NASA CR-166,397

NASA CONTRACTOR REPORT 166397

Final Technical Report

Stress Induced Long Wavelength Photoconductivity in Coped Silicon Infrared Detectors

J. R. Houck

NASA Grant NAG2-70
August 1982

NASA

NASA CONTRACTOR REPORT 166397

Final Technical Report

Stress Induced Long Wavelength Photoconductivity in Doped Silicon Infrared Detectors

J. R. Houck
Cornell University
Ithaca, New York

Prepared for
Ames Research Center
under Grant NAG2-70

NASA
National Aeronautics and
Space Administration

Ames Research Center
Moffett Field, California 94035

N82-32133#

FINAL TECHNICAL REPORT

NASA Grant NAG 2-70

STRESS INDUCED LONG WAVELENGTH PHOTOCONDUCTIVITY
IN DOPED SILICON INFRARED DETECTORS

Funded

November 1, 1980 to February 28, 1982

Principal Investigator: J. R. Houck

The long wavelength cutoff of a Si:P detector was extended to 34 μm by the application of a uniaxial stress. An unstressed Si:P photoconductive detector responds to photons of up to 28-μm wavelength. By applying a uniaxial stress to a detector along the [100] crystal axis, we were able to extend the response to ~34 microns. The [100] axis was chosen as the stress direction because theoretical calculations predicted that such a stress will extend the wavelength response more than one along the [110] axis. These theoretical calculations were based upon fits to experimental data obtained at stresses of up to ~2 kbar (Tekippe et al. 1972), and indicated that the extension in wavelength response should continue to increase at much larger stresses. These are the results which were used in the calculations in our proposal. Recent conflicting experimental results indicate that the wavelength response extension should level out to a constant value for stresses $\gtrsim$4 kbar (Cooke et al. 1978). The resulting limit to extension of response is ~35 microns, indicating that our detectors were near the ultimate limit. This is consistant with our observations on four separate test runs. We obtained a long wavelength limit of 33-34 microns.

The results from a test run are shown in the accompanying figure. In addition to the longer wavelength response, this figure also shows that the photoconductive response near the peak was approximately ten times smaller in the stressed detector. The reason for this drop is probably due to a decrease in

carrier mobility or lifetime. Increased electrical resistance parallel to a [100] compression has been observed in Si:P (Morin et al. 1957). (Any stress-induced resistance change is known as piezoresistance.) This increase has been interpreted as a result of an increased population of the conduction band minima parallel to the stress direction, resulting in a decreased mobility along the stress axis (Herring 1955; see also Keyes 1960). For low stresses ($\lesssim$0.06 kbar) in Si:P this piezoresistance has been found to be linear in stress and increases with decreasing temperature (Morin et al. 1957). However, no measurements have been found for the stresses and temperature which our detectors are subjected to (>3kbar). Under such conditions the piezoresistance effect becomes nonlinear (Fritzsche 1959) so that we cannot extrapolate from the low-stress values. Thus, although the piezoresistance effect may explain our loss of photoconductive response, we cannot quantitatively verify it.

Although the extension of wavelength response has been demonstrated, detector noise was a problem. Detector noise rose sharply with increasing bias voltage and was seen as voltage spikes in the output at voltages $\gtrsim$20% of the breakdown voltage. These spikes became more frequent as the bias was increased. Because of this noise, the detector signal-to-noise is severely degraded. This noise behavior is very similar to the "spiking" noise reported by Fischbach et al. (1981) in Si:P detectors, which they ascribe to electrical breakdown phenomena. Both our detectors and those of Fischbach et al.

were implanted with phosphorus ions to form ohmic contacts. Although ours were implanted at a single energy and dose and theirs with four energies and doses, the spike noise may arise from the implanted layers. However, origin in the bulk material cannot be ruled out.

We have recently been collaborating with G. Lamb of GSFC to investigate other contacting procedures for n-type silicon. It is clear from our low-background tests that this material has high quantum efficiency (∿20%); and if the spiking is a contact phenomena, then very high quality (unstressed) detectors can be fabricated from this material. This is an important consideration in view of the fact that we have in excess of 200 cm^3 of the material.

Recently we have been looking to the problem of extending the response of p-type Si by the application of stress. Unfortunately, less experimental data on the energy level shifts seem to exist for p-type material.

REFERENCES

Cooke, R. A., Nicholas, R. J., Stradling, R. A., Portal, J. C., and Ashkenazy, S., Solid-State Communications, Vol. 26, 1978, p. 11.

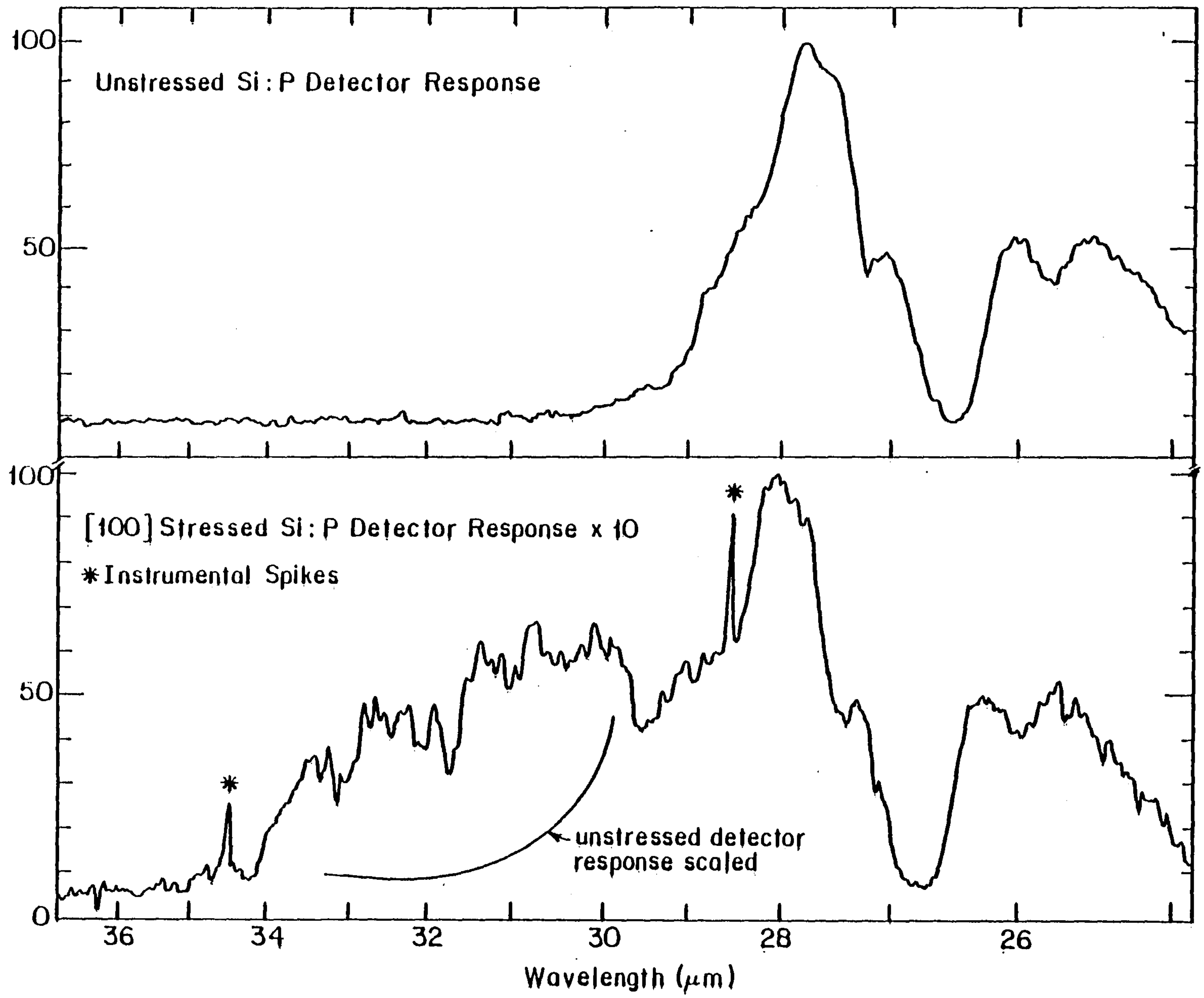
Fischbach, J. U., Brunsmann, U., Frenzl, O., and Egle, H., Infrared Physics, Vol. 21, 1981, p. 207.

Herring C., Bell System Tech Journal, Vol. 34, No. 2, March 1955, p. 237.

Keyes, R. W. in Solid-State Physics, edited by F. Seitz and D. Turnbull (Academic Press Inc., New York, 1960), Vol. 11, p. 149.

Morin F. J., Geballe, T. H., and Herring, C., Phys. Rev., Vol. 105, No. 2, 1957, p. 525.

Tekippe, V. J., Chandrasekhas, H. R., Fisher, P., and Ramdas, A. K., Phys, Rev. B., Vol. 6, No. 6, 1972, p. 2348.



Unstressed Si: P Detector Response
[100] Stressed Si: P Detector Response x 10
* Instrumental Spikes
unstressed detector
response scaled
100
50
0
36
34
32
30
28
26
Wavelength (μm)

TABLE

Si:P Stressed Detector Characteristics

Size:	$\sim 2 \times 2 \times 1$ mm
Resistivity:	$\rho \sim 1.2$ Ω-cm ($n \sim 4 \times 10^{15}$ cm^{-3})
Stress Direction:	parallel to [100] crystal axis (along 1-mm dimension)
Implant:	2×10^{15} atoms/cm^2 at 100 keV annealed at 700°C for 10 min in vacuum
Contacts:	Mo-Pt-Au vacuum sputtered layers (put on in that order) on 2×2-mm faces soldered to with In

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA CR-166397		
4. Title and Subtitle Final Technical Report - Stress Induced Long Wavelength Photoconductivity in Doped Silicon Infrared Detectors		5. Report Date August 1982 6. Performing Organization Code
7. Author(s) J. R. Houck		8. Performing Organization Report No.
9. Performing Organization Name and Address Cornell University Center for Radiophysics and Space Research Ithaca, New York 14853		10. Work Unit No. T 5496 11. Contract or Grant No. NAG2-70
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546		13. Type of Report and Period Covered Contractor Report 14. Sponsoring Agency Code 506-61-51

15. Supplementary Notes

Point of Contact: Technical Monitor, Craig R. McCreight, MS 244-7
Ames Research Center, Moffett Field, CA 94035
(415) 965-6549 or FTS 448-6549

16. Abstract

By application of compressive stress along the [100] crystal axis, the spectral response of Si:P infrared detectors was extended from 28 μm to 34 μm. The photoconductive response of the stressed detectors was about a factor of ten lower than that of an unstressed detector. The carrier mobility or lifetime may be reduced in the stressed condition, although it is suggested that piezoresistive effects may be decreasing device impedance. Detector noise was higher than for unstressed detectors, and voltage spikes were observed.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Infrared detectors Uniaxial stress Extrinsic silicon	Unclassified - Unlimited STAR Category 89

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	6	

*For sale by the National Technical Information Service, Springfield, Virginia 22161

End of Document