Wright State University

CORE Scholar

Physics Faculty Publications

Physics

3-1975

Ohmic Contacts to Al-Implanted ZnSe

B. K. Shin

David C. Look

Wright State University - Main Campus, david.look@wright.edu

Y. S. Park

Follow this and additional works at: <https://corescholar.libraries.wright.edu/physics>

Part of the [Physics Commons](#)

Repository Citation

Shin, B. K., Look, D. C., & Park, Y. S. (1975). Ohmic Contacts to Al-Implanted ZnSe. *Journal of The Electrochemical Society*, 122 (3), 450-451.

<https://corescholar.libraries.wright.edu/physics/618>

This Article is brought to you for free and open access by the Physics at CORE Scholar. It has been accepted for inclusion in Physics Faculty Publications by an authorized administrator of CORE Scholar. For more information, please contact library-corescholar@wright.edu.

the society for solid-state
and electrochemical
science and technology

Journal of The Electrochemical Society

Ohmic Contacts to Al–Implanted ZnSe

B. K. Shin, D. C. Look and Y. S. Park

J. Electrochem. Soc. 1975, Volume 122, Issue 3, Pages 450-451.
doi: 10.1149/1.2134234

Email alerting service

Receive free email alerts when new articles cite this article - sign up in the box at the top right corner of the article or [click here](#)

To subscribe to *Journal of The Electrochemical Society* go to:
<http://jes.ecsdl.org/subscriptions>

Fig. 9. Tin selenide growth on cleaved (111)BaF₂ (SEM photograph).

This work was supported in part by the Night Vision Laboratory USAECOM, Fort Belvoir, Virginia, under Contract No. DAAK02-73-C-0080.

Manuscript submitted July 30, 1974; revised manuscript received Nov. 5, 1974. This was Paper 12RNP presented at the San Francisco, California, Meeting of the Society, May 12-17, 1974.

Any discussion of this paper will appear in a Discussion Section to be published in the December 1975 JOURNAL. All discussions for the December 1975 Discussion Section should be submitted by Aug. 1, 1975.

Publication costs of this article were partially assisted by Rockwell International.

REFERENCES

1. H. M. Manasevit, *J. Crystal Growth*, **13/14**, 306 (1972).
2. H. M. Manasevit, *ibid.*, **22**, 125 (1974).
3. J. E. Coker, *This Journal*, **116**, 1352 (1969).
4. L. J. van der Pauw, *Philips Res. Rept.*, **13**, 1 (1958).
5. H. M. Manasevit and W. I. Simpson, *This Journal*, **116**, 1725 (1969).
6. H. M. Manasevit and W. I. Simpson, *ibid.*, **118**, 644 (1971).
7. H. M. Manasevit, F. M. Erdmann, and W. I. Simpson, *ibid.*, **118**, 1864 (1971).
8. S. E. Cook, Private communication, Ethyl Corp., Baton Rouge, La.
9. J. N. Zemel, J. D. Jensen, and R. B. Schoolar, *Phys. Rev.*, **140**, A330 (1965).
10. W. W. Scanlon, *J. Phys. Chem. Solids*, **8**, 423 (1959).
11. H. Holloway, E. M. Logothetis, and E. Wilkes, *J. Appl. Phys.*, **41**, 3543 (1970).
12. H. M. Manasevit, F. A. Pizzarello, R. P. Ruth, and W. I. Simpson, Submitted to *J. Electron. Mater.*
13. A. G. Mikolaichuk, Ya I. Dutchak, and D. M. Freik, *Sov. Phys. Cryst.*, **13**, 490 (1968).

Brief Communications

Ohmic Contacts to Al-Implanted ZnSe

B. K. Shin,¹ D. C. Look,² and Y. S. Park

Aerospace Research Laboratories, Wright-Patterson Air Force Base, Ohio 45433

The production and characterization of ohmic contacts is an important part of semiconductor technology. In this paper we report the formation of ohmic contacts on ZnSe, by evaporating or sputtering Au or Pt onto the Al-implanted, n-type substrate. Although these metals normally form rectifying Schottky barriers on n-type ZnSe, such barriers are precluded if the implanted layer is degenerate. An advantage of Au or Pt contacts is that much higher operating temperatures are possible than with the commonly used In or Ga.

The Al implantation was carried out at 90 keV to a dose of 10^{15} ions/cm² at room temperature.³ The substrate was a high-resistivity ($\sim 10^9$ ohm-cm) crystal cut to expose the (110) face. Before implantation, the surface was mechanically polished and chemically

etched at 90°C for 1 min in a mixture of 2 parts H₂SO₄ and 3 parts saturated aqueous solution of K₂Cr₂O₇, followed by a 20 sec rinse in a boiling 25% solution of NaOH. In a previous paper (1) it was reported that crystals implanted in such a manner and annealed in evacuated fused-silica ampuls for 4 hr at 900°C showed nearly degenerate electrical characteristics, with an effective electron mobility of about 4 cm²/V-sec and an effective sheet carrier concentration of about 10^{15} cm⁻². When unimplanted samples and samples implanted with Ar ions were annealed under the same conditions, they remained highly resistive. This showed that the Al implantation was essential for the production of the conductive layer, i.e., neither the annealing alone nor the radiation damage produced by Ar ions were sufficient to appreciably change the conductivity of the original substrate. The thickness of the implanted and annealed conductive layer was roughly checked by the use of the etch described above. This etch removes about 50 Å/sec from unimplanted ZnSe at room temperature and the rate for implanted ZnSe

¹ Permanent address: Systems Research Laboratories, Incorporated, Dayton, Ohio 45440.

² Permanent address: Department of Physics, University of Dayton, Dayton, Ohio 45469.

Key words: metal-semiconductor contacts, contact resistance, ion implantation.

³ The ion implantation was done at NASA Langley Research Center.

Fig. 1. I - V characteristics of Au and Pt contacts on Al-implanted, annealed ZnSe at 77° and 300°K.

is probably about the same. It was found that etching for about 1000 sec was necessary to reduce the conductivity to that of the original substrate. This suggests that the implanted layer, after annealing, was about 5 μm thick, giving an average doping concentration of about 10^{18} - 10^{19} cm^{-3} . Such a concentration is consistent with the observed nearly degenerate electrical characteristics.

Two Au (or Pt) contacts, of 0.1 cm diameter, were evaporated (or sputtered) 0.35 cm apart on the implanted, annealed surface. Current vs. voltage measurements were carried out at 77° and 300°K, over a voltage range of 4×10^{-4} -40V. The magnitude of the current was the same for both voltage polarities. The results are plotted in Fig. 1. Both Au and Pt contacts were found to be ohmic over five decades of voltage; however, the Pt did show some departure from ohmic behavior below 1 mV. The contact resistance, R_c , was determined from the relationship

$$R_c = \frac{1}{2} (R - R_{\square} L/W) \quad [1]$$

where $R \equiv V/I$, $R_{\square}$ is the sheet resistivity [denoted by ρ' in Ref. (1)], L is the contact spacing, and W is the sample width. The results of this calculation are presented in Table I, but it must be emphasized that Eq. [1] is only approximate with our contact geometry. For comparative purposes we also list the contact re-

Table I. Contact properties of Al-implanted annealed ZnSe

Contact metal	Temperature (°K)	$R_{\square}$ (kohm/ $\square$)	R (kohm)	R_c (kohm)	ρ_c (ohm-cm ²)
Au	300	8.76	10.40	2.13	16.72
	77	14.10	16.10	3.10	24.33
Pt	300	13.70	12.60	0.95	7.45
	77	28.50	25.40	1.60	12.56

sistivity (2), $\rho_c \equiv R_c A_c$, where A_c is the effective contact area, taken in this case to be just the actual contact area. It is seen that $\rho_c \approx 10$ -20 ohm-cm² for contacts produced in the manner described above.

The small temperature dependence of ρ_c suggests that a tunneling mechanism dominates the thermionic emission. For tunneling in a Schottky barrier at low temperatures and low bias voltages ($V \ll E_b/q$), ρ_c is dominated by (3, 4) $\exp(E_b/E_{\infty})$ where E_b is the effective barrier height, and $E_{\infty} \equiv (\hbar q/2) (N/\epsilon m^*)^{1/2}$. Here N is the doping density (assumed equal to the carrier concentration), ϵ is the specific permittivity, and m^* is the effective mass. If $N \approx 10^{18}$ - 10^{20} cm^{-3} , then E_b must be about 0.1-1 eV, a reasonable range, to give the right order of magnitude for ρ_c . However, this model would predict linear I - V characteristics only for $V \lesssim E_{\infty}/q$, and since $E_{\infty} = 20$ -200 meV for $N = 10^{18}$ - 10^{20} cm^{-3} we would not expect linear behavior above about 100 mV. The fact that such behavior is observed even at 10V suggests that the barrier becomes completely transparent in both forward and reverse bias conditions when a highly doped shallow layer having a surface carrier concentration of $\sim 10^{15} \text{ cm}^{-2}$ is formed.

Acknowledgments

This work was performed by one of the authors (B.K.S.) under Contract No. F33615-72-C-1099 supported by the Aerospace Research Laboratories, and by another of the authors (D.C.L.) under Contract No. F33615-71-C-1877 supported by the Aerospace Research Laboratories.

Manuscript submitted Feb. 11, 1974; revised manuscript received Oct. 30, 1974.

Any discussion of this paper will appear in a Discussion Section to be published in the December 1975 JOURNAL. All discussions for the December 1975 Discussion Section should be submitted by Aug. 1, 1975.

Publication costs of this article were partially assisted by the Department of the Air Force.

REFERENCES

1. B. K. Shin, Y. S. Park, and D. C. Look, *Appl. Phys. Letters*, **24**, 435 (1974).
2. H. H. Berger, *This Journal*, **119**, 507 (1972).
3. F. A. Padovani and R. Stratton, *Solid-State Electron.*, **9**, 695 (1966).
4. C. Y. Chang, Y. K. Fang, and S. M. Sze, *ibid.*, **14**, 541 (1971).

The Semiconductive Property of Gamma-Ferric Oxyhydroxide

Katsumi Kaneko and Katsuya Inouye

Department of Chemistry, Faculty of Science, Chiba University, Chiba, Japan

The recent investigations by Cohen *et al.* on the passive films deposited upon iron or platinum from neutral ferrous sulfate solution (1) or ferrous perchlorate solution (2) strongly suggest that the composition of these films corresponds to crystalline γ -FeOOH. It appears that the electrical properties of FeOOH-type oxides have not been studied extensively, although the

ultimate characteristics of such substances should have pregnant implications for the function of surface films.

In the preceding study on the electrical properties of ferric oxyhydroxides (3), the present authors found that α -, β -, and γ -FeOOH are semiconductors which show d-c conductivity in the order of $10^{-9} \text{ ohm}^{-1} \text{ cm}^{-1}$ and high-frequency (7 MHz) conductivity of 10^{-6} - $10^{-7} \text{ ohm}^{-1} \text{ cm}^{-1}$ and which probably have negative carriers. The appropriate value of conductivity ob-

Key words: passive film on iron, γ -FeOOH, electrical conductivity.