POSITRON ANNIHILATION SPECTROSCOPY IN MATERAILS STRUCTURE STUDIES

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AIM

- To study the Recovery and Recrystallization process in pure Titanium.

INTRODUCTION

METHODS OF POSITRON ANNIHILATION SPECTROSCOPY

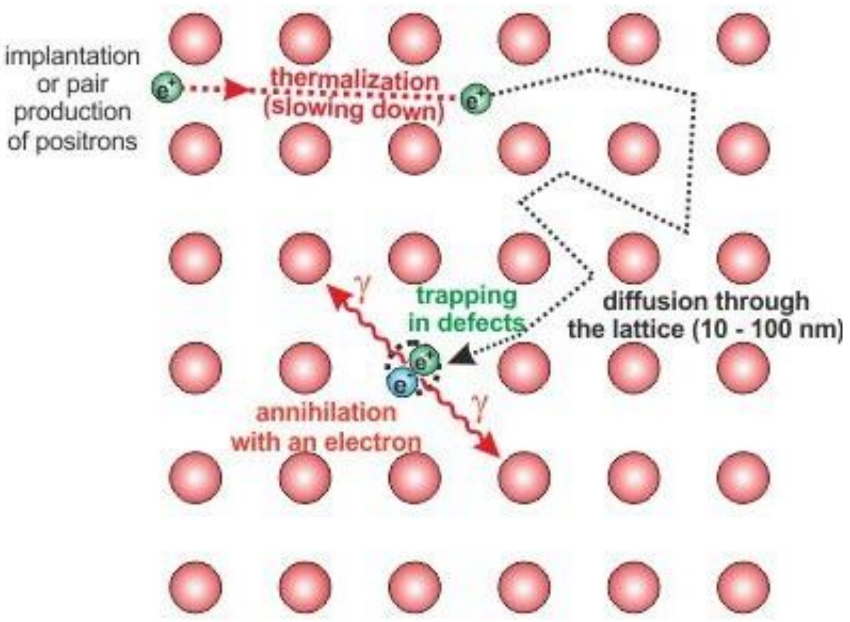
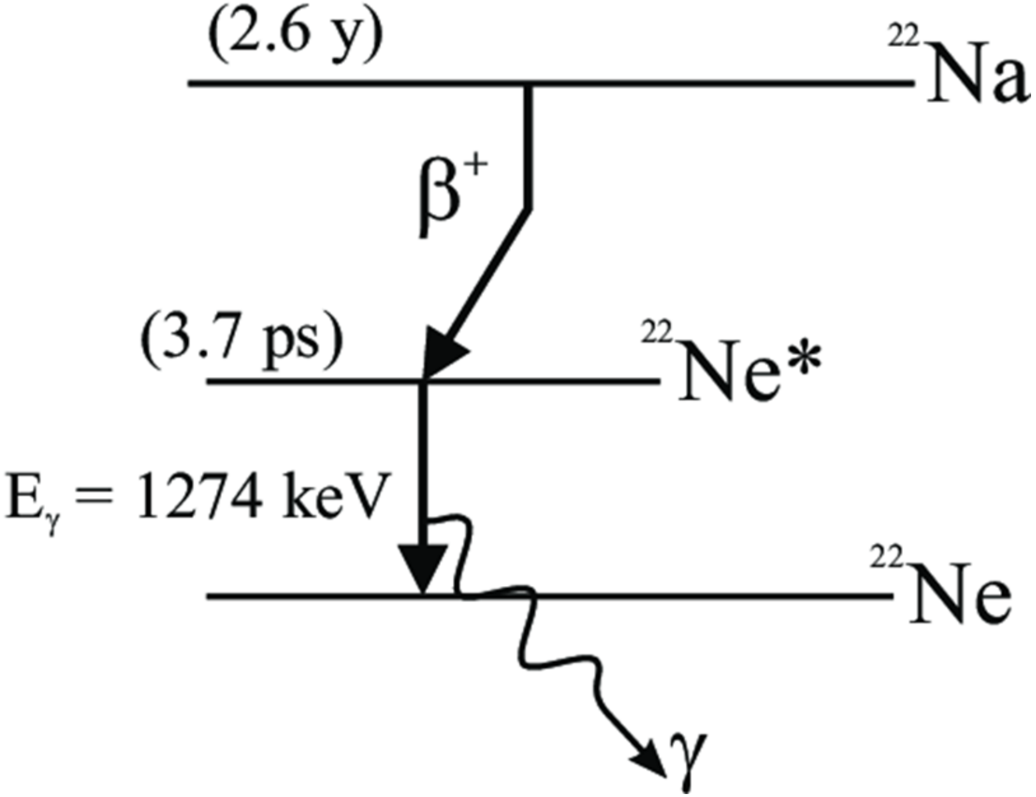


Figure 1: Methods Positron annihilation Spectroscopy

- **Positron Lifetime Spectroscopy** -measures the elapsed time between the implantation of the positron into the material and the emission of annihilation radiation.

Na-22 DECAY SCHEME



- Is emitted in the β^{+} decay of 22_{Na}
- β^{+} decay ➡ $:22_{Na}+\beta^{+}+v_{e}+\gamma\ (1.27MeV)$

Figure 2: Decay scheme of the radioactive isotope Na-22.

POSITRON LIFETIME TECHNIQUE

- **Positron annihilation lifetime spectroscopy** is a non-destructive spectroscopy technique to study voids and defects in solids.
- \- Positron lifetime is measured as time difference between 1.27 MeV quantum (β^+ decay) and 0. 115 Me V quanta.

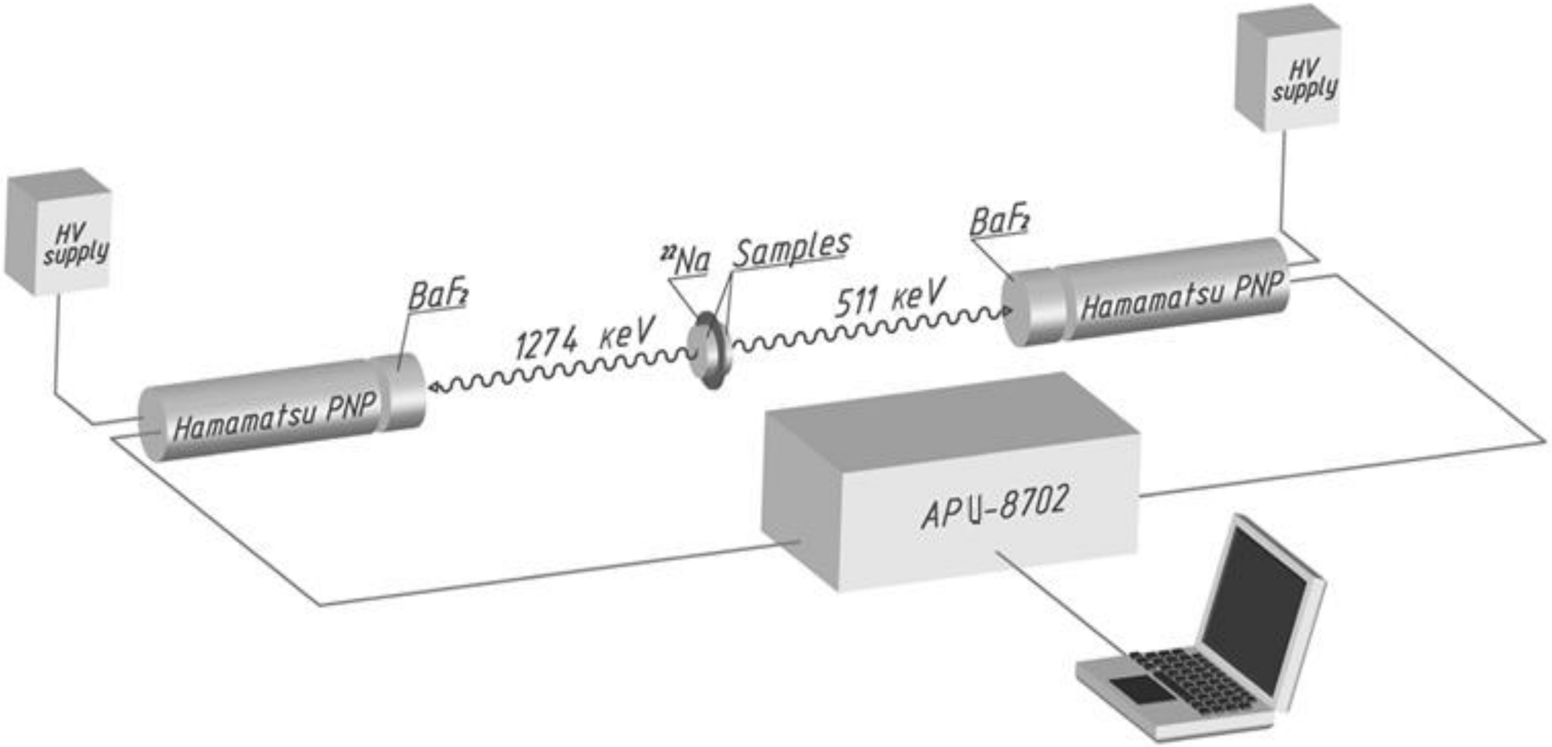


Figure 3: Positron annihilation lifetime Spectroscopy.

DOPPLER BROADENING SPECTROSCOPY

- The electron momentum in propagation direction of 511 KeV γ-rays leads to doppler broadening of annihilation line.
- This can be detected by Ge detector and standard electronics.

$$E_g = mc^2 + E_B \pm \frac{P_L C}{2}$$

E_B- binding energy of electron-positron pair

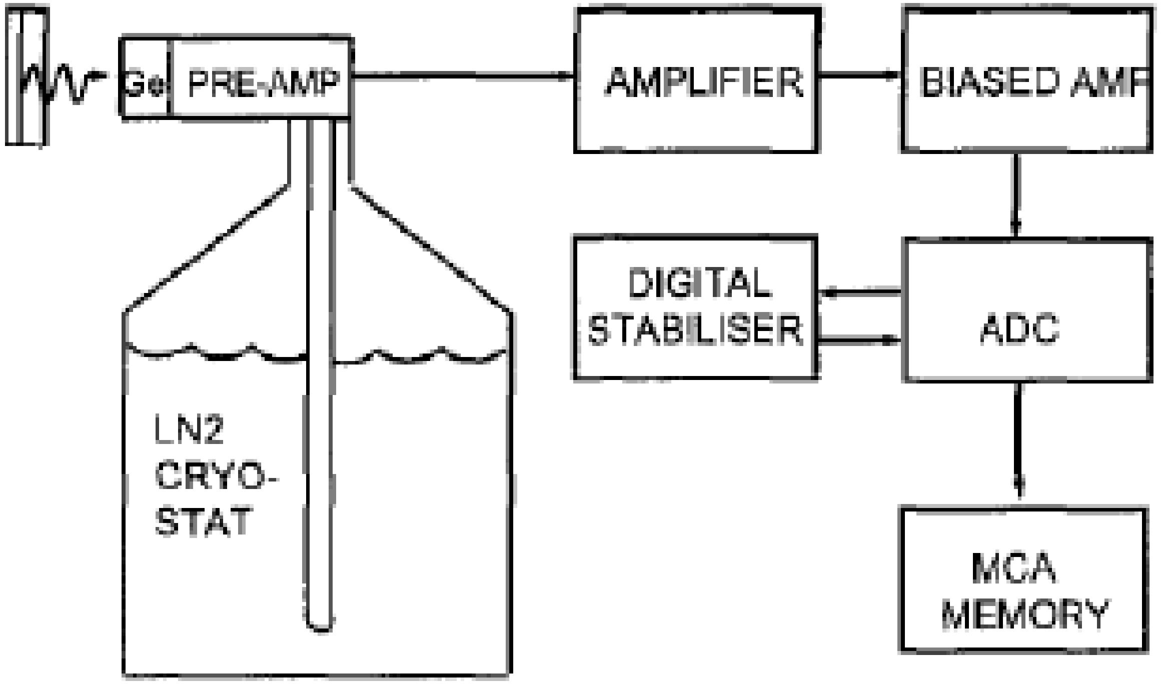


Figure 4: Doppler broadening Spectroscopy Setup.

METHODOLOGY

SAMPLES PREPARATION

- Titanium samples were polished with waterproof abrasive paper.
- The samples were cleaned with pure Acetone to remove dust and any surface contamination.
- All samples were annealed 850 C to remove defects.

PRESSING PROCEDURE

- The samples were pressed under a static pressure from 4.5 to 11.5 MPa for 1 minute at room temperature.
- The thickness of the samples were measured using Micrometer screw.

Figure 5: Hydraulic press

Figure 6: Micrometer Screw

ANNEALING

- The annealing treatments were carried out in a vacuum 10^{-4} Pa with temperature being controlled.
- The series of samples were heated at the temperature range from 100-850°C for 1 hour.

Molecular pump

Furnace

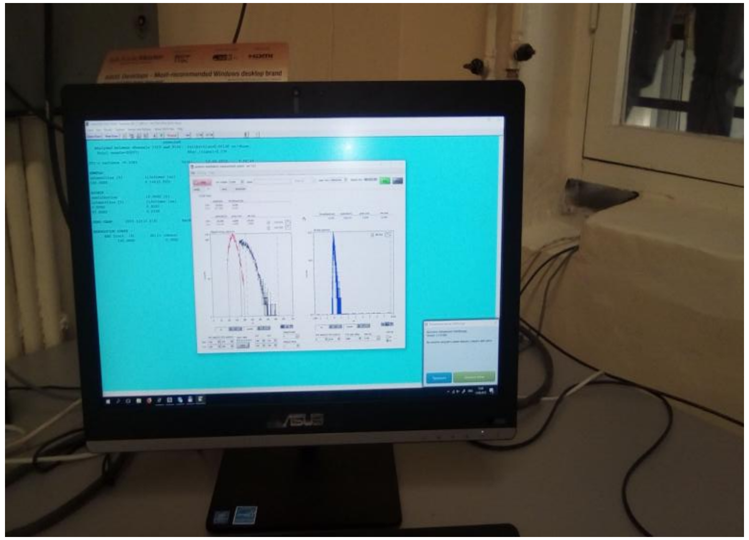
Figure 7: Vacuum system.

POSITRON LIFETIME SPECTROSCOPY MEASUREMENTS

- The 22_{Na} were placed between the identical Titanium samples and attached to two photomultiplier and computer display.
- The samples were analysed for 3 hours.

ADC

Titanium samples attached to two photomultipliers.



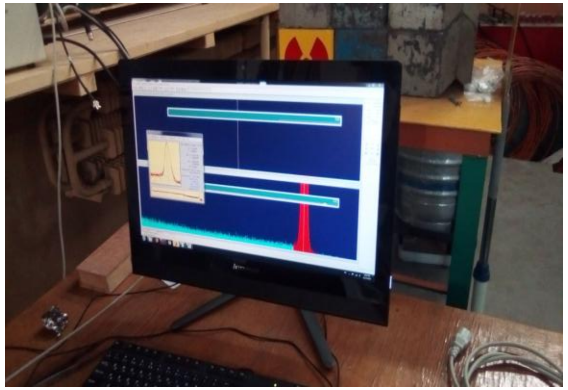
Computer display

Figure 8: Positron Lifetime Spectroscopy setup.

DOPPLER BROADENING SPECTROSCOPY MEASUREMENTS

- The samples were placed near the high-purity(HP)-Ge detector and standard electronics with energy resolution of about 1.2 KeV at 511 KeV.
- The samples were analysed for 2 hours in the detector system.

Liquid Nitrogen



Computer display

Power system

Titanium Sample(DBS-Stage)

Figure 9: Positron Doppler Broadening Spectroscopy Equipment.

S- AND W- PARAMETERS CALCULATIONS

$$E_g = mc^2 + E_B \pm \frac{P_L C}{2}$$

- E_B- binding energy of electron-positron pair

S-Parameter

- Relation of area under central part of annihilation line A_S to total area below this line *A*.

$$S = \frac{A_S}{A_0}$$

W-Parameter

- Sum of the area under wings of the spectrum.

$$W = \frac{A_w}{A_0}$$

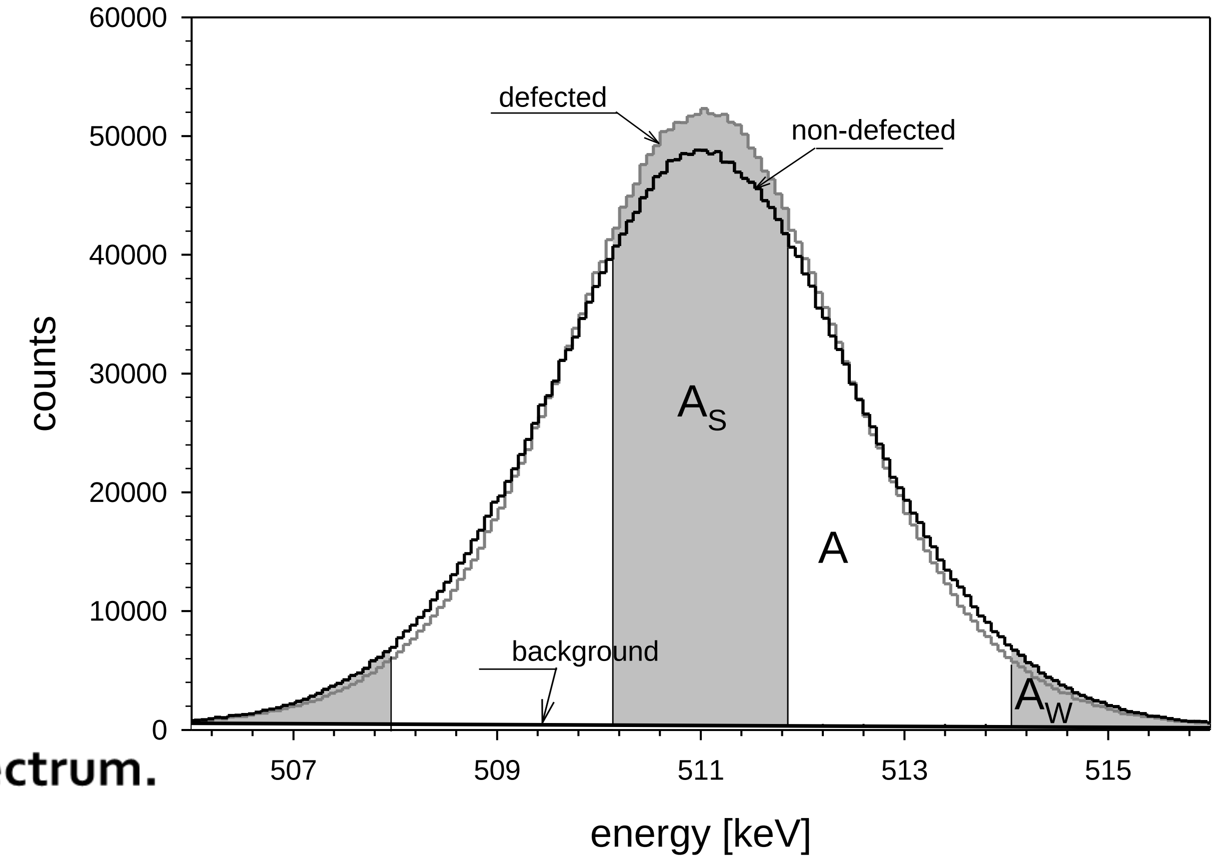


Figure 10: Comparison of annihilation for defected and non-defected samples. The rule of calculation of S-and W-parameters

THICKNESS REDUCTION

- The pressing procedure increases number defects on the sample.
- The S-parameter increases with the thickness reduction of the sample.

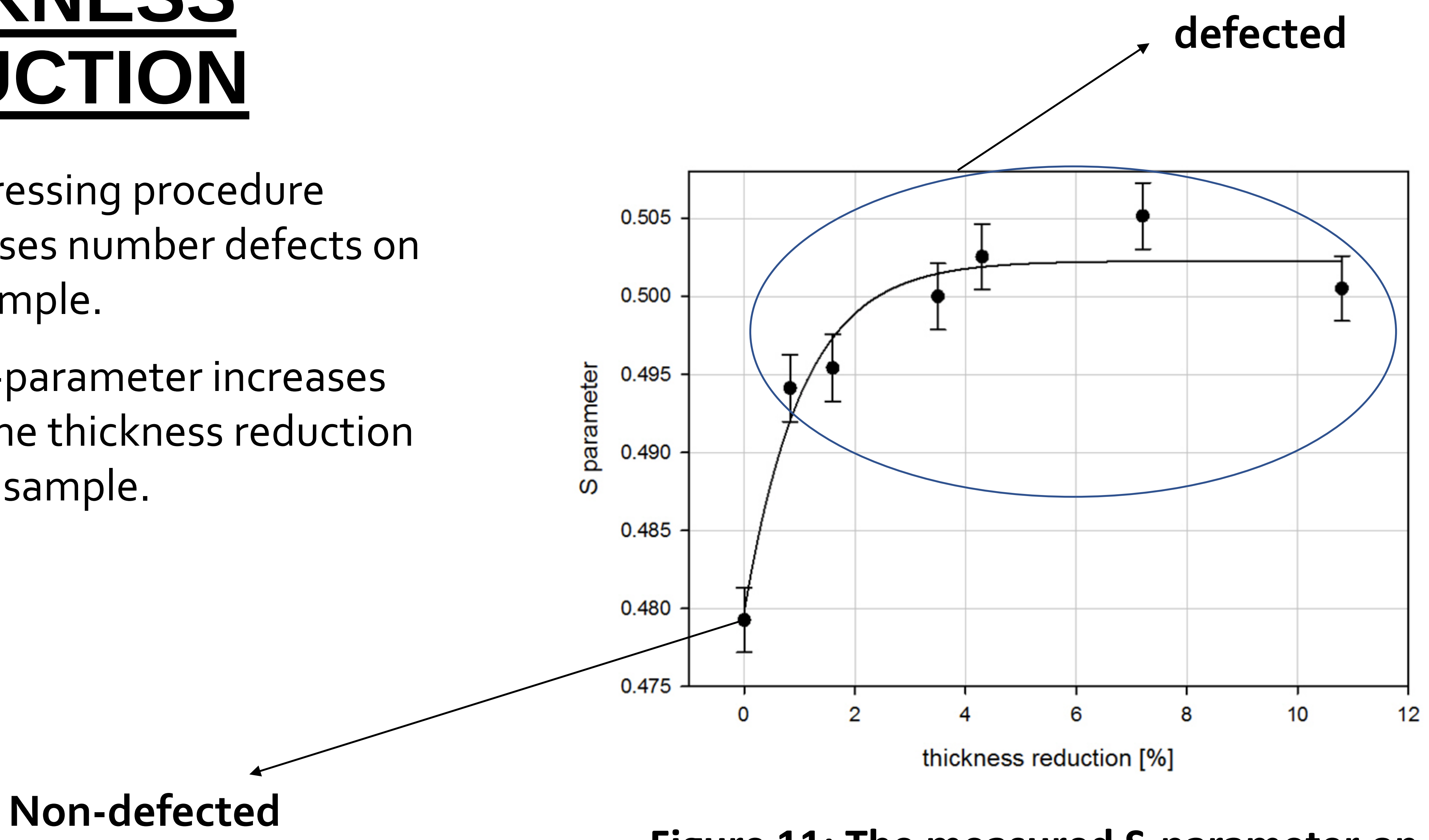


Figure 11: The measured S-parameter on the thickness reduction of the Ti sample.

RESULTS AND DISCUSSIONS

RECOVERY AND RECRYSTALIZATION

- Are changes in microstructures of an atom during annealing temperature.

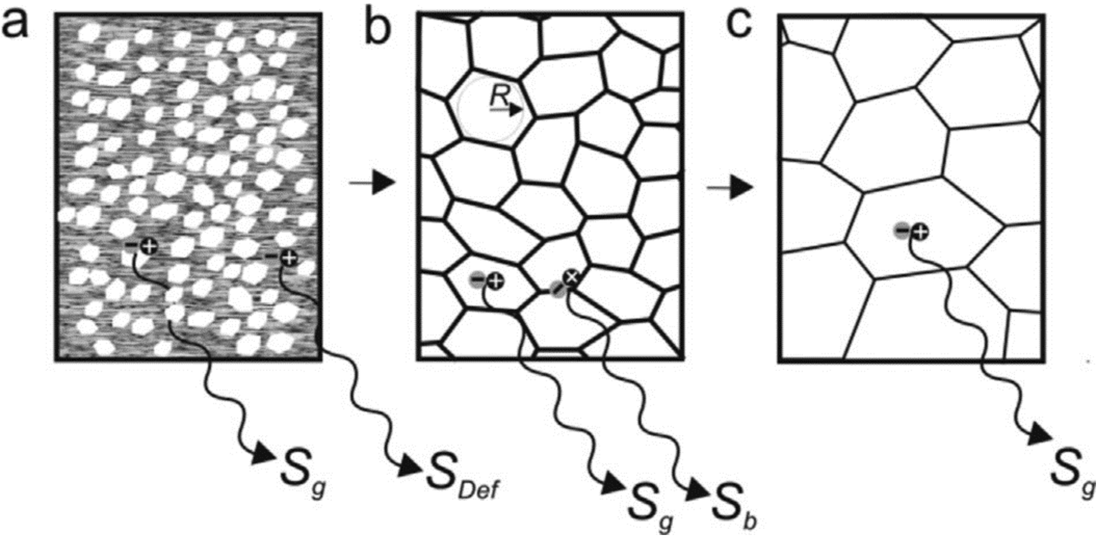


Figure 12: Schematic diagram of the main processes in the deformed sample exposed to annealing.

- $S = S_g + (S_b - S_g)\frac{L_+}{R}\left[coth\left(\frac{R}{L_+}\right)\right] - \frac{L_+}{R},$
- $\tau = \tau_g + (\tau_b - \tau_g)\frac{L_+}{R}\left[coth\left(\frac{R}{L_+}\right)\right] - \frac{L_+}{R},$
  - Where S_b and S_g- S-parameter.
- $R^m = R_0^m + t\exp\left(-\frac{Q_m}{kT}\right),$
  - Where R_0 – initial grain radius;
  - R – mean radius;
  - m – grain growth exponent;
  - t – time.

J.Dryzek, M. Wrobel,and E.Dryzek. Phys.Status solidi,1-12 (2016).

Doppler broadening and positron lifetime Spectroscopy

- The **S-Parameter** and **Positron lifetime** decreases with an increasing temperature.
- Type of Defects: **Vacancies on dislocations lines**

$$Q_m - Activation\ energy\ of\ boundary\ migration$$

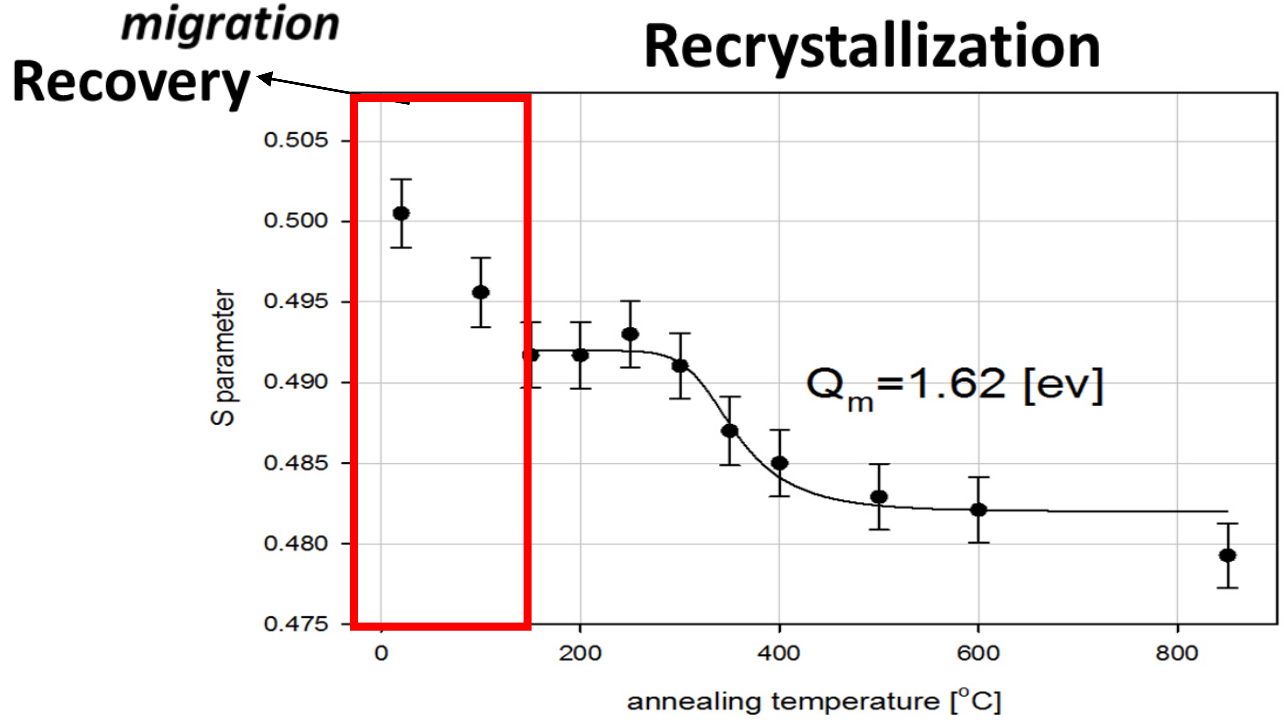


Figure 13: The S-parameter dependency on the annealing temperature of deformed Ti.

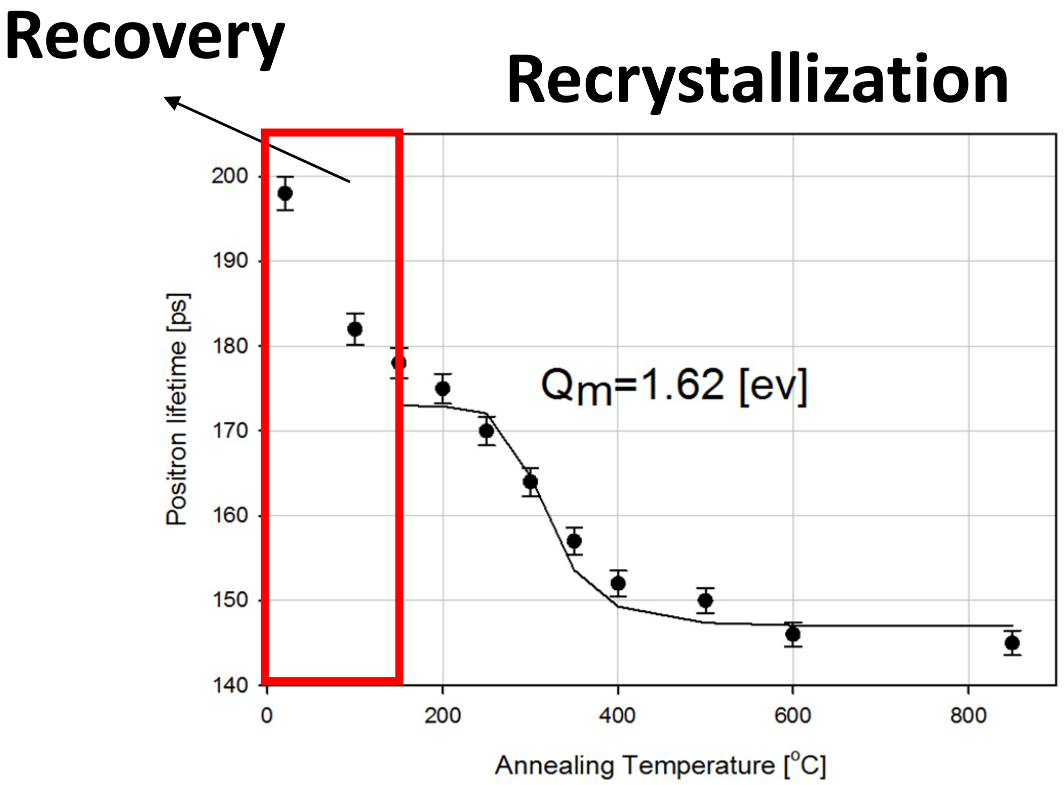


Figure 14: Positron lifetime dependency on annealing temperature.

CONCLUSION

The aim was to study the **Recovery** and **Recrystallization** on **pure Titanium**. According to obtained results of the positron lifetime, it tells that the type of defects formed are **Vacancies on the dislocation line.** From the dependencies of the positron lifetime and the S-parameter, activation energy of boundary migration $\boldsymbol{Q_m}$ was determined and equal to **1.62 eV**.

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Thank you!