Characterization and Analysis of Radiation Effects on Semiconductor Devices

Group 34: Elaine Greer, Isa Valdez, German Rodarte, Munir Tufail, Ghaith Ayyoub

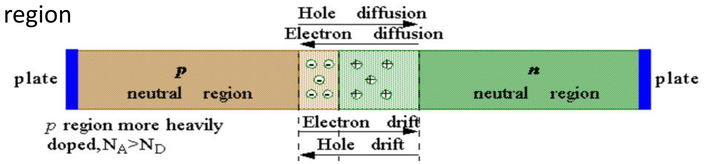
Mentor: Dr. Hugh Barnaby | School of Electrical, Computer, and Energy Engineering

Introduction

- Aerospace, medical imaging, and military devices are regularly exposed to damaging **ionizing radiation**
  - Non-destructive **defect detection** is critical to supporting radiation hardened design
- Laser-assisted device alteration (**LADA**) is a defect detection method that makes **localized photocurrents** inside a device, altering device characteristics and changing user defined pass/fail outcomes

P-N Junction Physics

- Light absorption ⟶ generation of electron-hole pairs in depletion region ⟶ current generated by electron/hole movement in depletion region



- Generation rate is a function of the **incident light intensity** as well as the **absorption** coefficient of the material
- **Wirth-rogers model** can be used to model photocurrent as a function of generation rate and depletion region width

$$I_L = qAG(x_d + L_P + L_n)$$

$$x_d = \sqrt{\frac{2\epsilon_{Si}(\phi_{Bi} + V_s)}{qN_A}}$$

x_d - depletion region width
q - elementary charge
N_A - acceptor concentration
V_s - source voltage
ϵ_{si} - permittivity of Si
ϕ_{Bi} - built in voltage

Interface Traps

- **Radiation** breaks bonds at interfaces creating interface traps in the form of **dangling bonds** and defect states
- Traps make **generation** and **recombination** of e-h pairs at the surface **easier**⟶ Higher Trap Density (NIT) = More Generation Current (I_{gen})

$$NIT = SRV/(\sigma V) \qquad I_{gen} = G*P*SRV*x_d*q$$

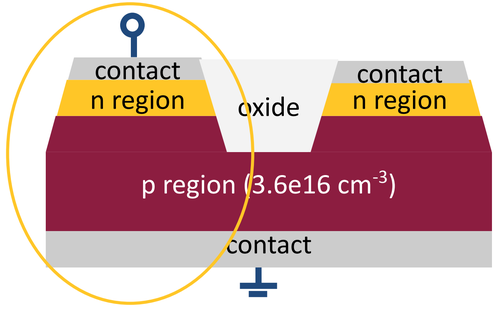
SRV - surface recombination velocity
σ - capture cross-section
V - thermal velocity
G - generation rate
P - perimeter
x_d - depletion region width
q - elementary charge

Objective

- Use LADA technique to detect damage from Cobalt-60 gamma radiation
- Calculate interface trapped charge density due to radiation through changes in body current

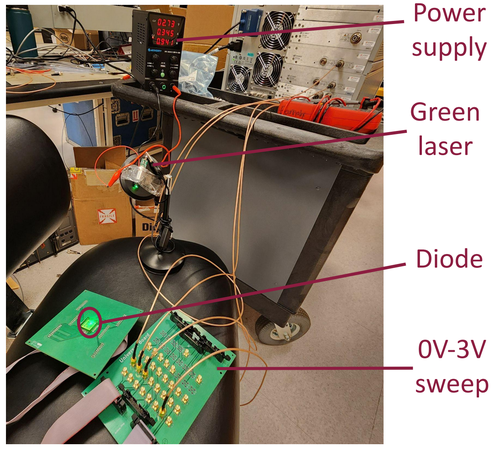
Create STI diodes and testing board → Use lasers before and after gamma radiation → Observe changes in body current

STI Diode Fabrication



1. Si substrate
2. Pattern with lithography
3. Etch trench
4. Remove mask
5. PCVD - oxide deposition

Testing Setup



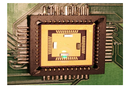
Procedure

1. Vary laser power at 0.2W increments and perform 0V-3V sweeps
2. Irradiate with 500krad gamma-ray radiation
3. Repeat step 1 post-rad

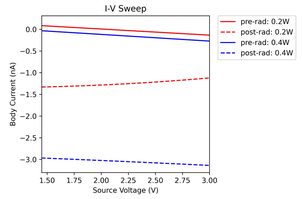
Laser Intensities

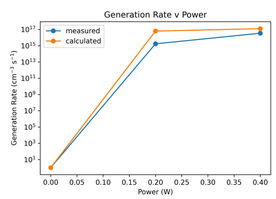
0.2W

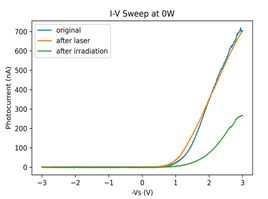
0.4W



Results







Power (W)	I_{gen} (A)	SRV (cm/s)	NIT (cm^{-2})
0.2	1.81E-09	2.69E-03	2.69E+08
0.4	3.03E-09	3.05E-04	3.05E+07

- Formation of generation current was detected as an **increase** in observed **current** magnitude **after radiation**
- Gamma radiation created interface traps
  - the traps **increased** the surface recombination velocity (**SRV**)
  - higher SRV led to a generation current
- Increased incident light intensity increased the generation rate
- Gamma **radiation permanently** altered the device while the **laser** alterations were **temporary**

Conclusions

- Radiation was used to permanently damage the device, forming traps at the Si-SiO2 interface
- LADA **non-destructively** detected the presence of these interface traps through observing an increase in body current
- **Future work:** use LADA to investigate effects of other types of radiation

Acknowledgements

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Ira A. Fulton Schools of Engineering
Arizona State University