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# Electron Irradiation Impact on Silicon Schottky Diode

Erkan UĞUREL[1*], Şakir AYDOĞAN[2]

**Highlights:**

- Au/n-Si/Au-Sb Schottky diodes with very good rectification properties were fabricated
- Different doses of electron irradiation were applied.
- Au/n-Si/Au-Sb device is sensitive to electron irradiation

**Keywords:**

- Schottky diode,
- n-Si,
- Electron irradiation,
- Defects

**ABSTRACT:**

Au/n-Si/Au-Sb Schottky diode was fabricated, and electron irradiation was applied to the diode at 25 and 50 gray doses. The effects of irradiation on the electrical characteristics of the diode were analyzed by means of current-voltage, capacitance-voltage, conductance-voltage, and capacitance-frequency measurements before and after irradiation. With increasing irradiation dose, changes were observed in the ideality factor, barrier height, interface states, series resistance, dielectric constant, and diffusion potential values. The n value was found to be 1.231, 1.306, and 1.350 before, for 25-gray, and 50-gray irradiation, respectively. The value of $\Phi_b$ was 0.742 eV, before irradiation. Depending on 25 and 50 gray irradiations, it was calculated as 0.768 and 0.761 eV, respectively. It has been observed that the diode deviates from ideality due to defects in the diode interface depending on irradiation. Furthermore, it has been observed that electron irradiation causes changes in the electrical properties of the Au/n-Si/Au-Sb Schottky diode.

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## INTRODUCTION

Schottky diodes are widely used in the electronics industry in structures such as solar cells, transistors, microwave diodes, and photodetectors (Aydın et al., 2006; Veeramania et al., 2008). Electronic circuits operating in fields such as atomic power plants, nuclear fusion systems, solar cells, and space studies are exposed to strong ionizing radiation. The radiation that causes changes in the metal-semiconductor interface causes the devices' electrical, mechanical, and other physical properties to change. The electronic circuits used in these areas must have stable performance. Demonstrating the effects of irradiation on the material is important for determining the properties of the materials to be used in such environments. Electron irradiation is known to cause more damage than X-rays and gamma rays (Zoutendyk et al., 1988; Yamaguchi, 2001; Aydogan et al., 2011).

Radiation causes electronic devices deformation in two ways: ionization and displacement damage. Ionization damage causes the formation of free charges in the material and generally does not affect the device's performance. Displacement defects, on the other hand, create a stable radiation defect with one or more levels in the bandgap. These defects, acting as recombination and carrier centers, can significantly affect the electrical properties of the device (Aboelfotoh, 1989; Ntsoenzok et al., 1994; Karataş & Türüt, 2004; Uğurel et al., 2008; Parida et al., 2018; Bodunrin & Moloi, 2022). Radiation causes the produces of defect complexes in silicon semiconductor materials, which reduce minority carrier lifetime, change majority carrier density, and reduce mobility (Messenger, 1992). Ionizing radiation causes permanent effects such as the buildup of positive space charge on oxidized silicon surfaces, the creation of fast surface states at the oxide-silicon interface, and the resulting increase in the surface recombination velocity (Snow et al., 1967).

The damage caused by radiation depends on the amount of energy absorbed by the device, the fluency of the radiation, and the total radiation dose to which the device is exposed. How the Schottky contact parameters of all semiconductor-based devices in an electronic circuit react to high-energy electron irradiation is important. Because these devices communicate with each other via metal /semiconductor (MS) contacts (Coşkun et al., 2006). Determining the effects of radiation on devices and producing radiation-resistant devices has been an important research topic recently (Radwan, 2007; Narita et al., 2013; Kumar et al., 2024; Ren et al., 2024).

In this study, Au/n-Si/AuSb Schottky diode was exposed to electron irradiation at different doses, and the effect of the irradiation on the current-Voltage (I-V), capacitance-voltage (C-V), conductance-voltage (G-V), and capacitance-frequency (C-f) characteristics was investigated. Measurements were carried out at room temperature before and after irradiation; changes in basic diode parameters such as ideality factor, barrier height, series resistance, and donor concentration were determined.

## MATERIALS AND METHODS

In this study, an n-Si crystal with 400 μm thickness and 1-10 Ω-cm resistivity was used. The chemical cleaning of the crystal was carried out according to the RCA procedure (boiled in $6H_2O$ + HF + $NH_3$ at 60 $^oC$ for 10 minutes, then boiled in $6H_2O$ + $H_2O_2$ + HCl for 10 minutes at 60$^oC$). Au-Sb was evaporated to the n-Si crystal surface under $10^{-5}$ torr pressure as an ohmic contact. Then, the sample was annealed in an $N_2$ environment at 450 $^0C$ for 3 minutes. Hence, the ohmic contact process was completed. The other surface of the sample was evaporated by Au under $10^{-5}$ torr pressure to the Schottky contact. The device architecture is given in Figure 1.

The "KEITHLEY 487 Picoammeter / Voltage Source" device was used for I-V measurements of the Au/n-Si/Au-Sb Schottky diode. The "HP 4192 A (50 Hz-13 MHz) LF IMPEDANCE ANALYZER " was used to obtain the C-V and C-f measurements of the diode. Measurements were performed at room temperature and in the dark. Siemens-Primus linear electron accelerator was used for irradiation. The sample was exposed to electron irradiation with an effect of $3x10^{12}$ $e^-$ / $cm^2$, 25, and 50 gray doses. In the research, 25 and 50 gray electron irradiation were used to demonstrate the operability of Schottky diodes by exposing them to high dose radiation. In addition, these irradiations were used within the scope of the possibilities at the time the research was conducted.

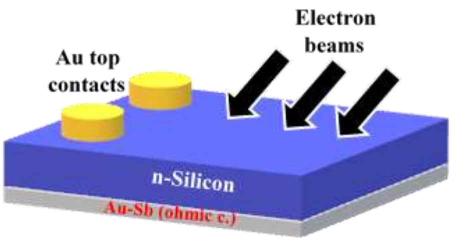


**Figure 1.** Architecture of Au/n-Si/Au-Sb device

## RESULTS AND DISCUSSION

Figure **1** a shows the I-V characteristics of the diode graph in the forward and reverse bias conditions before and after irradiations, at different doses. In inhomogeneous semiconductor-based diodes, the current is explained by the thermionic emission theory (TE) in the case of a forward bias voltage (Rhoderick & Williams 1988). According to this theory,

$$I = AA^{*}T^{2}\exp\left(\frac{-e\phi_b}{kT}\right)\left[\exp\left(\frac{eV}{kT}\right)-1\right] \tag{1}$$

Here,

$$I_0 = AA^{*}T^{2}\exp\left(\frac{-e\phi_b}{kT}\right) \tag{2}$$

is the saturation current; $\Phi_b$ effective barrier height at zero bias; A* is Richardson constant, and its value is 112 A / $cm^2.K^2$ for n-Si; e charge of the electron; V applied potential; A is the area of the diode ($7.85x10^{-3}$ $cm^{-2}$); k Boltzmann constant; T is Temperature in Kelvin; n is the ideality factor. The value of the ideality factor is determined from the slope of the forward bias linear region of the lnI-V graph as:

$$n = \frac{e}{kT}\frac{dV}{d(\ln I)} \tag{3}$$

n is 1 for ideal diodes. However, the value of n becomes greater than 1 depending on the thin oxide layer formed at the interface, the series resistance, the interfacial states, and the recombination of electrons and holes in the depletion region (Rhoderick & Williams 1988; Vieira et al., 2021). The value of $\Phi_b$ is obtained from the following equation:

$$\Phi_b = \frac{kT}{e}\ln\left(\frac{AA^{*}T^{2}}{I_0}\right) \tag{4}$$

The experimental diode parameters obtained from the I-V graph are given in Table 1. The ideality factor of the diode was found to be 1.231 before irradiations and was calculated as 1.306 and 1.350 due to 25 and 50 gray irradiations, respectively. Furthermore, the rectification ratio of the device before irradiation was obtained as 8244. Salari et al. (2016) calculated the ideality factor value of the Au/n-Si/ Au-Sb diode as 1.44 before, and 1.82 after irradiation, respectively. The ideality factor of the diode was increased due to irradiation (Şahin et al., 2016; Vali et al., 2017; Salari et al., 2018). Defects in the interface due to irradiation act as the center of trap and recombination. This inhomogeneity at the interface may have caused an increase in the ideality factor. Besides, this increase; can be attributed to reasons such as image force effect, recombination, formation, and tunneling (Karataş & Türüt, 2006; Krishnan et al.,2008; Çaldıran & Taşyürek, 2021). This increase in ideality factor may be due to the recombination current due to irradiation-induced atomic displacement defects in addition to the thermionic emission mechanism of the current carrying mechanism for the diode (Roccaforte et al., 2006; Paradzah et al., 2015; Wang et al., 2021).

**Table 1** The n and $\Phi_b$ values of the Au/n-Si/Au-Sb diode before and after irradiation calculated from the I-V plots.

| **Process** | ***n*** | ***$\Phi_b$* (eV)** |
|---|---|---|
| **Before irradiation** | 1.231 ± 0.02 | 0.742 ± 0.03 |
| **25 gray** | 1.306 ± 0.02 | 0.768 ± 0.03 |
| **50 gray** | 1.350 ± 0.02 | 0.761 ± 0.03 |

The barrier height was 0.742 eV, before irradiation. Depending on 25 and 50 gray irradiations, it was calculated as 0.768 and 0.761 eV, respectively. It was observed that the barrier height increased as a result of 25 gray irradiation (Vaitkus et al.,1998; Bose et al., 2001; Tuğluoğlu et al., 2015; Demir et al., 2018). There was a decrease in the reverse bias current of the diode with irradiation. This irradiation-induced decrease in reverse polarization current was attributed to the increase in interface defect density and generation currents (Uğurel et al., 2008; Şahin et al., 2016; Salari et al., 2018; Oeba et al., 2021). This increase in barrier height is due to the reduction of the reverse bias current of the diode (Umana-Membreno et al., 2003; Salari et al., 2016). Besides, this increase can be attributed to the interface defect density increase and hence the interface carriers' trapping Cao et al., 2020). The decrease in $\Phi_b$ after 50 gray irradiation may be due to the tunneling effect (Wang et al., 2021).

Furthermore, the change of interface states (Nss) versus interface states energy (Ec-Ess) is determined using the (Card & Rhoderick, 1971) method and the curves are given in Figure 1 b. It is clearly seen that the distribution of Nss in the band gap of n-Si at the Au and n-Si interface changes with irradiation. After irradiation, the values of Nss showed a partial decrease and the exponential distribution showed a partial shift towards the bottom of the conduction band of n-Si. This means that the energy states are partially ionized by irradiation (Akgül et al., 2021; Kaymaz et al., 2021).

Figures 1c and d show the voltage-dependent changes of shunt resistance (Rsh) and series resistance (Rs) obtained using Ohm's law, respectively. While the shunt resistance increases with increasing reverse voltage, the series resistance shows a more stable change except for partial decreases. These variations are to be expected, as the slopes at high forward bias voltages show almost the same dependence on voltage. However, under 50 gray electron irradiation, the series resistance is of the highest value, and this can be explained by the deformations on the interface and surface of the high-dose electron irradiation. Partial fluctuations in the shunt resistance can also be attributed to electron irradiation effects on n-Si device (Sharma et al., 2020; Kaymaz et al., 2021).

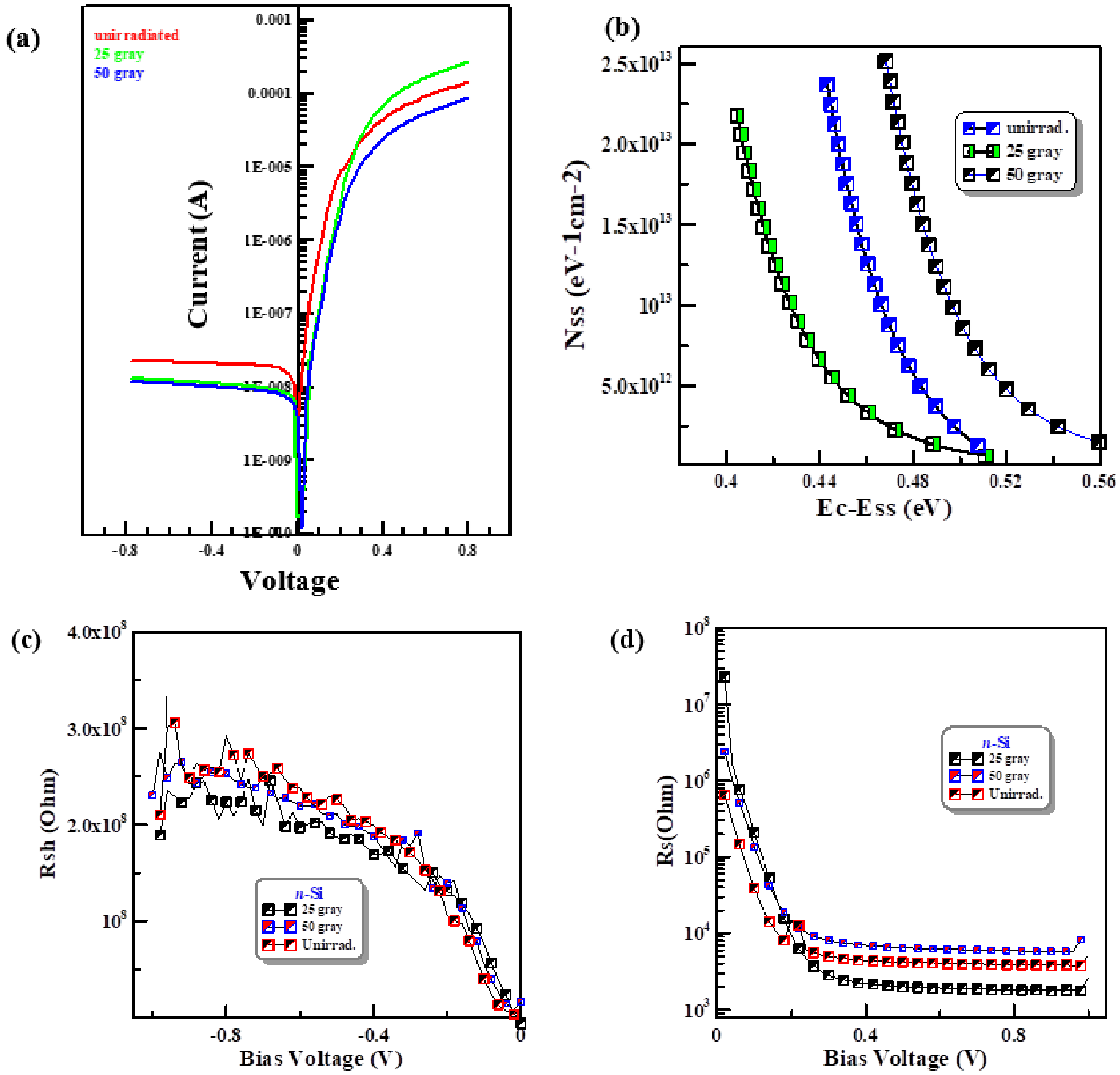


**Figure 1 a)** I-V graphs, **b)** the change of interface states (Nss) versus interface states energy (Ec-Ess), **c)** shunt resistance versus reverse bias, and **d**) series resistance-Forward bias curves of the Au/n-Si/Au-Sb diode before and after irradiation for different doses

With the help of Cheung functions, series resistance ($R_s$) value, and ideality factor, which are important electrical parameters of Schottky contacts, can be calculated by using the dV / d(lnI) - (I) (Eq. 6) plots. Furthermore, by using H (I)-I (Eq. 7) plots, series resistance values, and barrier heights can be calculated (Cheung & Cheung 1986). In the case of series resistance, the current equation according to thermionic emission theory (TE) using the forward bias I-V characteristics of the diode is expressed as:

$$I = I_0 \exp\left[\left(\frac{e(V - IR_s}{nkT}\right)\right] \tag{5}$$

The term IRs presents the voltage drop in the series resistance of the device. Series resistance value:

$$\frac{dV}{d(\ln I)} = \frac{nkT}{e} + IR_s \tag{6}$$

In this equation, the graph of $\frac{dV}{d(\ln I)}$ - I is in the form of a linear, and the slope of this linear gives the Rs value of the diode. The point where the line intersects the y-axis gives the $\frac{nkT}{e}$ ratio, from which the ideality factor *n* is found.

To find the barrier height from the Cheung functions, Eq. 7 can be used:

$$H(I) = V - \left(\frac{nkT}{e}\right)\ln\left(\frac{I}{AA^{*}T^{2}}\right) \quad (7)$$

Eq.7 can be arranged as follows (Cheung & Cheung 1986):

$$H(I) = n\Phi_{b} + IR_{s} \quad (8)$$

The H (I) graph is linear, and the slope of this graph gives another value of the $R_s$ (Umana-Membreno et al., 2003). The n value found in Eq. 3 is replaced by this equation, and the barrier height ($\Phi_b$) is obtained from the point where the line intersects the y-axis at the point I = 0. Figure 2 and Figure 3 show dV/dln(I)-(I) and H(I)-(I) graphs of the Au/n-Si/Au-Sb diode before and after irradiation, respectively.

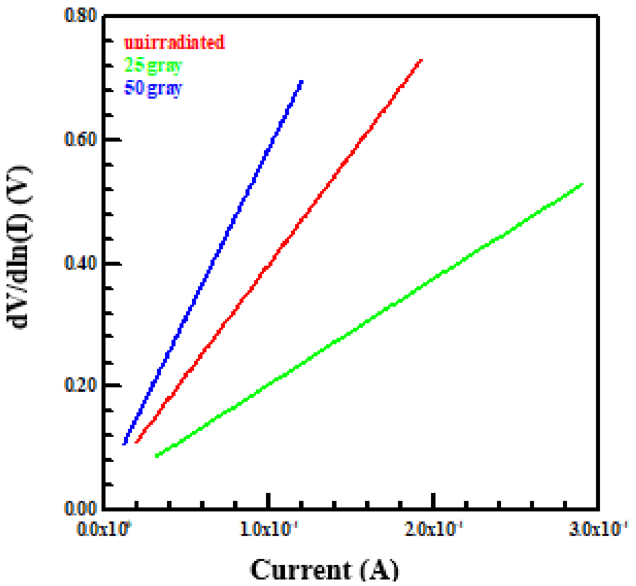


**Figure 2** dV/dln(I)-I graph of the Au/n-Si/Au-Sb diode before and after irradiation for different doses

The values obtained from the dV/dln(I)-(I) and H(I)- (I) graphs of the Au/n-Si/Au-Sb diode are given in Table 2. From the dV/dln(I)-(I) graph of the diode, the n value was found to be 1.428, 1.342, and 1.555 and Rs values were calculated as 3622, 1693, and 5463 Ω before, for 25, and 50-gray irradiation respectively. Furthermore, the Rs value from the H(I)-(I) graph was found as 3626, 1696, and 5493 Ω before, for 25, and 50-gray irradiation, respectively. The series resistance values obtained are in accordance with the values obtained from Ohm's law. In addition, the $\Phi_b$ values were calculated as 0.717, 0.751, and 0.738 before, for 25, and 50-gray irradiation, respectively. The decrease in n value after 25 gray irradiation can be explained by the increase in the width of the depletion layer and the reduction in the surface state density due to the effect of irradiation (Kaymaz et al., 2021). In addition, the annealing effect on the interface trap centers as a result of secondary electrons produced by irradiation may also have caused a decrease in the n value (Coşkun et al., 2006; Verma et al., 2014). After 50 gray irradiation, the n value increased. The increase can be explained by the formation of highly concentrated defects near the metal/semiconductor interface by irradiation and change of the pure thermionic mechanism (Huang et al., 2024; Zhang et al., 2024). Depending on the irradiation, first, a decrease and then an increase in the value of Rs occurred. The decrease in Rs after 25 gray irradiation may be due to trap charges with energy that can escape from the traps between metal-semiconductors (Kutluoğlu et al., 2021). An increase in Rs value was observed after 50 gray irradiation. Point and displacement defects caused by the effect of irradiation act as deep trap centers. Trapping of carriers at this center results in a reduction in carrier concentration. The increase in series resistance can be explained by this decrease in carrier concentration (Aydoğan et al., 2011; Al-Taii et al., 2015; Vieira et al., 2021). It is seen that the $\Phi_b$ values obtained from the H(I)- (I) graphs first decrease and then increase depending on the irradiation in accordance with the values obtained from the I-V graphs.

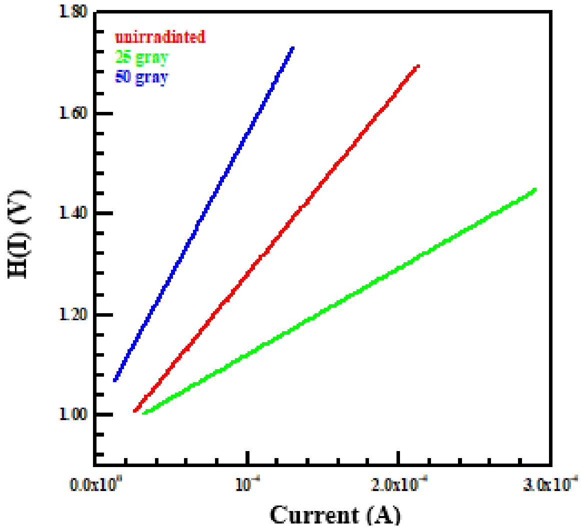


**Figure 3** H (I)-I graphs of the Au/n-Si/Au-Sb diode before and after irradiation for different doses

**Table 2** The values of the main diode parameters calculated from the dV/d(lnI)-I and H(I)-I plots of the Au/n-Si/Au-Sb diode before and after irradiation.

| | ***dV/dln(I)-I*** | ***dV/dln(I)-I*** | ***H(I)- (I)*** | ***H(I)- (I)*** |
|---|---|---|---|---|
| **Process** | ***n*** | **$R_s$ (Ω)** | **$R_s$ (Ω)** | **$\Phi_b$ (eV)** |
| **Before irradiation** | 1.428 ± 0.02 | 3622 ± 0.02 | 3626 ± 0.03 | 0.717 ± 0,03 |
| **25 gray** | 1.342 ± 0.02 | 1693 ± 0.02 | 1696 ± 0.03 | 0.751 ±0.03 |
| **50 gray** | 1.555 ± 0.02 | 5463 ± 0.02 | 5493 ± 0.03 | 0.738 ±0.03 |

The clear response of the basic diode parameters to the electron irradiation is observed. This apparent change due to the dose of electron irradiation can be attributed to the redistribution of the structure at the interface between Au and n-Si as a result of electron irradiation (Salari et al., 2016).

In addition to the I-V measurement, diode parameters such as barrier height ($\Phi_b$), diffusion potential ($V_{dif}$), Fermi energy level ($E_f$), and donor concentration ($N_d$) of Au / n-Si / Au-Sb Schottky diode were calculated by the C-V measurements. For this, the following equation which indicates the reverse bias relation between C and V is used:

$$C^{-2} = \frac{2(V_d + V)}{\varepsilon_s \varepsilon_0 e A^2 N_d} \tag{9}$$

here $V_d$; is the diffusion potential in the case of zero bias voltage. When the graph $C^{-2}$-$V$ is drawn, and the linear fit is made, $V_d$ =V is for $C^{-2}$=0. The $N_d$ in Eq. 9 is the ionized donor concentration; $\varepsilon_s$ is the dielectric constant of the silicon semiconductor ($\varepsilon_s$ =11.7) ( Neamen, 1992).

The value of the barrier height can be calculated using the C-V measurements with the following equation:

$$\Phi_b = V_d + V_n \tag{10}$$

here, $V_n$ is equal to the Fermi energy level.

Figure 4 shows the C-V graphs of the diode performed at 10 kHz before and after irradiation. It is clearly seen from the graphs that the capacitance values depend on the irradiation (Aydoğan et al., 2011; Teffahi et al., 2016 ). This reduction in capacitance with irradiation dose can be attributed to the change in dielectric constant at the metal-semiconductor interface and the decrease in ionized charge concentration (Uğurel et al., 2008). The decrease in capacitance can also be explained by the formation of acceptor-like defects as a result of irradiation.

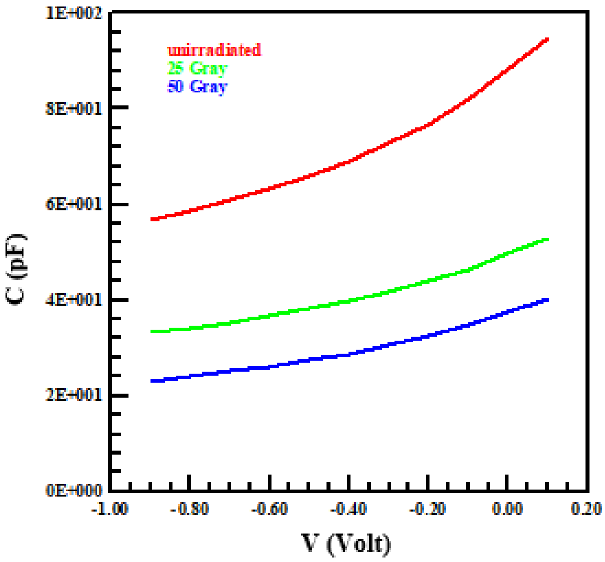


**Figure 4.** The C-V graphs of the Au /n-Si/Au-Sb diode performed before and after irradiation at 10 kHz

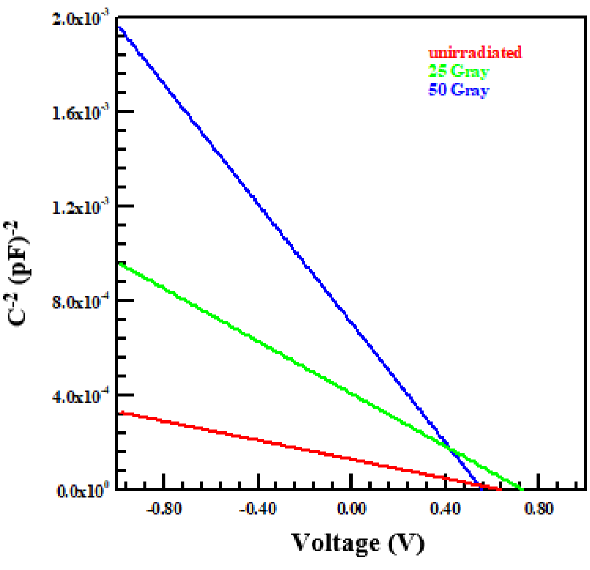


**Figure 5**. $C^{-2}$-V graphs of Au/n-Si /Au-Sb diode achieved before and after irradiation at 10 kHz

Figure 5 depicts the reverse bias $C^{-2}$-V graphs of the diode obtained at 10 kHz frequency before and after irradiation. It is seen that the capacitance decreases after both 25 and 50 gray irradiation. This can be attributed to the decrease in ionized charge concentration due to irradiation and the change in dielectric constant at the metal-semiconductor interface (Tuğluoğlu et al., 2015; Oeba et al., 2021). The linearity of the graphs can be explained by the absence of excess capacitance (Uğurel et al., 2008). Table 3 shows the diode parameters obtained from the reverse bias $C^{-2}$-V measurements.

**Table 3**. Values calculated from $C^{-2}$-V plots of the Au/n-Si/Au-Sb diode before and after irradiation.

| Process | $V_{dif}$ (eV) | $N_d$ ($cm^{-3}$) | $E_f$ (eV) | $\Phi_b$ (eV) |
|---|---|---|---|---|
| **Before irradiation** | 0.642± 0.02 | 9.74 x$10^{14}$ | 0.266± 0.02 | 0.907± 0.02 |
| **25 gray** | 0.733± 0.02 | 3.53 x$10^{14}$ | 0.292± 0.02 | 1.025± 0.02 |
| **50 gray** | 0.560± 0.02 | 1.55 x$10^{14}$ | 0.313± 0.02 | 0.873± 0.02 |

Table 3 shows the values of diode parameters obtained from the reverse bias $C^{-2}$-V graph of the diode. The diffusion potential, donor concentration, Fermi energy level, and barrier height of the diode were found to be 0.642 eV, $9.74\times10^{14}$ $cm^{-3}$, 0.266 eV, and 0.907 eV, respectively before irradiation. However, after 25 gray electron irradiation, the $V_{dif}$, $N_d$, $E_f$, and $\Phi_b$ were calculated to be 0.733 eV, $3.53 \times 10^{14}$ $cm^{-3}$, 0.292 eV, and 1.025 eV, respectively. After 50 gray irradiation, the $V_{dif}$, $N_d$, $E_f$, and $\Phi_b$ were calculated to be 0.560 eV, $1.55 \times 10^{14}$ $cm^{-3}$, 0.313 eV, and 0.873 eV, respectively. The donor concentration decreased with increasing irradiation. This decrease can be attributed to the decrease in semiconductor free carrier density by irradiation (Prochazkova et al., 2005). However, there was an increase in the Fermi energy level (Brudnyi et al., 2004). The diffusion potential and barrier height changed depending on the irradiation dose (Selçuk & Ocak, 2007; Teffahi et al., 2016). $V_{dif}$ and $\Phi_b$ values increased as a result of 25 gray irradiation and decreased as a result of 50 gray irradiation. An increase in diffusion potential causes an increase in barrier height (Aydoğan et al., 2011). The decrease in $V_{dif}$ and $\Phi_b$ values as a result of 50 gray irradiation can be explained by providing a dynamic balance between the creation and destruction of defects with the effect of annealing caused by irradiation (Kaymaz et al., 2021). In addition, the effect of defects in the semiconductor band gap caused by irradiation on the free carrier concentration may also have caused a decrease (Xu et al., 2019). The barrier height value obtained from the C-V curve is higher than that obtained from the I-V graph due to the difference between I-V and C-V analysis methods. This difference can be explained by the non-ideal diode, the oxide layer between Au and n-Si, or the inhomogeneity of the barrier (Werner & Guttler, 1991).

Figure 6 depicts the conductance-voltage (G-V) graphs of the Au/n-Si/Au-Sb diode. The graphs were drawn at different frequency values before and after 25 and 50 gray irradiation.

In Figure 6, it is seen that the conductance value of the Au/n-Si/Au-Sb diode increases depending on the increasing frequency before and after the irradiation. The increase in charge carrier density after irradiation causes an increase in conductance. This increase in conductance; can also be explained by the decrease in the series resistance of the structure and the interfacial state effects depending on the increase in frequency (Alsmael et al., 2022).

All graphs show an increase in the conductance of the diode depending on the increasing potential. As can be seen in the graphs, the conductance value of the Au/n-Si/Au-Sb diode increased after 25 gray irradiation and decreased after 50 gray irradiation in the bias voltage.

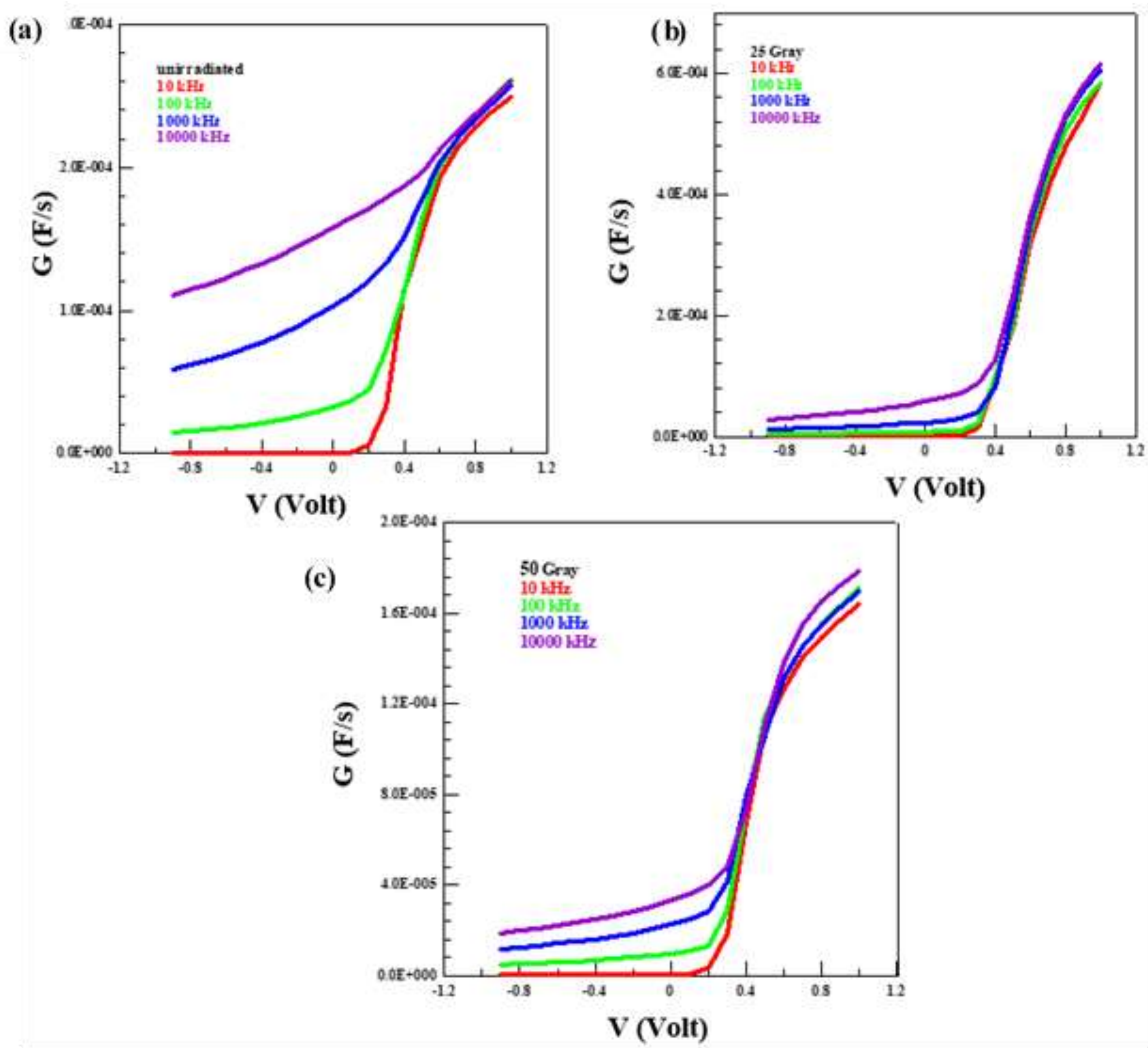


**Figure 6** The G-V graphs of Au/n-Si/Au-Sb diode performed at different frequencies; a) before irradiation, b) after 25 gray irradiation, and c) after 50 gray irradiation

The increase in conductance as a result of 25 gray irradiation can be explained by the irradiation causing an increase in free charge carriers and the increase in defects that provide pathways for these charge carriers. (Kaymaz et al., 2020).

The reduction as a result of 50 gray irradiation can be explained by the decrease in the interfacial trap charges as a result of the gaps and lattice defects formed at the metal-semiconductor interface with irradiation (Karataş & Türüt, 2006). This is consistent with the decrease in Rs value after 25 gray irradiation and the increase in Rs value after 50 gray irradiation obtained from C-V graphs. Rs and G show a decrease and increase in contrast to each other (Yılmaz & Kaya, 2016). The increase in the resistivity of the semiconductor due to the decrease in the width of the depletion region as a result of irradiation and the increase in the interfacial states and trap centers with irradiation can also cause a decrease in the conductance. Defects caused by irradiation in the semiconductor; It creates electrical effects such as the recombination of electron-hole pairs with trap centers, tunneling of carriers at the interface, and trapping of carriers. The decrease in conductance can be explained by the fact that ionizing irradiation causes a decrease in trap charges at the insulator-semiconductor interface (Maurya, 2016; Kaymaz et al., 2020; Kutluoğlu et al., 2021).

The capacitance-frequency (C-f) measurements of the diode were performed at different bias voltage values before and after irradiation, in the range of 1kHz-10MHz. Thus, the effect of both irradiation and voltage on capacitance was investigated. Figure 7-a depicts the C-f graphs of the Au/n-Si/Au-Sb diode before irradiation, while Figure 7-b and Figure 7-c show two different electron doses of irradiation, respectively. The decrease in capacitance due to irradiation is also seen in the C-f graphs. This can be explained by the change in the interfacial dielectric constant and the decrease in the ionized charge concentration due to irradiation. In addition, the capacitance has decreased due to the increase in frequency. This decrease can be attributed to the fact that the interface states in equilibrium with n-Si can follow the alternating current signal at low frequencies but not at high frequencies (Güllü et al., 2008). While the capacitance of the diode depends on the space charge capacity and interface states at low frequencies, it only consists of the space charge capacity at high frequencies (Nuhoğlu et al., 2000).

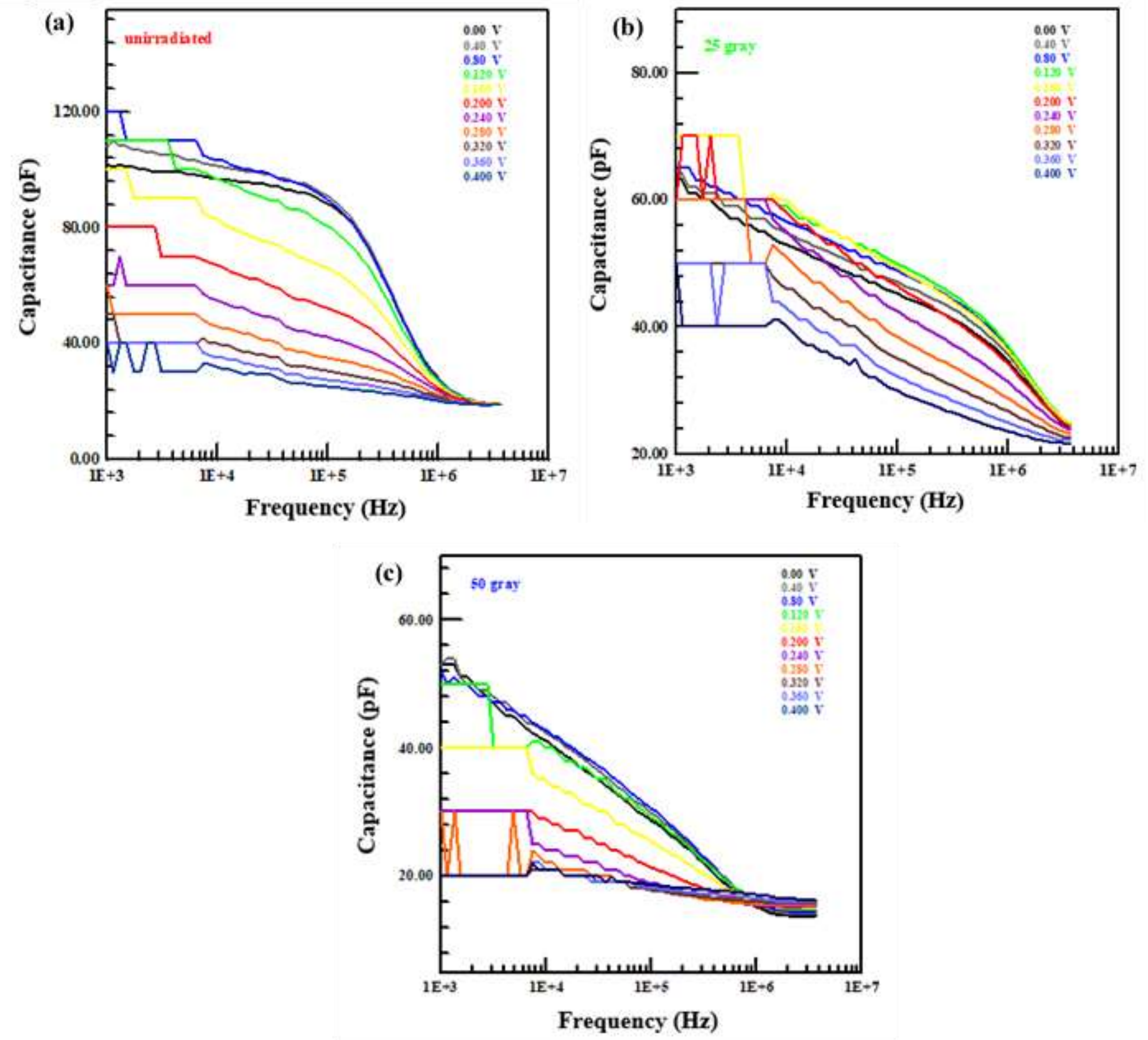


**Figure 7.** The C-f plots of the Au/n-Si/Au-Sb diode obtained in the range of 0.00-0.40 V in 0.04 Volt steps; a) before irradiation, b) after 25 gray electron irradiation, and c) after 50 gray electron irradiation

## CONCLUSION

In this study, the change of electrical properties of the Au/n-Si/Au-Sb Schottky diode due to electron irradiation was investigated. An increase was observed in the ideality factor of the diode after irradiation; It was explained by the fact that the defects formed at the interface by irradiation act as traps and recombination centers, and the current conduction mechanism deviates from the thermionic emission theory. Diffusion potential and barrier height increased after 25 gray irradiation and decreased after 50 gray irradiation. The increase due to 25 gray irradiation was attributed to the trapping of carriers due to the increase in interfacial defect density with irradiation. The decrease after 50 gray irradiation was explained by the tunneling effect. Depending on the increase in the irradiation dose, a decrease in the reverse bias current, donor concentration density, and capacitance of the diode was observed. This decrease was explained by the disappearance of semiconductor free charge carriers in the traps formed by irradiation and a decrease in the interfacial dielectric constant. After 25 gray irradiation, a decrease in series resistance and an increase in conductance were observed. This situation was explained by the trap charges that have the energy to escape from the traps formed between the metal-semiconductor. After 50 gray irradiation, there was an increase in series resistance and a decrease in conductance. This change was attributed to the decrease in the interfacial trap charges as a result of the gap and lattice defects formed between the metal-semiconductor due to irradiation. The capacitance decreased with increasing frequency. It was explained by the fact that the interface states support the capacitance by following the low frequencies of the alternating current while not contributing to the capacitance by failing to follow the alternating current signal at high frequencies. As a result, it has been seen that electron irradiation has a significant effect on the electronic properties and performance of the Au/n-Si/Au-Sb Schottky diode.

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### Conflict of Interest

The article authors declare that there is no conflict of interest between them

### Author's Contributions

The authors declare that they have contributed equally to the article.

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