Aging of Aluminium contacts to Ion-implanted Silicon Radiation Detector

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Introduction

The aging effect of Aluminium contact made to silicon is a known problem in Si technology [1]. Because of the presence of native oxide on silicon, Al takes some time, depending on the temperature, to form intimate contact and form ohmic Al/n^+- and Al/p^+-Si contacts. Changes in the characteristics of ion-implanted silicon detectors with Al contacts due to this aging process are reported here.

Al Contacts

Electrical nature of Al contacts made to ion-implanted p^+- as well as n^+-Si layer on hyper pure (~ 10 kΩ-cm) n-type Si<111> wafers, we use for detector fabrication, was investigated. Si samples were lapped and given a mirror polish by etching in CP4A. They were implanted with 25 keV-ions of $^{11}B^+$ and $^{31}P^+$ to the dose of $1x10^{15}$ /cm^2 to prepare the p^+- and n^+-Si layers respectively. Dopant activation was carried out at 900 ^oC for 30 minutes in an open quartz tube under the flow of dry nitrogen. Two concentric Al contacts (see Fig.1(a)) with thickness of ~40 µg/cm2 were deposited by thermal evaporation in vacuum (~$1x10^{-5}$ torr). Their areas were kept different (~1:3) to see the contact-area dependent (non-ohmic) nature of the I-V characteristics at low bias voltage.

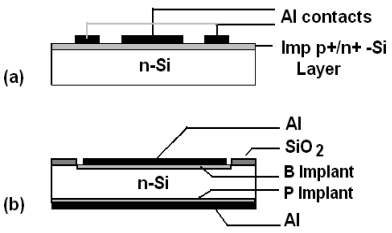

Fig.1 . Schematics of: (a) Contact test structure and (b)Ion-imp Si diode (detector).

I-V characteristics (see Figs. 2 & 3) of the contacts were measured in vacuum (~$1x10^{-1}$torr) at room temperature. The as-evaporated Al/p^+ -Si contacts showed linear characteristics with slope increasing over a period of 1 week. It indicated the lowering of the effective metal-semiconductor barrier height due to the aging process. A low temperature heat treatment was given at ~350 ^oC for 30 minutes under the flow of dry nitrogen to accelerate the aging process. As expected, it helped in lowering the Al/p^+- Si contact resistance further.

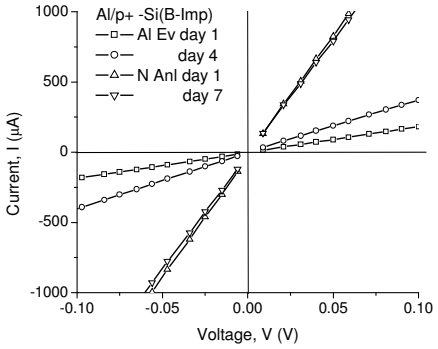

Fig.2. I-V characteristics of Al/p^+-Si contact.

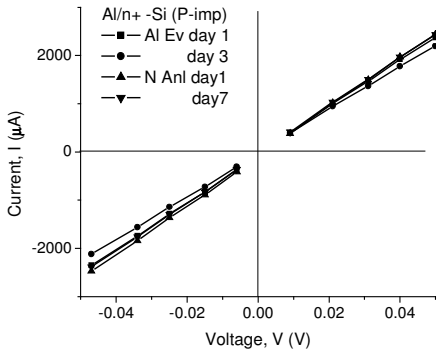

Fig.3. I-V characteristics of Al/n^+-Si contact.

In case of the Al/n^+ contacts, almost no change in linearity and slope of their characteristics, even after giving the low temperature treatment, was observed. The barrier height for the implanted n^+ layer seems to be large enough to cause efficient tunneling and make the Al/n^+ -Si contact ohmic [1].

Ion-implanted Detectors

Oxide passivated ion-implanted silicon radiation detectors having active area of about 100 cm^2 were fabricated from the high-resistivity n-type material by following the procedure reported earlier [2]. The schematic of the $p^+/n/n^+$ detector (diode) structure with Al contacts is given in Fig.1(b). Samples were thermally oxidized at 1050 ^oC to prepare the ~0.6 μ thick silicon oxide. Circular type of windows was opened to implant the boron ions to make the passivated rectifying junction. The n^+ and p^+ layers were prepared by following the same procedure used to test the Al/p^+ and Al/n^+ -Si contact structures. Al contacts were evaporated as already mentioned.

Detectors were tested for their reverse as well as forward characteristics (see Figs. 4 & 5) at room temperature in vacuum. The leakage current was seen dropping with time. A low temperature annealing at ~350 ^oC helped in reducing the leakage further to a stable level. The dropping of the barrier height of the Al/p^+-Si contact with time is thought to help in reducing the injection of minority carriers to the p-type region that contributes to the leakage.

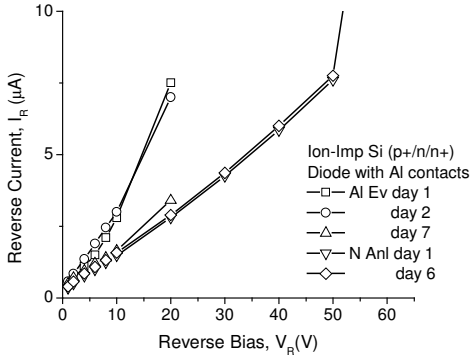

Fig.4. Reverse I-V characteristics of ion-implanted Si detector .

The low temperature treatment changed the forward characteristics drastically. It resulted in lowering the series resistance, mostly due to the drop in resistance of the Al/p^+-Si contact.

There was improvement in the performance (leakage, energy resolution and timing) of the implanted Si detectors (see Fig.6) due to the aging of the Al/p^+ contacts.

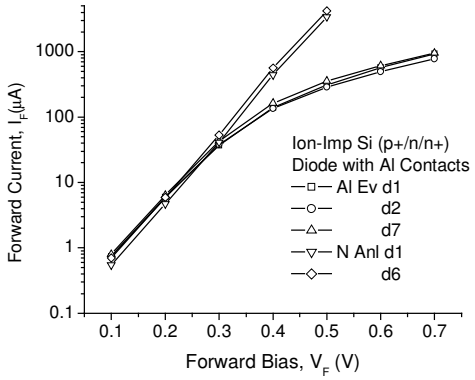

Fig.5. Forward I-V characteristics of Si detector.

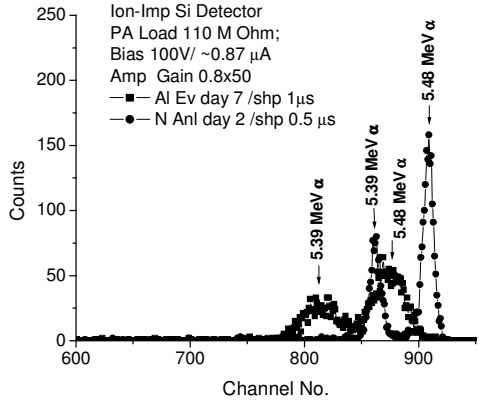

Fig.6. ^{242}Am –^{239}Pu alpha spectra.

Acknowledgement:
The author is very much thankful to Dr J.V. Yakhmi, Associate Director, Physics Group (S) for his encouragement.

References

[1] H.C. Card, IEEE Trans. Electr. Dev. ED-23(1976)538.
[2] R. Prasad and D. Sahoo, DAE Nucl. Phy. Symp. 45B(2002)422.