COMMENTS AND ADDENDA

The Comments and Addenda section is for short communications which are not of such urgency as to justify publication in Physical Review Letters and are not appropriate for regular Articles. It includes only the following types of communications: (1) comments on papers previously published in The Physical Review or Physical Review Letters; (2) addenda to papers previously published in The Physical Review or Physical Review Letters, in which the additional information can be presented without the need for writing a complete article. Manuscripts intended for this section may be accompanied by a brief abstract for information-retrieval purposes. Accepted manuscripts will follow the same publication schedule as articles in this journal, and galleys will be sent to authors.

Electrical conduction in Si-implanted amorphous Si

J. J. Hauser and L. C. Kimerling
Bell Laboratories, Murray Hill, New Jersey 07974
(Received 16 December 1974)

The electrical properties of amorphous Si layers produced by Si implantation are similar to those of amorphous Si films obtained by evaporation or sputtering.

The electrical properties of a-Si films prepared by evaporation[1,2] and by sputtering[3] have been previously described. The amorphous character of ion-implanted Si has been inferred from numerous experiments which have been recently reviewed.[4,5] In particular, electron-spin resonance (ESR) and optical-absorption studies were performed on both a-Si layers obtained by ion implantion and sputtered as well as evaporated a-Si films.[6] The purpose of this paper is to complete the previous studies by measuring the electrical properties of ion-implanted a-Si.

The amorphous Si layer was produced by room-temperature bombardment with 10^{16} Si^+/cm^2 at 75 keV in a 3000-Ω cm float-zoned silicon wafer 0.05 cm thick. The thickness of the amorphous layer was estimated to be equal to the projected range of the implanted ion, 1000 Å.[7] The temperature dependence of the resistance for two different regions of the same irradiated wafer which was measured by the same technique used for the amorphous films[3] is shown in Fig. 1. It is clear from Fig. 1 that just as in the case of sputtered or evaporated a-Si films,[1-3] the low-temperature resistivity is well fitted by the relation

$$\rho = \rho_0 \exp(T_0/T)^{1/4}, \qquad (1)$$

where T_0 is given[8] by $16\alpha^3/kN(E_F)$; α is the coefficient of exponential decay of localized-state wave functions and $N(E_F)$ is the density of localized states at the Fermi level. The deviation towards lower resistance at about 220 °K is not related to the a-Si layer, but is caused by the lower resistance of the crystalline substrate which becomes more dominant above 220 °K. The temperature dependence of relation (1) suggests a thermally activated hopping conductivity via localized states[9] similar

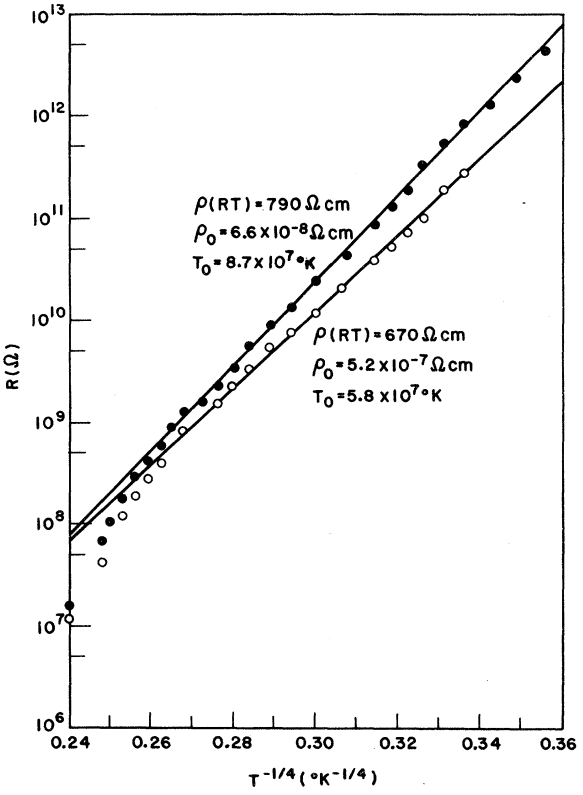

FIG. 1. Temperature dependence of the resistance for two regions of the same irradiated Si wafer.

to the one described in amorphous semiconducting films.[1-3] Furthermore, the values of the prefactor ρ_0 and of the temperature coefficient T_0 (both shown in Fig. 1) are very close to those for evaporated[1,2] and sputtered a-Si films.[3] Using $\alpha = 10^7$ cm^{-1} (the accepted value for a-semiconductors[3]), one concludes that the density of localized states in ion-implanted Si and in a-Si films[1-3] is the same and equal to $(2-3)\times 10^{18}$ (eV cm^3)$^{-1}$. This electrical similarity supports the similarity in optical absorption and in ESR measurements already reported.[6]

We would like to thank K. A. Jackson for having suggested this experiment, J. M. Poate for assistance in the ion bombardments, and C. M. Antosh for this technical assistance.

[1]P. A. Walley, Thin Solid Films 2, 327 (1968).
[2]M. Morgan and P. A. Walley, Philos. Mag. 23, 661 (1971).
[3]J. J. Hauser, Phys. Rev. B 8, 3817 (1973).
[4]J. W. Mayer, L. E. Eriksson, and J. A. Davies, *Ion Implantation in Semiconductors* (Academic, New York, 1970), Chaps. 3 and 4.
[5]L. C. Kim and J. M. Poate, in *Proceedings of International Conference on Lattice Defects in Semiconductors, Freiburg, Germany*, 1974 (Institute of Physics, London, to be published).
[6]B. L. Crowder, R. S. Title, M. H. Brodsky, and G. D. Pettit, Appl. Phys. Lett. 16, 205 (1970).
[7]B. J. Smith, AERE Report, 1971 (unpublished).
[8]V. Ambegaokar, B. I. Halperin, and J. S. Langer, Phys. Rev. B 4, 2612 (1972).
[9]N. F. Mott, Philos. Mag. 19, 835 (1969).