Effect of 1 MeV neutron-irradiation on the electrical properties of Si-based diodes

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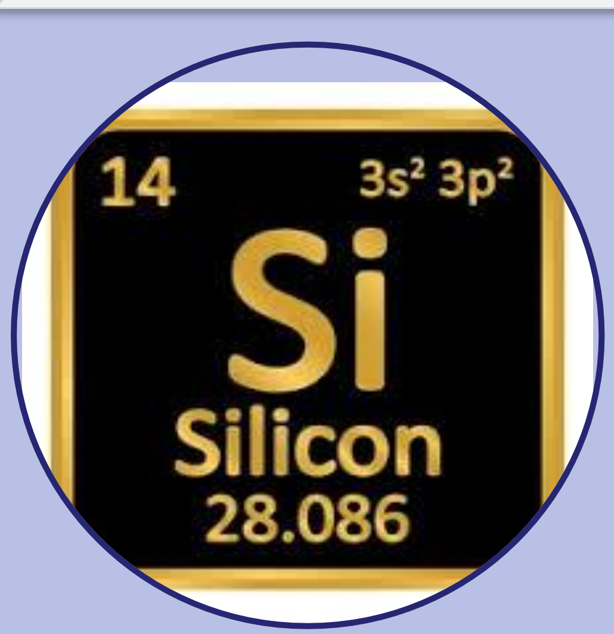
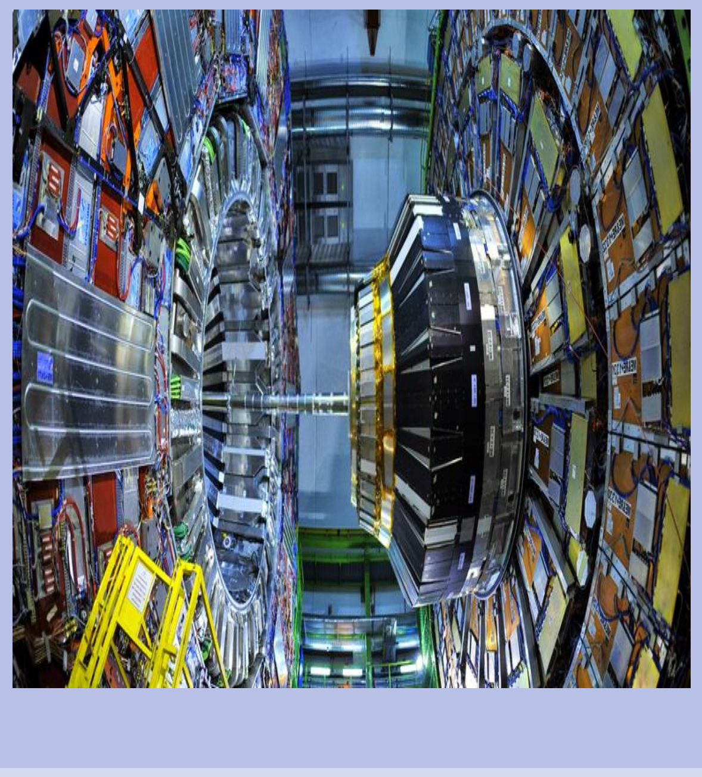
INTRODUCTION



Silicon (Si)-based diodes are widely used as radiation detectors for various applications such as space applications, nuclear power plants and particle accelerators due to their excellent electrical properties and compatibility with integrated circuit technology.

Common areas of applications include:



However, the prolonged use of these detectors in extreme radiation environments leads to detrimental effects on their performance, resulting in compromised reliability and reduced effectiveness in acquiring data. Although the electrical characteristics of diodes at radiation fluences below the conductivity-type change threshold (1.4×10^{13} n/cm^2) are well-studied, parameters like ohmic *I-V* behaviour and negative capacitance at higher fluences remain poorly understood.

Limited research exists on diodes irradiated beyond this threshold, where damage becomes less fluence-dependent, unlike at lower levels. Investigating the electrical properties of highly irradiated silicon diodes is crucial to address these gaps and to ensure detectors can operate effectively in environments 10 times harsher than current conditions.

AIM OF THE RESEARCH

The aim of this research is to investigate the impact of 1 MeV neutron irradiation on Si-based diodes by analysing their *I-V* characteristics across various radiation fluences. The study seeks to identify specific changes in electrical properties and quantify radiation-induced damage, providing insights that will contribute to the development of more efficient and resilient electronic devices.

EXPERIMENTAL PROCEDURE

Device Fabrication

Device Irradiation

Device Characterization

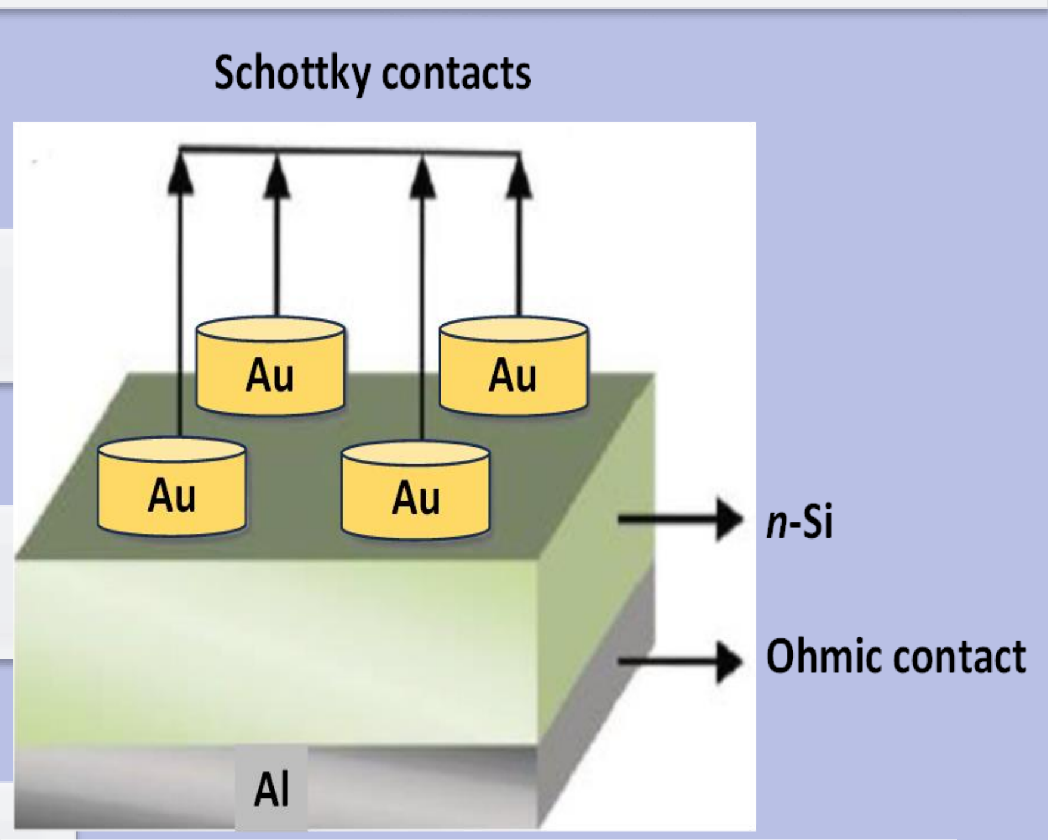


Fig. 1*: Schematic of the fabricated diode with Al and Au used for Schottky and ohmic contacts.*

RESULTS AND DISCUSSION

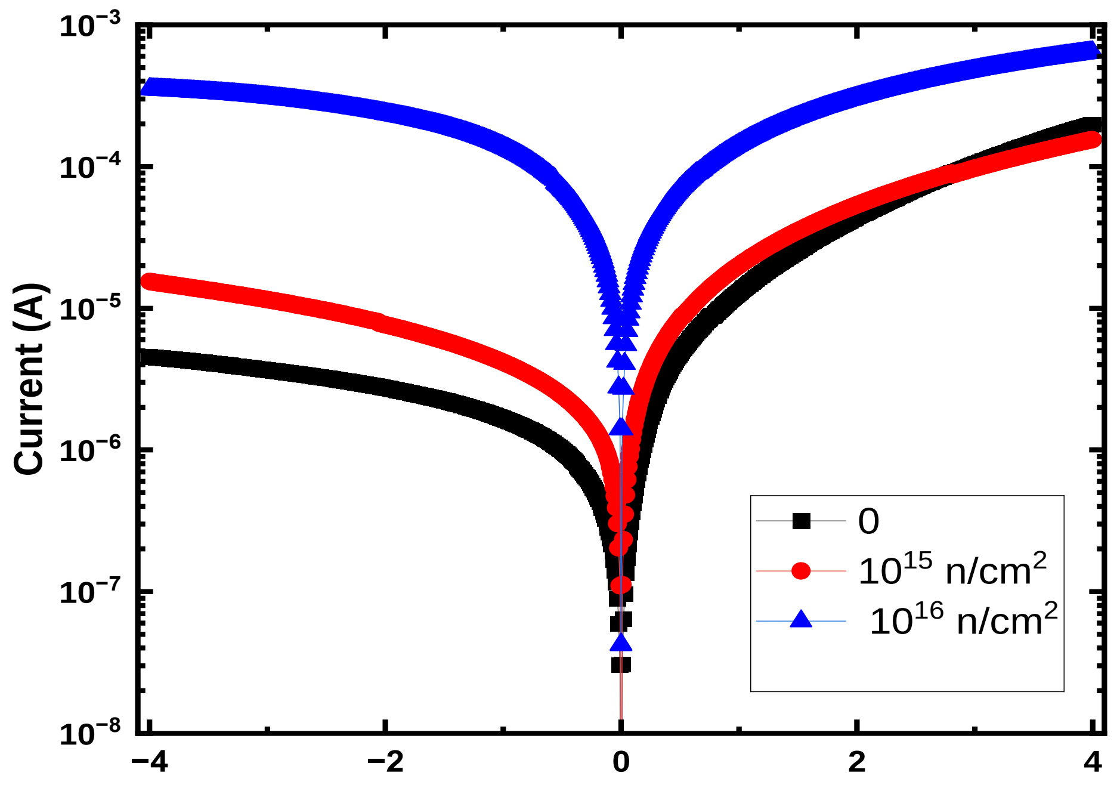


Fig. 2*: lnI-V plot of unirradiated and neutron-irradiated n-Si diode to fluence of 10^{15} and 10^{16} n/cm^2.*

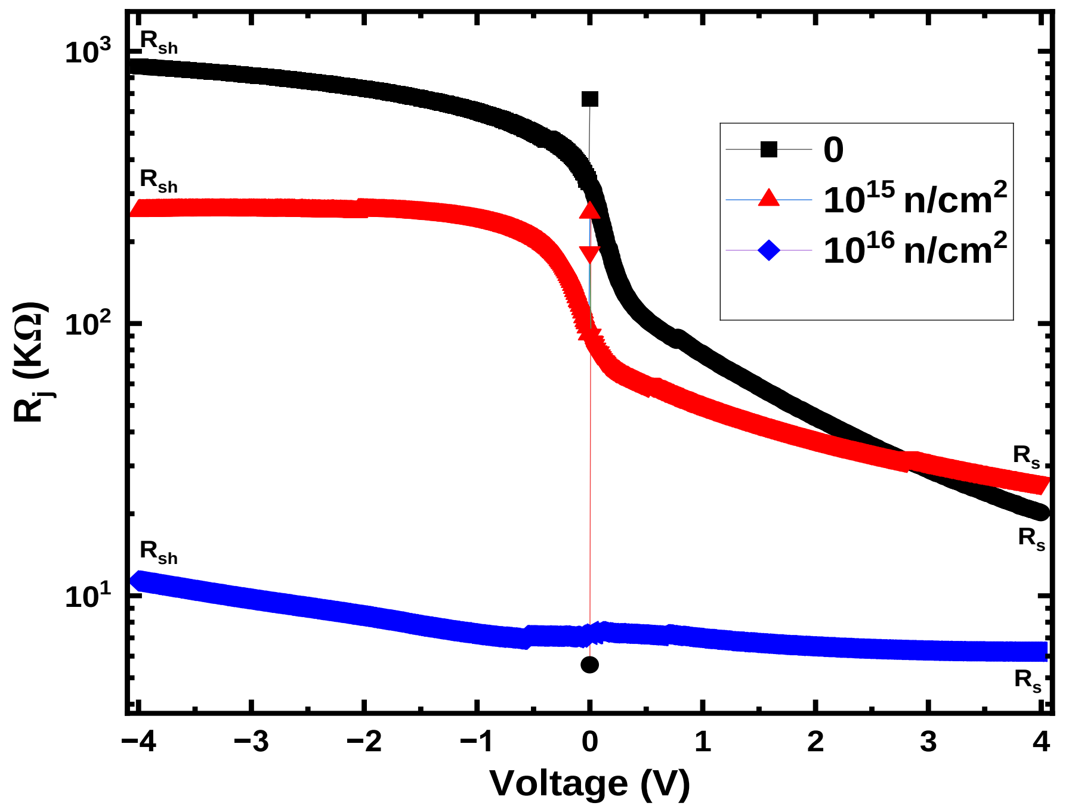


Fig. 3: *R_j-V plots of unirradiated and neutron-irradiated n-Si diode to fluence of 10^{15} and 10^{16} n/cm^2.*

- ❖ Neutron irradiation significantly impacts reverse current in *n*-Si diodes, increasing leakage current by factors of 3 and 70 at fluences of 10^{15} and 10^{16} n/cm^2.
- ❖ Radiation-induced defects generate minority carriers, raising defect density with fluence and contributing to the reverse current increase.
- ❖ Forward bias current shows minimal effect at 10^{15} n/cm^2, with a 1.22-fold decrease, but rises by 3.42-fold at 10^{16} n/cm^2 due to introduced majority carriers.
- ❖ Rectification ratio drops from 45 (unirradiated) to 10 and 2 at 10^{15} and 10^{16} n/cm^2, showing reduced diode rectification behavior due to radiation damage.
- ❖ R_j analysis shows that neutron irradiation reduces the diode's R_{sh} and increases R_s, with R_{sh} and R_s shifting from 919.95 and 19.06 KΩ (unirradiated) to lower values at higher fluences, indicating degraded diode quality.

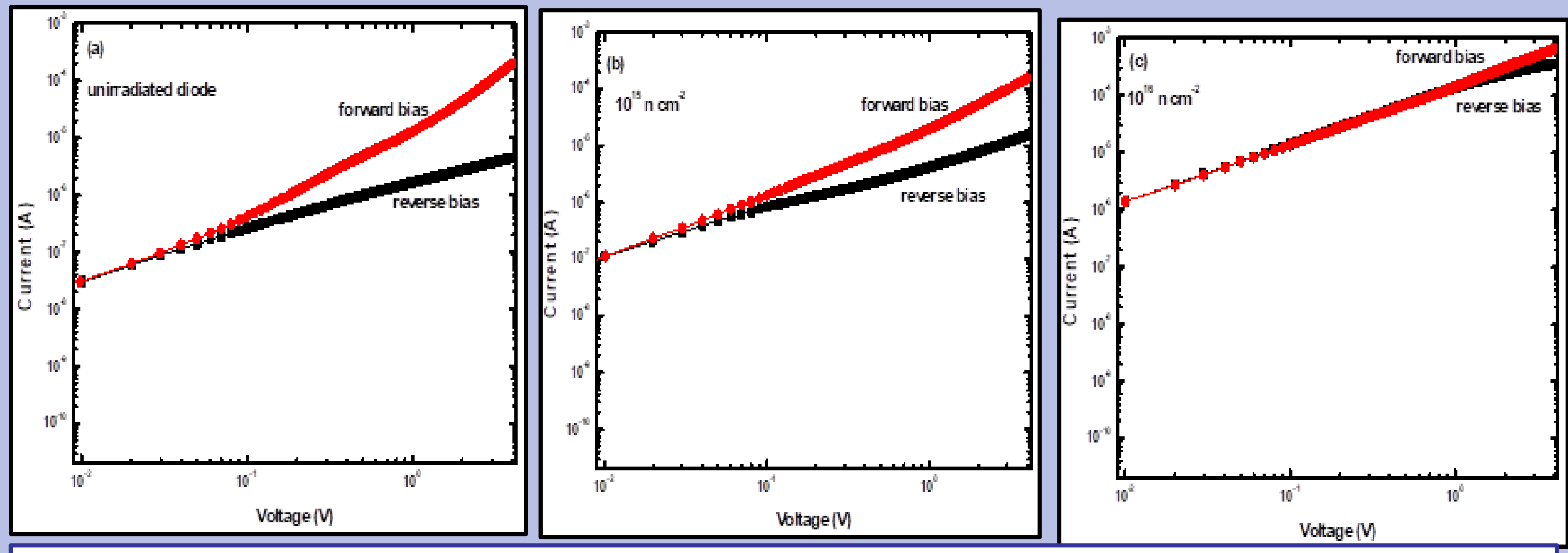


Fig.5: *log. (I-V) plot of unirradiated n-Si diode (a), neutron-irradiation n-si diode to 10^{15} n/cm^2 (b) and 10^{16} n/cm^2 (c).*

- ❖ Narrowing current gap: Irradiation reduces the reverse-forward current gap, with 10^{16} n/cm^2 showing near-ohmic behaviour.
- ❖ Ohmic transition: Increased fluence introduces defects, disrupting rectification and promoting ohmic conduction.
- ❖ Defect impact: Radiation-induced defects reduce current asymmetry, causing similar current flow in both directions.

CONCLUSIONS

- ❖ The *n*-Si diode showed a good rectification behaviour, confirming that the diodes were well fabricated
- ❖ Neutron irradiation significantly affects the electrical properties and conduction mechanisms of *n*-Si diodes
- ❖ *I–V* measurements revealed a shift from exponential to ohmic conduction with increasing neutron fluence, indicating defect level formation.
- ❖ The ohmic region expands with higher fluences, suggesting intensified defect levels due to irradiation.
- ❖ Findings provide valuable insights into the impact of neutron irradiation on semiconductor devices, especially in radiation-heavy environments, by altering electrical characteristics and introducing defect-driven mechanisms.

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