Improved depth resolution of slow positron method - detailed determination of defect profiles

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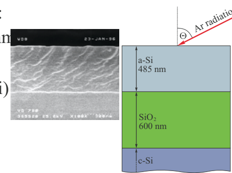
Motivation

- Limited depth resolution of Variable Energy Positron Annihilation Spectroscopy (VEPAS):
  - broadening of the positron implantation profile at high energies
  - positron diffusion
- Solution [1]:
  - removal of the surface
  - determination of annihilation characteristics at low energies
- Chemical etching [2-5]:
  - uncomfortable handling and bad control of the removal depth
  - suitable mainly for deep defect structures
- New idea: etching on a nm-scale → **ion sputtering**

Sample

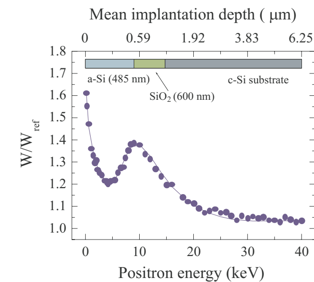
- Epitaxial deposited layer structure:
  - amorphous Si (a-Si) on top (485 nm)
  - SiO_2 (600 nm)
  - crystalline (100)-Si substrate (c-Si)



Sputter conditions

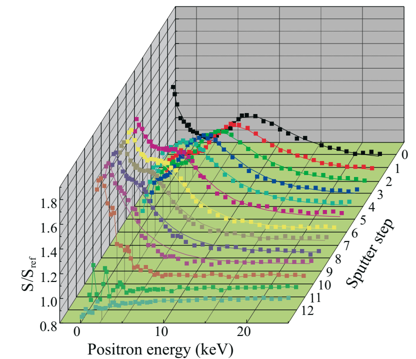
- Conventional Ion etching via low-energy ion bombardment of the surface of the sample
- Comercial sputter gun
- Conditions:
  - ion species: Ar^+
  - partial pressure: 1×10^{-6} Torr
  - ion energy: 2.5 keV
  - ion current: 30 - 50 μA
  - radiation angle Θ: 60°
  - sputter time per step: 20 min

Conventional VEPAS



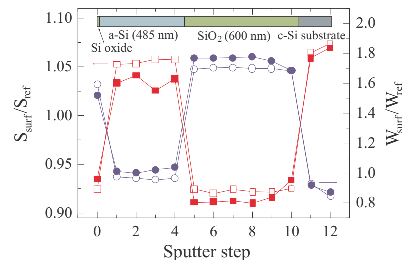
- Comparison of the $W(E)$ scan with the layer structure of the sample (obtained from SEM)
- Line: fit by VEPFIT [6] using known parameters of the structure, e.g. thickness of the layers, positron diffusion length and S parameter of the c-Si

Stepwise removal of the surface



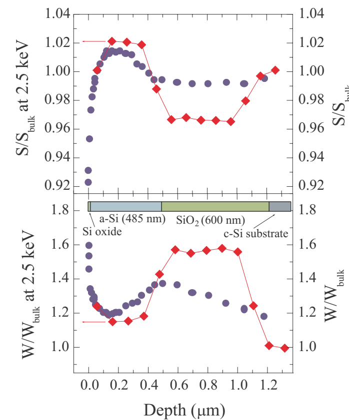
- $W(E)$ scans as a function of the sputter steps carried out
- Removal of the surface is visible by the leftward shift of the decrease of the initial curve at high positron energies

Surface parameters - Determination of the etching rate



- Surface-related S and W parameters after each sputter step as a function of the number of sputter steps
- Two runs at identical sample material ensure reproducibility
- Comparison with the known layer thicknesses allows the determination of the etching rate to be (3.5 ± 0.5) nm/min

Comparison



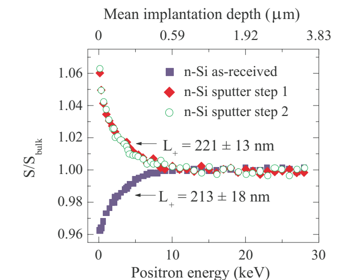
- Comparison with results from conventional VEPAS

→ strongly improved depth resolution of the new technique

Sputter defects

- Controlled formation of vacancies during sputtering at Si:P (in-diffusing vacancies would cause E centers which are stable at room temperature)
- Ion etching changes surface S parameter by removal of the natural oxide layer
- Positron diffusion length indicates defect-free Si [7] before and after the ion etching

→ Sputter defects will not obscure defect profiles



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