Study of the electrical properties of vacancy-oxygen-hydrogen defect in Au/n-Si Schottky diodes characterized using DLTS techniques.

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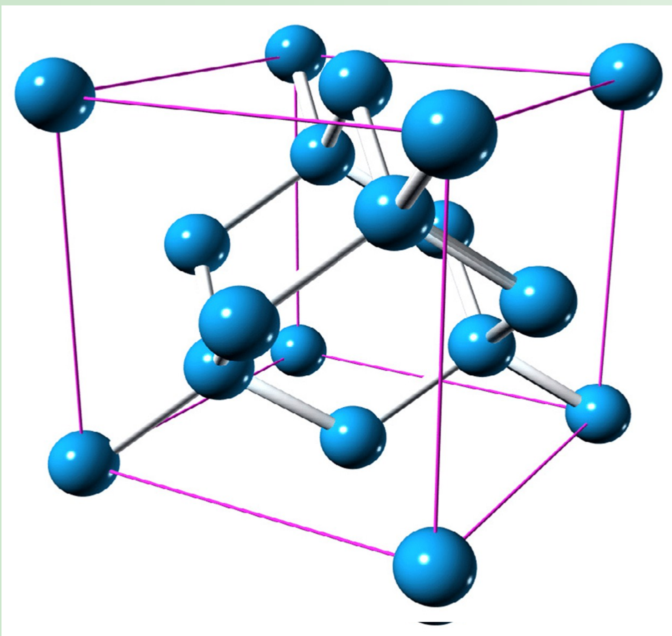
Introduction

Silicon is one of the most important semiconductor materials that has been widely studied and used in electronic devices [1]. Succeeding very high n-type doping levels in silicon has recently prompted renewed interest in related defects[2]. The vacancy-oxygen-hydrogen (VOH) is one of the longest known defects in Si, being studied first by Watkins and Corbett in 1959[3]. VOH is often formed when hydrogen is unintentionally introduced during the growth and they can easily react with the reconstructed bond[3]. It is an important to know the behavior of the hydrogen in silicon for its use in device fabrication. In this study, the effect of doping the n-Si wafer with different dopants such as (P, As), (P, Sb), and (P, Sb, As) on the VOH defect are studied.

Crystal structure



- Diamond
- a = 543 pm

Advantages and applications

- Low cost
- Well established fabrication processes
- High efficiency solar cells
- High electrical conductivity
- Optoelectronic devices (photodiodes)

Defects

Generally, defects are introduced either intentionally or unintentionally (during growth and processing)

Intentionally introduced defects:

- Doping through adding external atoms to crystal structure
- Implantation and radiation

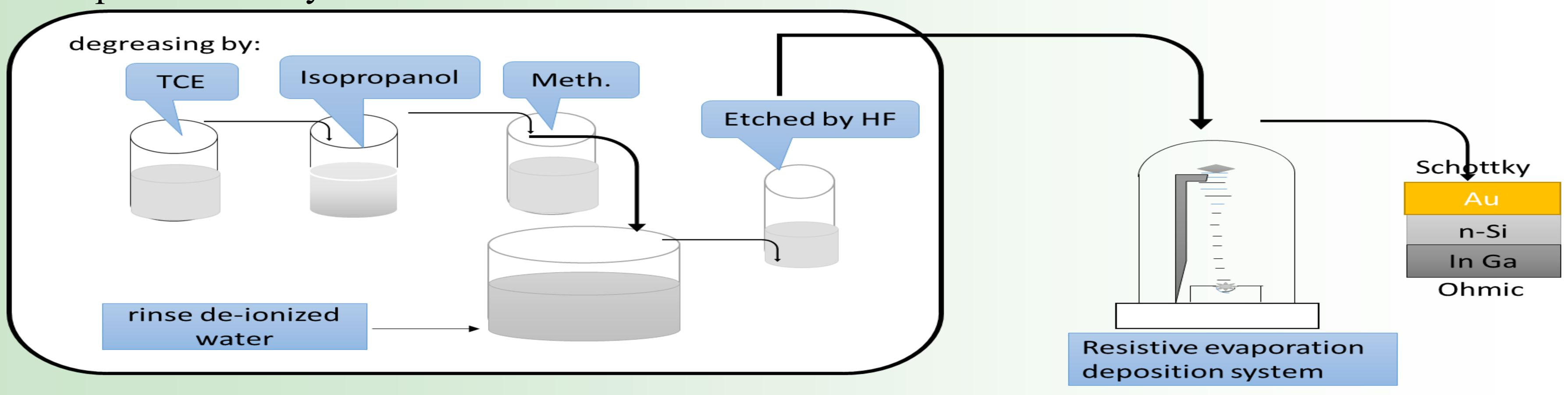
Unintentionally introduced defects:

Vacancies - Dislocation - Substitution
Stacking faults - Foreign interstitial - External surfaces - Self-interstitial

Experimental procedure

Samples preparation :

- The starting materials for this sample was (100)5" diameter epitaxial Si. The epitaxial P-doped n-layer with a free concentration of 1.1×10^{16} cm^{-3} and 6 µm thick was grown by (CVD) on n^{+2} substrate. The S1to S3, were implanted with As and Sb, respectively after implantation Si samples were annealed at 950 C for 30 min in nitrogen to activation to dopant and to remove implantation-induced disorder in the Si. The samples wafers were irradiated by high-energy (3.5 MeV) electrons to doses (1.5x1016 cm-2 (S1-S3).
- Samples were cleaned in an ultrasonic bath for 5 min each in (TCE., Isopropanol ., Methanol, de-ionized water, and etched in 40% hydrofluoric acid for 30s.
- Resistive deposition of Au Schottky contacts on the surface of the substrate .
- The fabricated Schottky diodes on the n-Si doped with (P, As), (P, Sb), and (P, Sb, As) were referred to S1, S2, and S3, respectively.
- I-V and C-V measurements of these samples were carried out at room temperature to test the quality of the contact using an HP 4140 B pA meter/ DC Voltage source and HP 4192 A LF Impedance Analyser.



Results and discussions

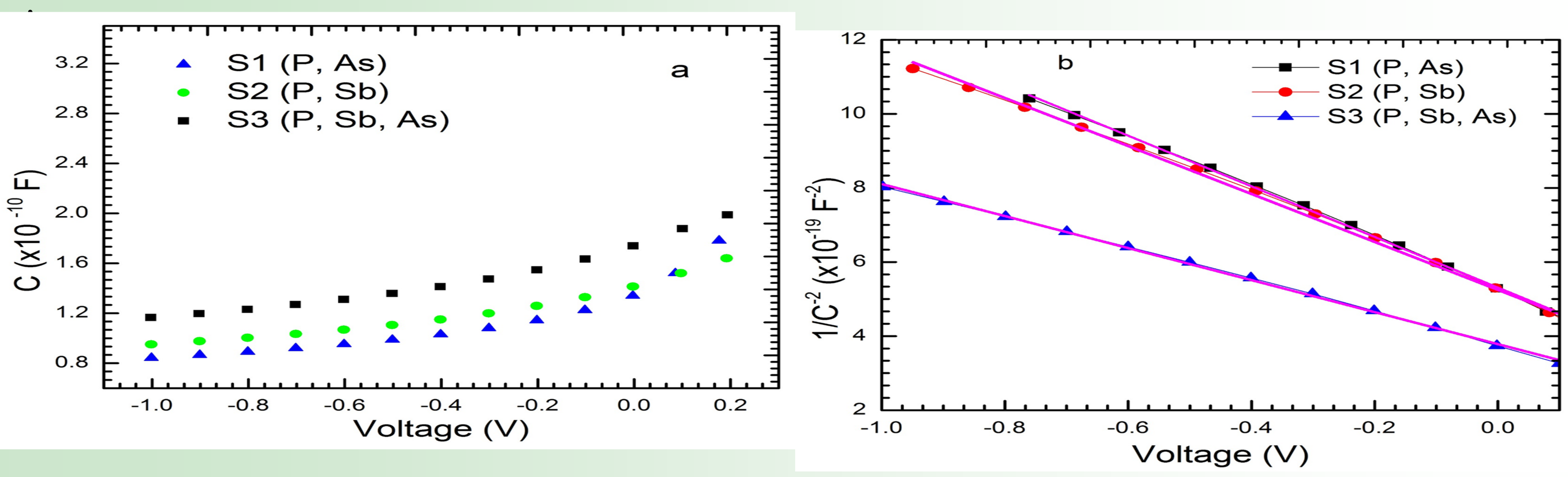


Fig. 1: (a) and (b) C-V characteristics of the Au/n-Si Schottky diodes doped with (P, As), (P, Sb), and (P, Sb, As) measured at room temperature 1 MHz .

- Figure 1 shows the *C-V* characteristics for n-Si doped with different dopants (P, As, Sb). The carriers concentration for S3 found to be the highest compared to S1 and S2.
- The obtained Schottky barrier height from the *C-V* characteristics are presented in Table 1.
- The *I-V* characteristics of the Au/n-Si Schottky barrier diode are presented in Figure 2. The properties of the fabricated Schottky diodes are shown in Table 1.

- Figure 3 represents the conventional DLTS spectra of the three samples, all spectra contain 4 peaks: E-center, vacancy oxygen–hydrogen (VOH), single negative state of the divacancy (VV$^{0/-}$), vacancy–oxygen (VO). The general features of the spectra for all samples are similar with different peak amplitudes.
- Activation energies for all defects were calculated from Figure 4. Activation energies of the VOH defect for S1, S2, and S3 were found to be 0.34 eV to 0.33 eV, and 0.22 eV, and the corresponding apparent capture cross-sections of these defect were 5.9×10^{-19} cm^2, 7.9×10^{-15} cm^2, and, 5.3×10^{-17}cm^2, respectively. Also this defect has been observed by I.L. Kolevatov *et al*[5], which they attributed to the hydrogen-vacancy complex in n-Silicon. The VOH peak intensity S3 was found to decrease and its position shifted to the lower temperature. This could be due to the effect of the implantation of the three dopants (i.e P, As, and Sb).
- Figure 5 shows the depth profile of the E-center defect and the shape of these curves resembles. diffusion profile.

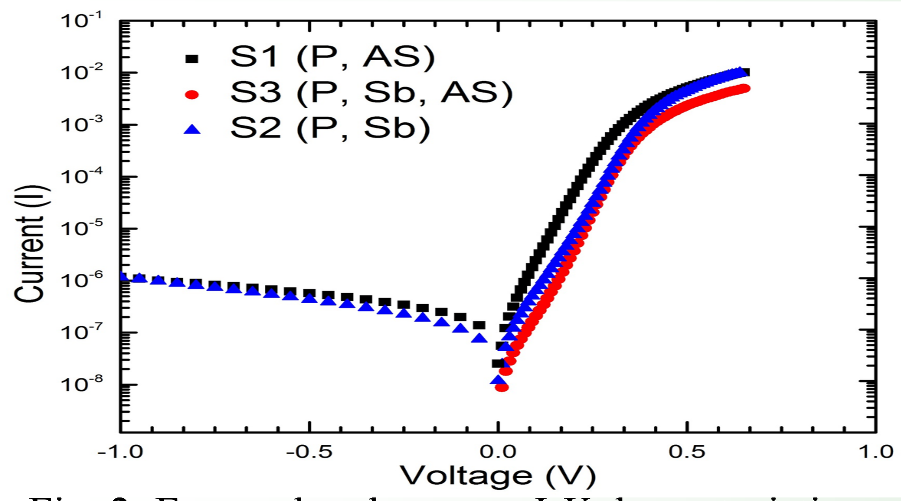


Fig. 2: Forward and reverse *I-V* characteristics of Au/n-Si Schottky diode doped with (P, As), (P, Sb), and (P, Sb, As) measured at temperature.

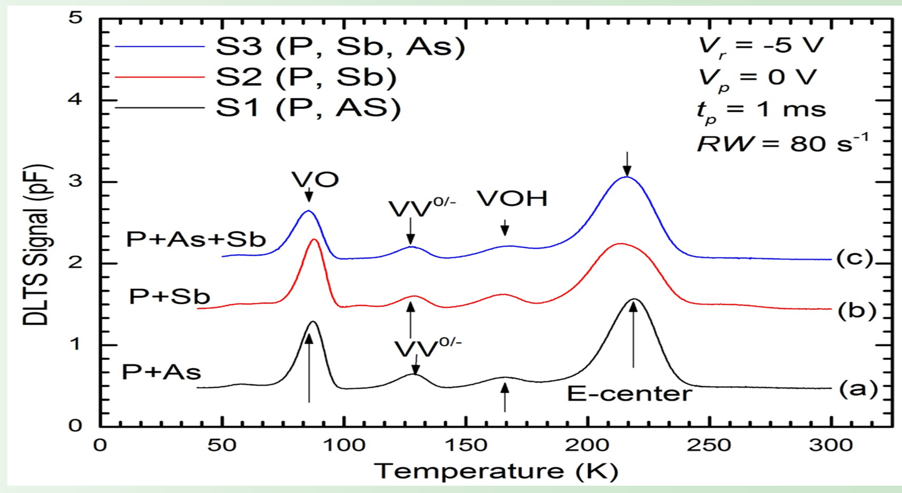


Fig. 3: DLTS spectra of electron irradiated Au/n-Si doped with P, As (curve (a)), and P, Sb (curve (b)), and P, Sb and As (curve (c)).

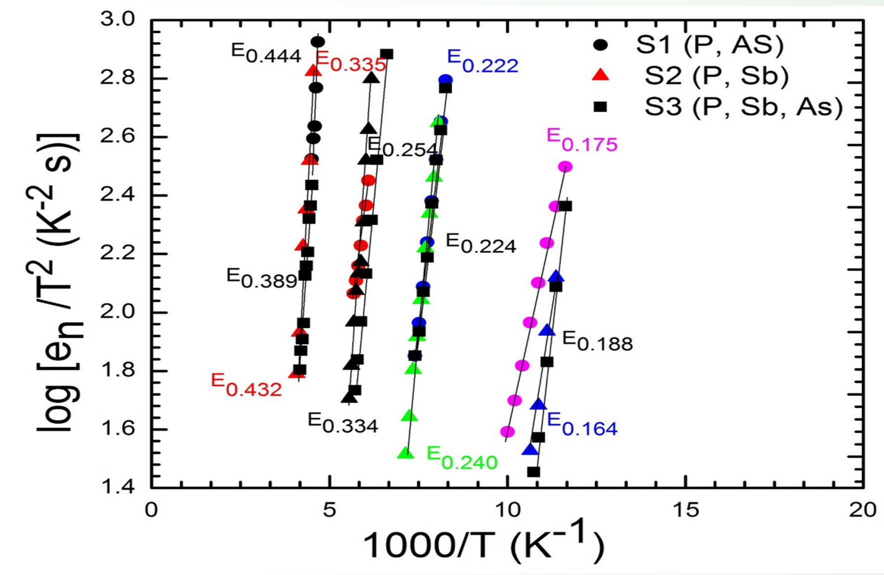


Fig. 4: Arrhenius plots of electron-irradiation n-Si doped with (P, As) (circles), (P, Sb) (up-triangles) and (P, As, Sb) (square).

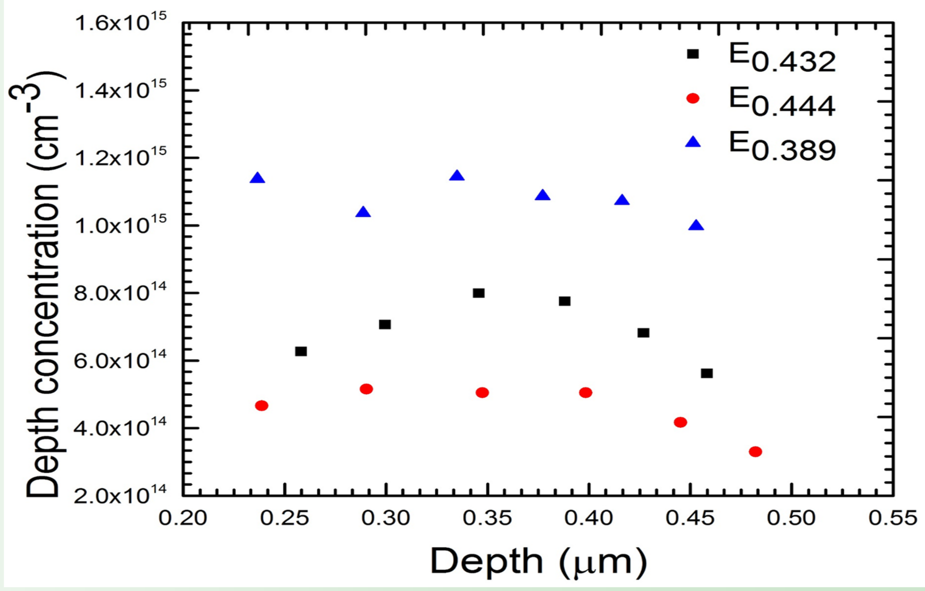


Fig. 5: Depth profiles of doped in S1, S2, and S3 for E-center defect.

Table 1: Comparison of some electrical parameters, activation energy (E_t), and the apparent cross-section (σ_a) of the VOH defect for the fabricated Au/n–Si Schottky diodes.

Samples	n	I_s $\times10^{-6}$ (A)	R_S (Ω)	N_d $\times10^{16}$ (cm^{-3})	SBH ϕ_{I-V} (eV)	SBH ϕ_{C-V} (eV)	Defect	E_t (e V)	σ_a(cm^2)
S1 (P, As)	2.20	2.36	14	1.56	0.57	0.98	VOH	0.34	5.9 x10^{-19}
S2 (P, Sb)	2.03	1.04	3	1.60	0.59	1.01	VOH	0.33	7.9 x10^{-15}
S3 (P, Sb, As)	1.57	0.057	27	2.40	0.67	1.07	VOH	0.22	6.8 x10^{-16}

Conclusion

- The I-V characteristics shows that all samples exhibited good rectifying behaviour with S3 being the best device.
- DLTS: irradiation induces defects (E-center , VOH, VV$^{0/-}$, and VO).
- The VOH peak position shifted to the lower temperature and the intensity decreased in S3 compared to S2 and S1 .
- Arrhenius plots: shows four featured levels for each sample, the activation energy of the VOH
- Depth profiles of the E-center defect showed that the concentration of the E-center defects increased with depth.

References

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