUS IN ION IMPLANTED SILICON

Author
Seshan, K.

Publication Date
1972-02-01

Submitted to Radiation Effects

ON PRECIPITATION OF PHOSPHOROUS IN ION IMPLANTED SILICON

K. Seshan and J. Washburn

February 1972

AEC Contract No. W-7405-eng-48

LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA • BERKELEY •

40

UNIVERSITY OF CALIFORNIA

Lawrence Berkeley Laboratory
Berkeley, California

January 12, 1973

ERRATA

TO: All recipients of LBL-493

FROM: Inorganic Materials Research Division and Technical Information Division

SUBJECT: LBL-493, "On Precipitation of Phosphorous in Ion Implanted Silicon" by K. Seshan and J. Washburn

Please make the following corrections on subject report.

The micron markers on Figs. 1, 2 and 3 should show 1000 A.

ON PRECIPITATION OF PHOSPHOROUS IN ION IMPLANTED SILICON

by

K. Seshan and J. Washburn

ABSTRACT

Electron microscope observations on phosphorous ion implanted p-silicon after annealing at 800°C are reported. Heating for 1/2 hour after implantation of 2×10^{14} ions/cm^2 at 20°C was found to produce dislocation loops and rod-like defects similar to those observed in baron implanted silicon. It was concluded that the rod-shaped defects are associated with phosphorous precipitation.

INTRODUCTION

Ion implantation in silicon is accompanied by damage along the path of each implanted ion which above a critical number of ions per cm^2 of the order of 10^{14} results in an amorphous layer.[1,2] On subsequent annealing recrystallization of this layer occurs and interstitials and vacancies aggregate into defects large enough to be detected by transmission electron microscopy.[3,4] The present experiments are part of a continuing study of the nature and effects of these defects.

EXPERIMENTAL PROCEDURE

Phosphorous ions were accelerated to 100 kV, mass selected and scanned over the surface of a polished p-type silicon wafer. The surface of the wafer was (111) and it was mounted in an orientation that minimized the probability of channelling. The wafer was maintained at 20°C during an implantation of 10^{14} to 2×10^{14} ions/cm^2. This dose has been shown to produce a continuous amorphous layer.[1,2]

Discs 2.3 mm in diameter were ultrasonically cut from the implanted wafer, dished from the non-implanted side, then chemically thinned until light transmission through the center indicated that the specimens were thin enough for electron transmission. The foils were annealed in an atmosphere of purified helium. Observations were made in a 125 kV Hitachi electron microscope.

RESULTS AND DISCUSSION

Figure 1 shows a specimen that was implanted with 2×10^{14} phosphorous ions/cm^2 then heated to 800°C for 1/2 hour. In addition to dislocation loops there are numerous rod-shaped defects that lie along <110> directions. Similar rod-shaped defects have been observed in boron implanted silicon[5,6] and in silicon implanted with phosphorous at 200°C.[7] These rod defects have previously been reported to be absent when phosphorous is implanted at 20°C.[5,7]

The diffraction contrast effects exhibited by these rods are similar to those described by Davidson and Booker.[8] Dark field (Fig. 2) and weak beam dark field[9] (Fig. 3) observations suggest that the defects cannot be simple dislocation dipoles. The type of black-white contrast which appears for rods that lie parallel to the foil surface is similar to that which is observed for the rod-shaped precipitates in Al-Mg_2Si.[10] The present rod-shaped defects also resemble the rod-shaped precipitates that were previously observed in boron and phosphorous diffusion treated silicon.[11,12]

It is found that rod-like defects are absent from n-type silicon of the same dose and heat treatment.[13] This indicates that boron, already present, has an important influence on the formation of linear defects. However, the dose of boron in the 1 micron implantation layer is about 10^{12} per cm^2. This alone is insufficient to cause a high density of defects observed.

Therefore, it is concluded that these rod defects also involve the precipitation of phosphorous.

ACKNOWLEDGEMENTS

We wish to thank Drs. T. Cass and V. G. K. Reddy of the Fairchild Co., Inc. for providing us with phosphorous implanted silicon wafers. We are grateful to Dr. W. Bell for discussions concerning the interpretation of observed diffraction contrast effects. The financial support of the U.S. Atomic Energy Commission through the Inorganic Materials Division of the Lawrence Berkeley Laboratory is also acknowledged.

REFERENCES

1. J. A. Davies, J. Denhartog, L. Ericksson and J. W. Mayer, Can. J. Phys. 45, 4053 (1967).

2. J. W. Mayer, L. Ericksson, S. T. Picaraux, and J. A. Davies, Can. J. Phys. 46, 663 (1968).

3. B. L. Crowder and R. S. Title, Rad. Eff. 6, 63 (1970).

4. J. W. Mayer, Rad. Eff. 8, 269 (1971).

5. R. W. Bicknell, European Conference on Ion Implantation IPPS/IEE, September 1970.

6. L. T. Chadderton and F. H. Eisen, Rad. Eff. 7, 129 (1971).

7. M. Tamura, T. Ikeda, and Tokuyama, Proc. Second International Conference on Ion Implantation in Semiconductors, I. Ruge and J. Graul, Eds. p. 46(Springer-Verlag 1971).

8. S. M. Davidson and G. R. Booker, Rad.Eff. 6, 83 (1970).

9. D. J. H. Cockayne, I. L. F. Ray and M. J. Whelan, Phil. Mag. 20, 1265 (1969).

10. W. L. Bell and G. Thomas, Proc. 6th International Congress for Electron Microscopy, Kyoto (1966).

11. E. Levine, J. Washburn, and G. Thomas, J.A.P. 38, 81 (1967).

12. H. J. Queisser, G. Thomas, and J. Washburn, J.A.P. 35, 1909 (1964).

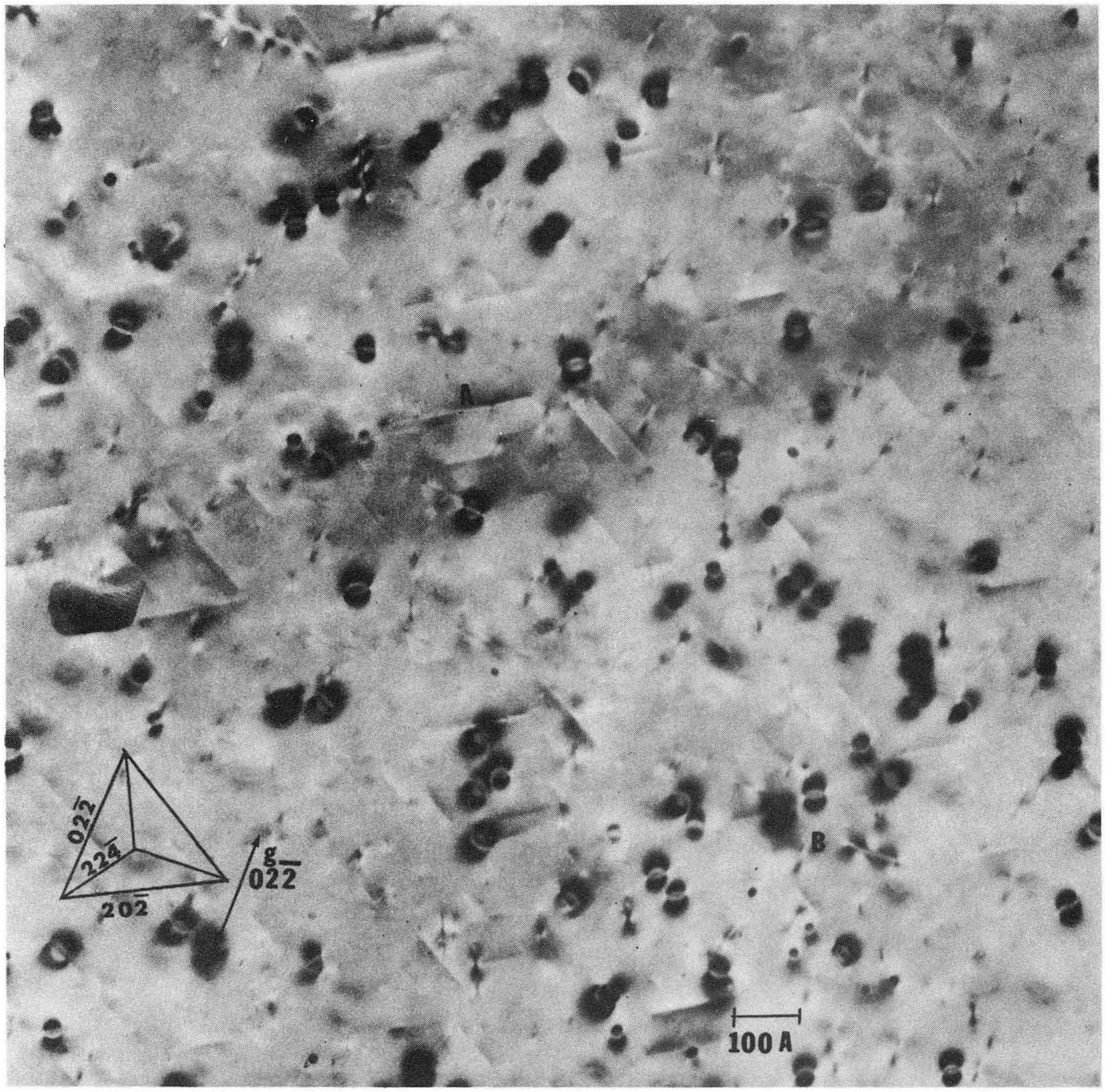
13. Jagdish Narayan, private communication.

FIGURE CAPTIONS

Fig. 1. Bright field image of a p-type silicon sample irradiated with 2 x 10^{14} p ions/cm^2. The foil is oriented for a two-beam case. The three <110> and <112> directions are drawn, projected to the plane of the foil. It will be seen that the linear defects lie along the two sets of crystallographic directions.

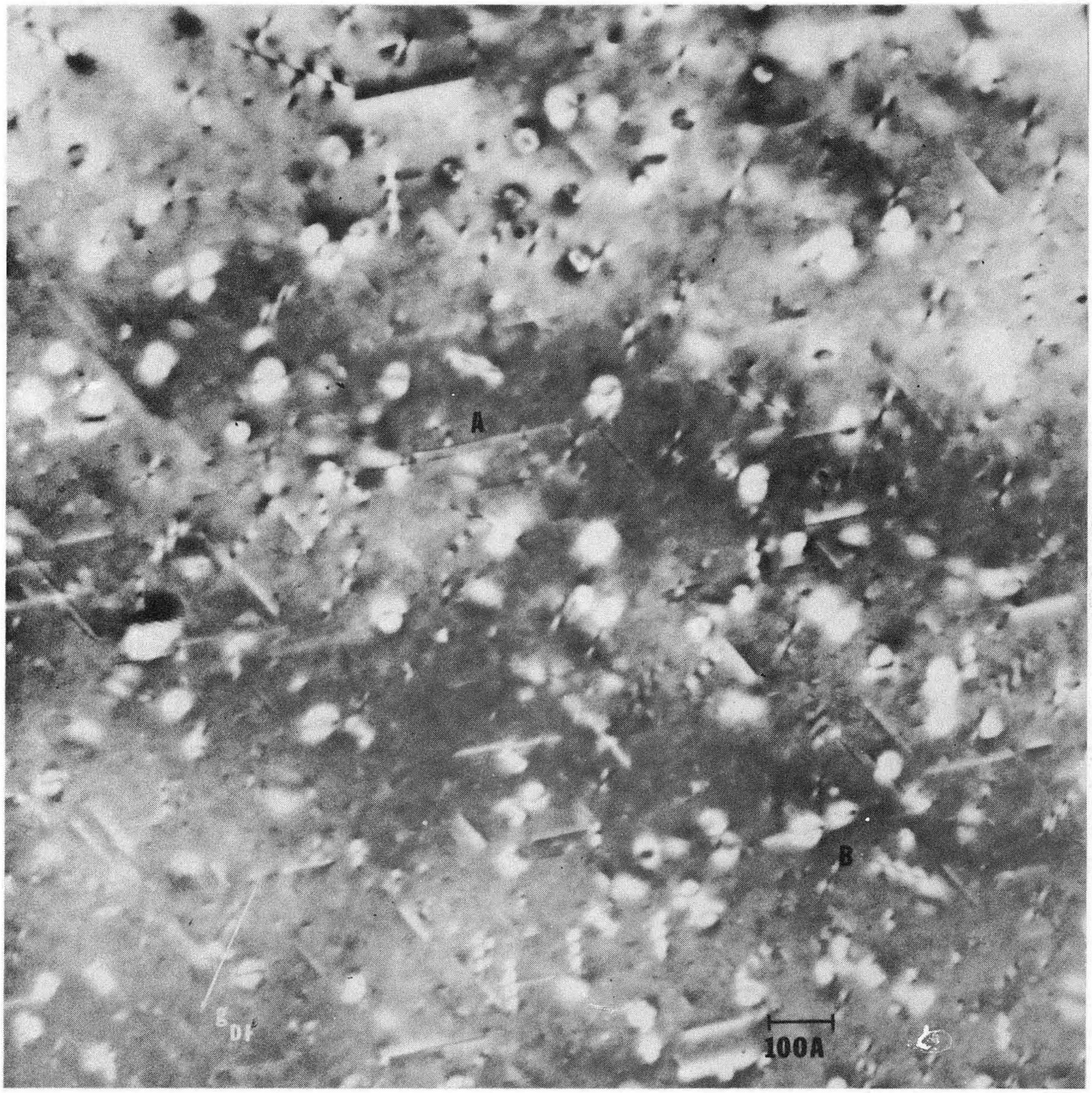
Fig. 2. Dark field image of the same area. Notice that the defects lying along directions not in the (111) plane show split, bead and oscillatory contrast. Reference to the Thomson tetrahedron in the bright field shows these are along the three <112> directions.

Fig. 3. Weak beam dark field image of the same area . The greatly reduced image widths confirm that some form of dopant precipitation is involved .



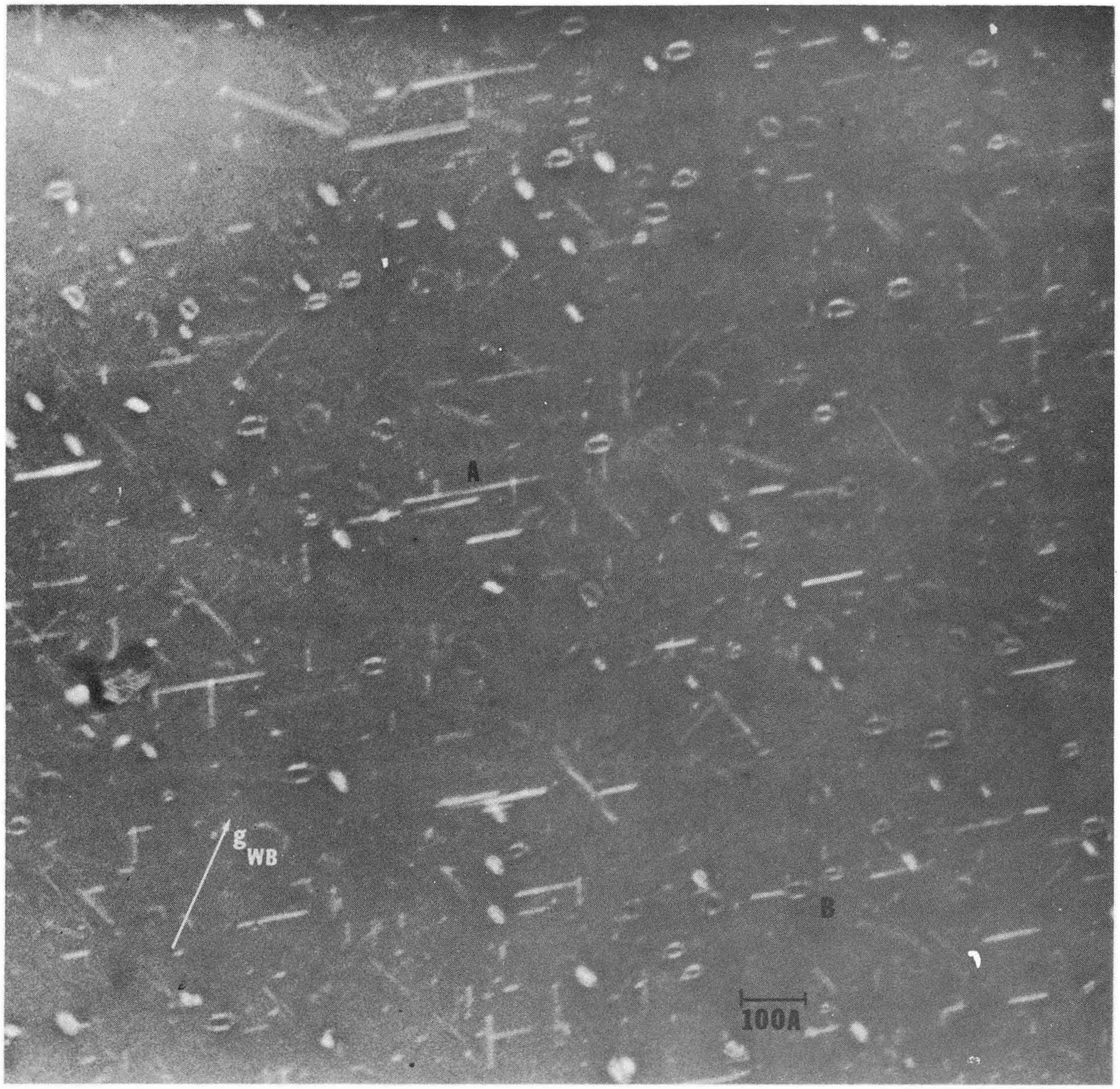
XBB 722-748

Fig. 1



XBB 722-749

Fig. 2



XBB 722-750

Fig. 3

TECHNICAL INFORMATION DIVISION
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720