Material Research under Extreme Conditions

at AREAL Fasility

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Introduction

At present, the study of effects in materials and electronic equipment under the influence of ionizing radiation is of great importance for the creation of radiation-resistant elements and devices for space, military and other special applications.

The nature and extent of the radiation effect on the physical parameters of materials strongly depends on the:

- type and energy of radiation
- intensity
- irradiation conditions

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Aim

Develop an experimental setup (vacuum chamber) for studying the physical properties of materials and electronic devices under extreme conditions (space environment simulation) at AREAL Facility with the following parameters:

- Vacuum - 10^{-5} Torr. (1.33×10^{-3} Pa),
- Electron beam with energy up to 4MeV, pulse duration 4×10^{-13} sec,
- Measurement temperature range from -100 ^{0}C to +100 ^{0}C,
- Solar ultraviolet radiation.

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1.Experimental setup

Fig.1. General view of the experimental chamber

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1.Experimental setup

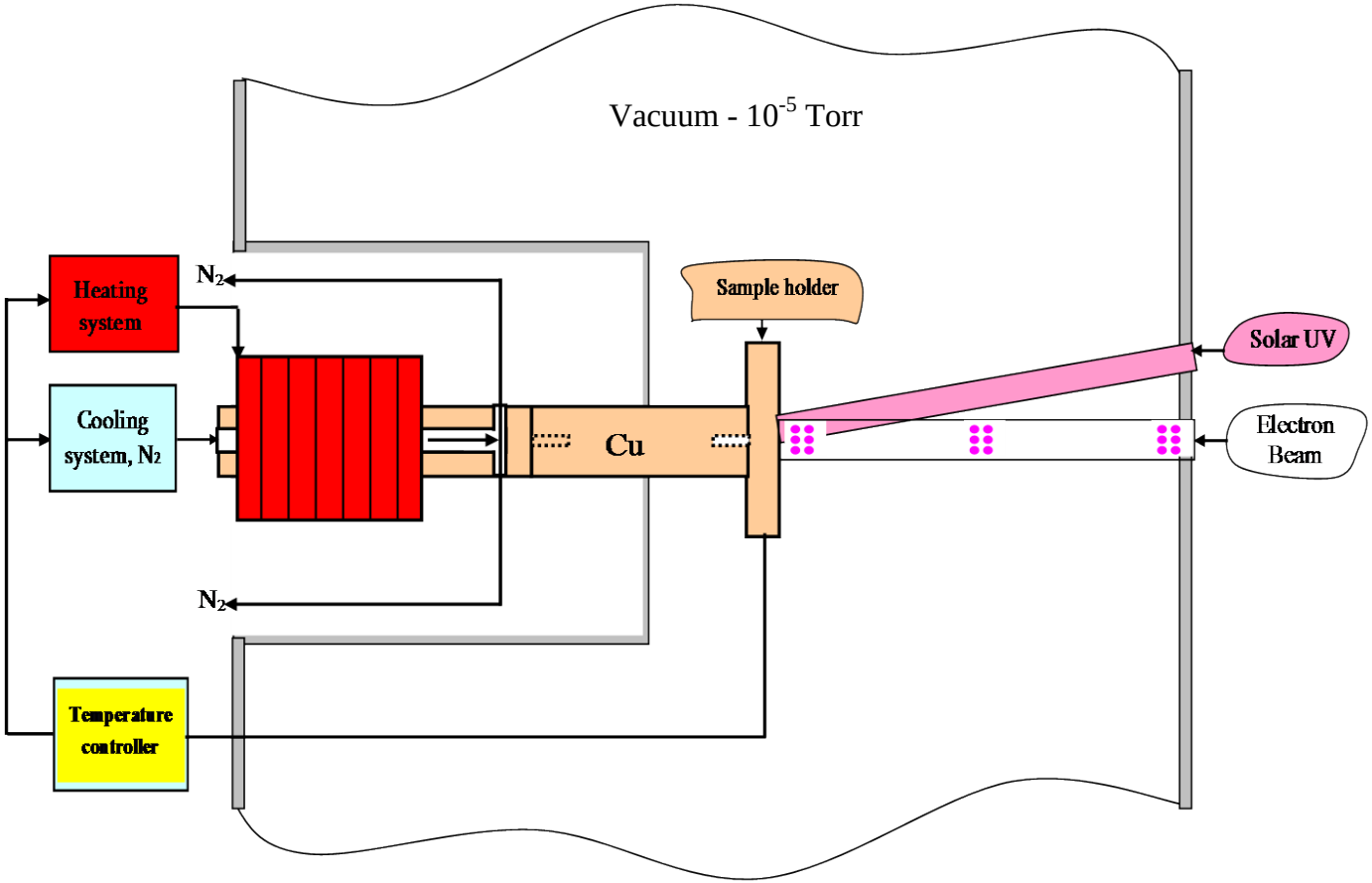

Fig.2. Schematic diagram of heating/cooling system and temperature control of experimental setup: (volume 60 liters)

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1.Experimental setup

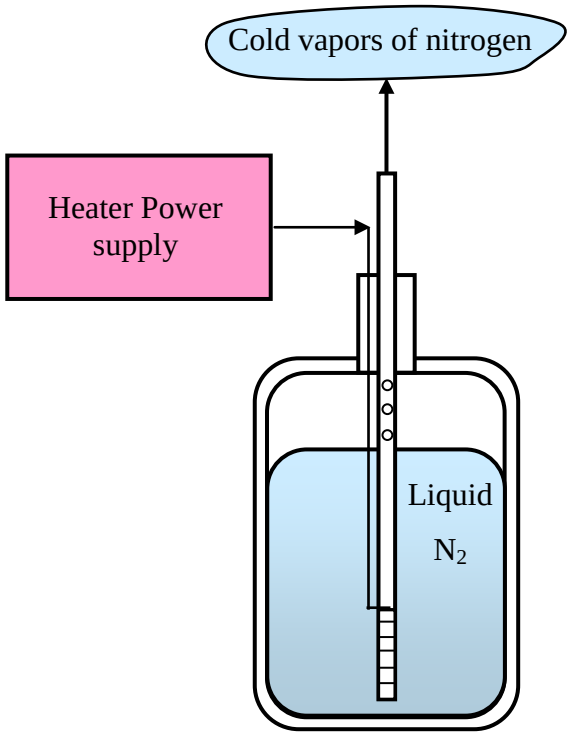

Fig.3. Schematic diagram of cooling system

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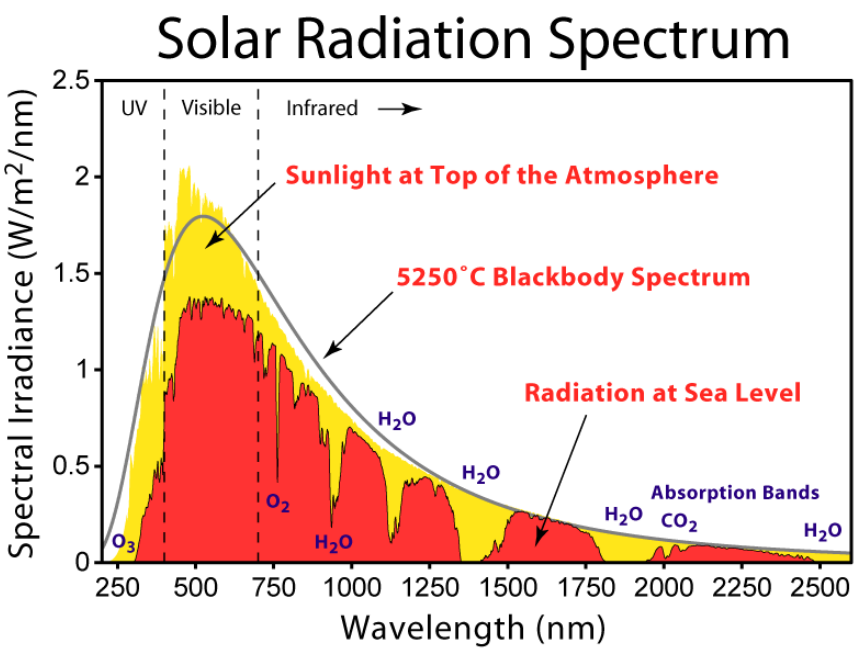
1.Experimental setup



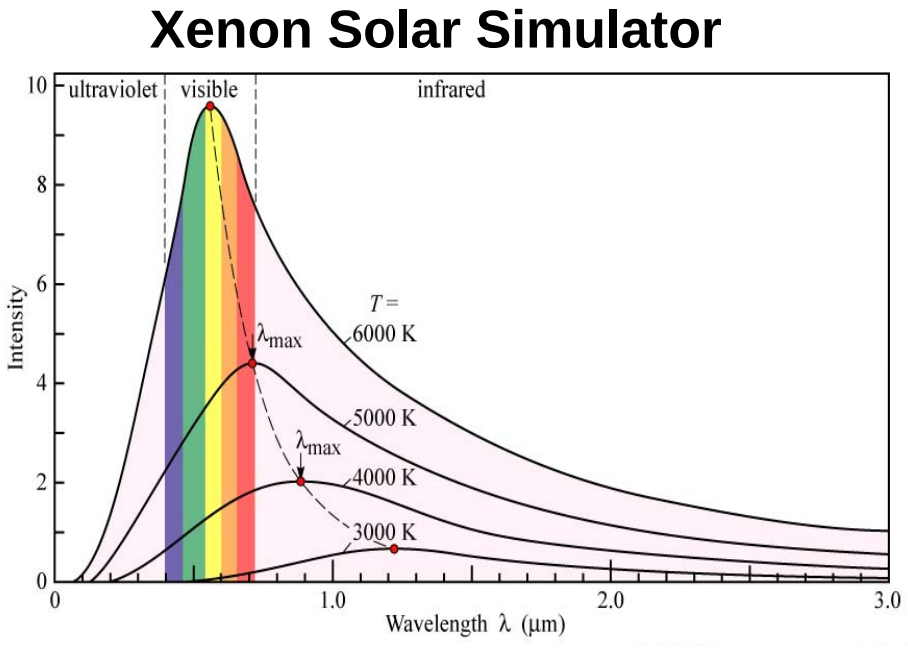


Fig. 4.Spectra of sunlight and xenon lamp

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2. Experimental results

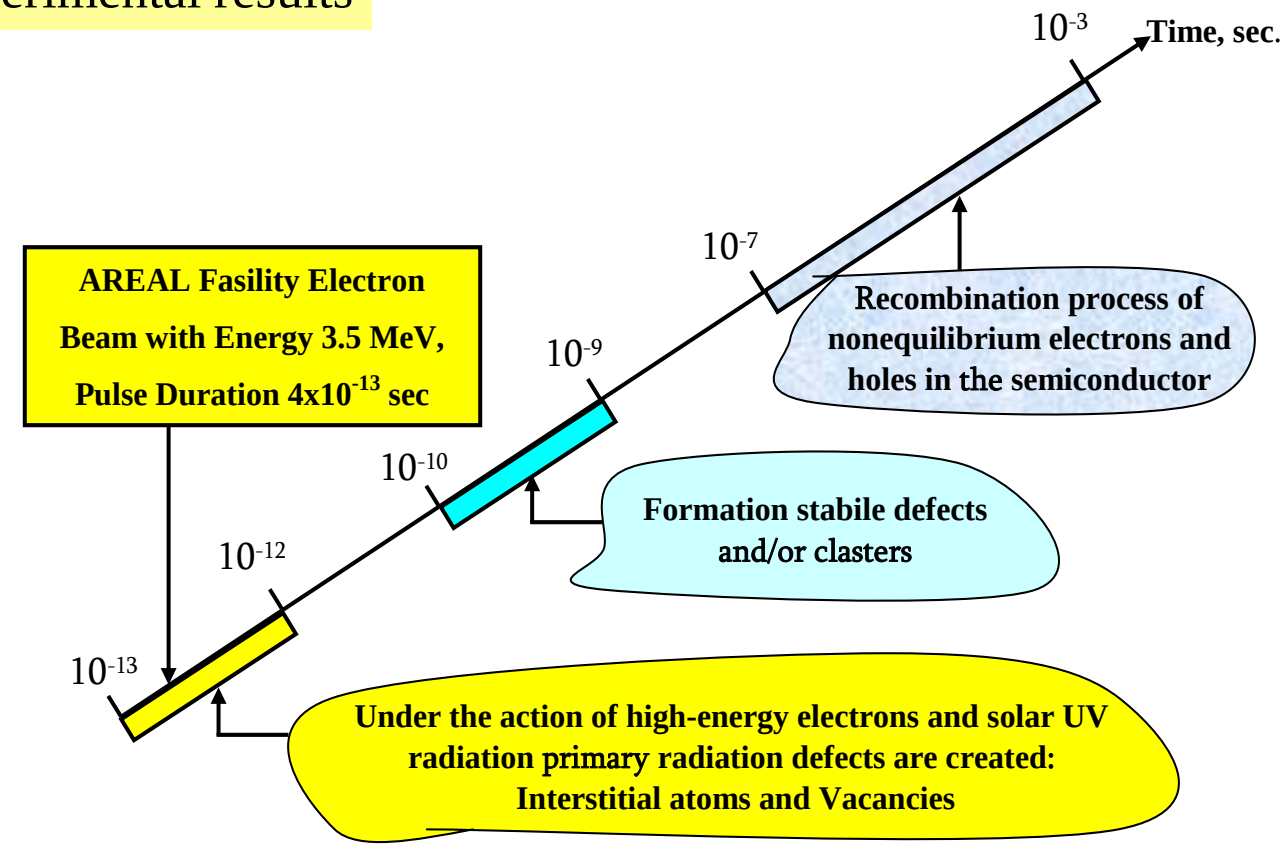

Fig.5. Schematic presentation of the processes occurring in a semiconductor crystal after the iradiation by electrons.

2. Experimental results

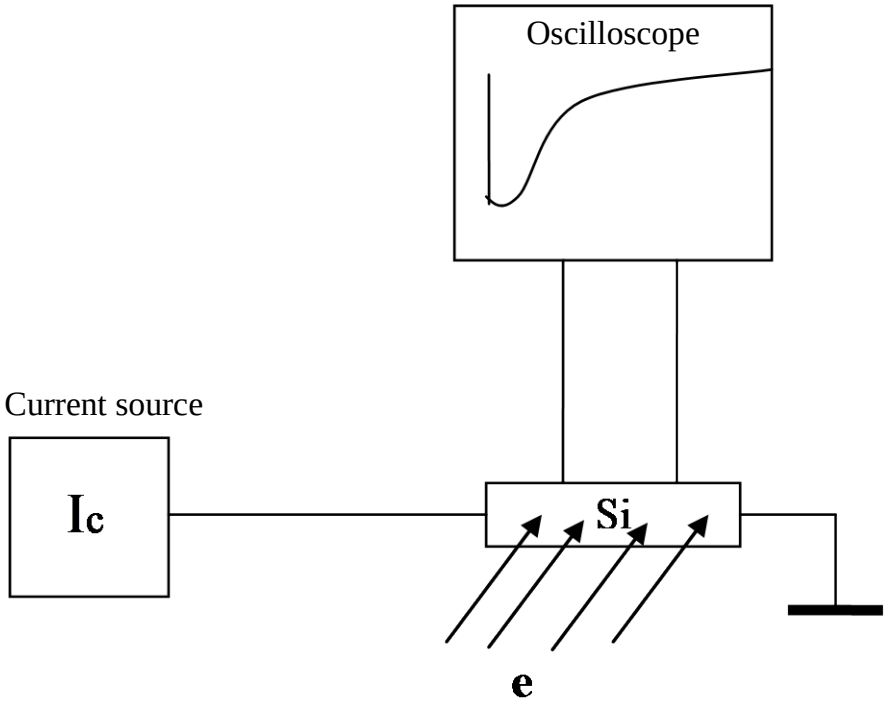

Fig.6. Scheme of silicon crystal measuring system under irradiation (in-situ)

The growing part of the oscillograms is well described by an exponential law with a time constant τ_0.

$$\frac{U}{U_0} = \frac{R}{R_0}\left[1 - \exp(-\frac{t}{\tau_0})\right]$$

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2. Experimental results

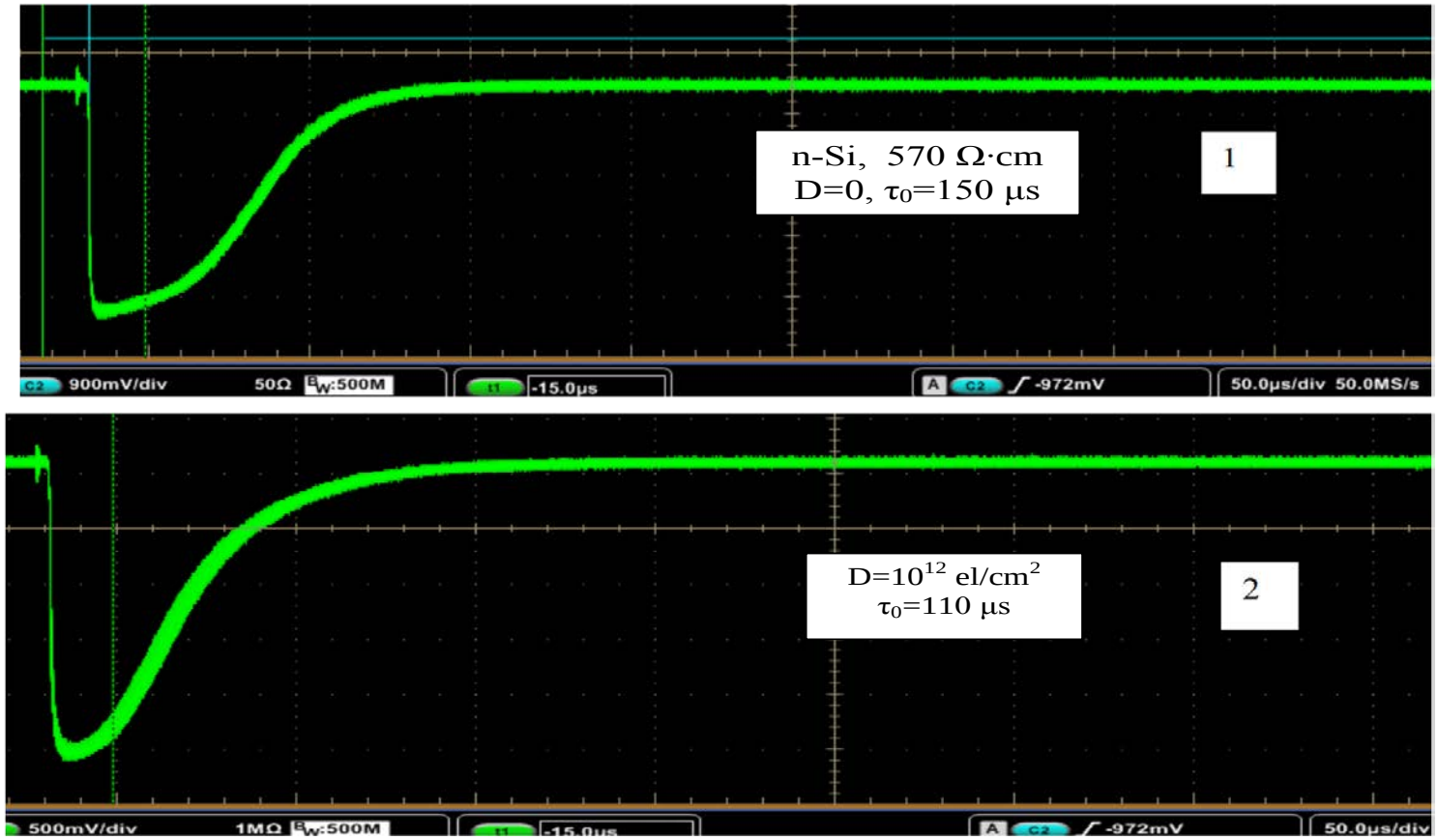

Fig.7. Behavior of silicon crystal resistance under irradiation by ultrafast electron pulses of energy 3.5 MeV.(Measuring temperature T=300 K).

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2. Experimental results

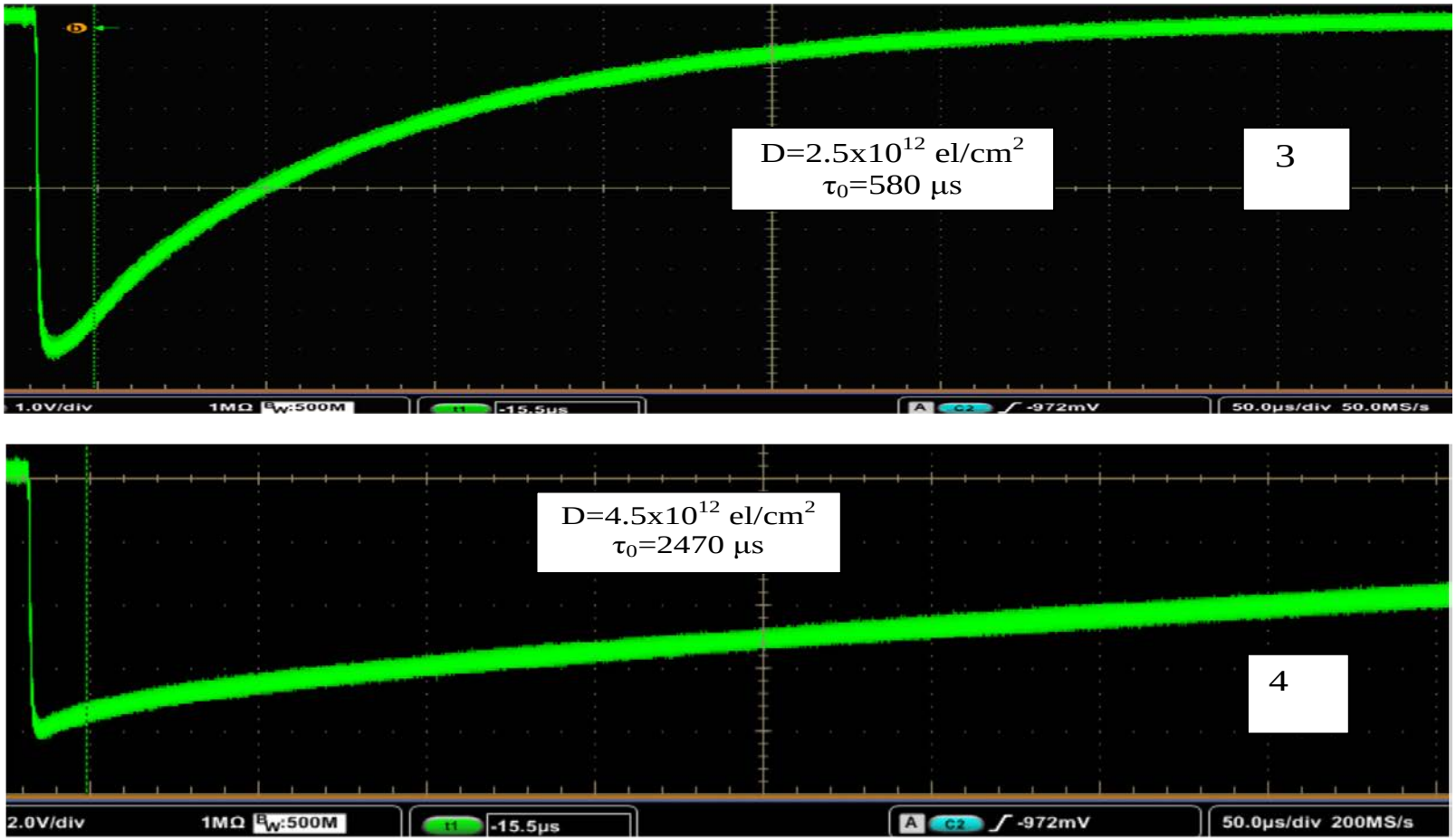

Fig.8. Behavior of silicon crystal resistance under irradiation by ultrafast electron pulses of energy 3.5 MeV.

2. Experimental results

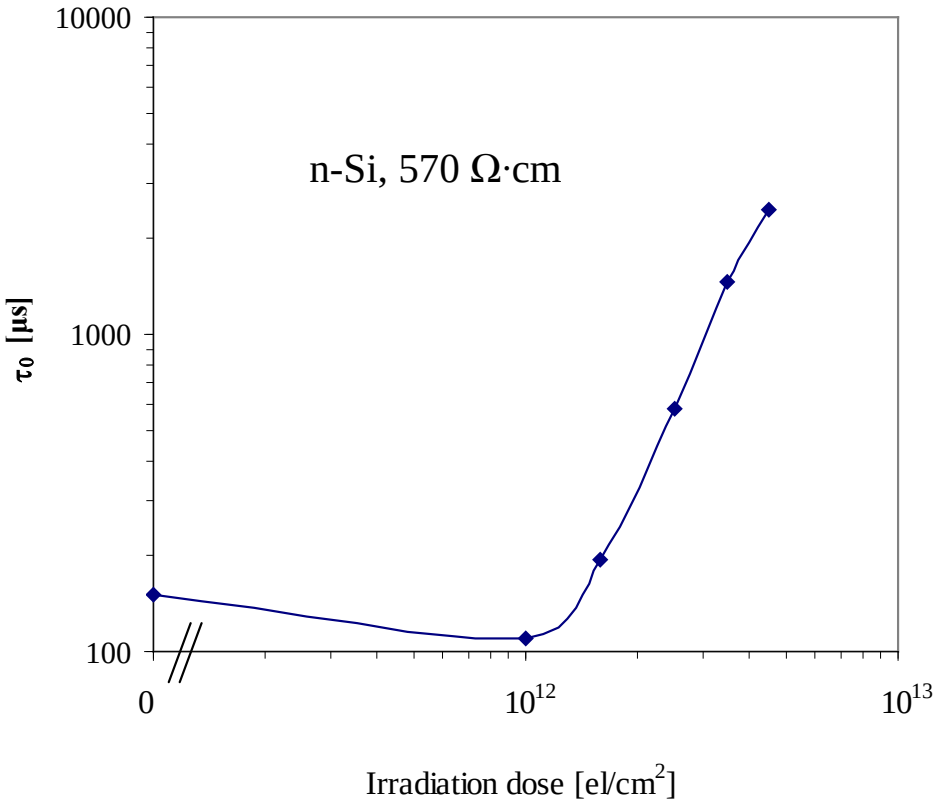

Fig.9. The recombination time constant τ_0 of nonequilibrium electrons and holes under irradiation depending on irradiation dose.

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2. Experimental results

- In radiation physics of semiconductors, an image of the recombination process of nonequilibrium carriers of electrons and holes under ultrafast electron pulses irradiation was obtained at the first time.
- It was found that the time constant of the recombination process of nonequilibrium electrons and holes, occur in the silicon crystal during exposure ultrafast electron pulses, decreases and then increases with increasing irradiation dose.

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3.Conclusion

1. It was designed an experimental setup (vacuum chamber) for the study of materials characteristics under extreme conditions at the AREAL Fasility with the following parameters:
   - Vacuum - 10^{-5} Torr. ($1{,}33 \times 10^{-3}$ Pa),
   - Electron beam with energy up to 4 MeV, pulse duration 4×10^{-13} sec,
   - Measurement temperature range from -100 ^{0}C to +100 ^{0}C,
   - Solar ultraviolet radiation.
2. Due to irradiation by electrons with ultrafast pulse duration 4×10^{-13} sec, at the first time in radiation physics was obtained image of nonequilibrium electrons and holes recombination process in materials.

Acknowledgement

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The authors are thankful for this assistance.

Thank you!