VACANCY-IMPURITY INTERACTIONS IN ION-IMPLANTED SILICON

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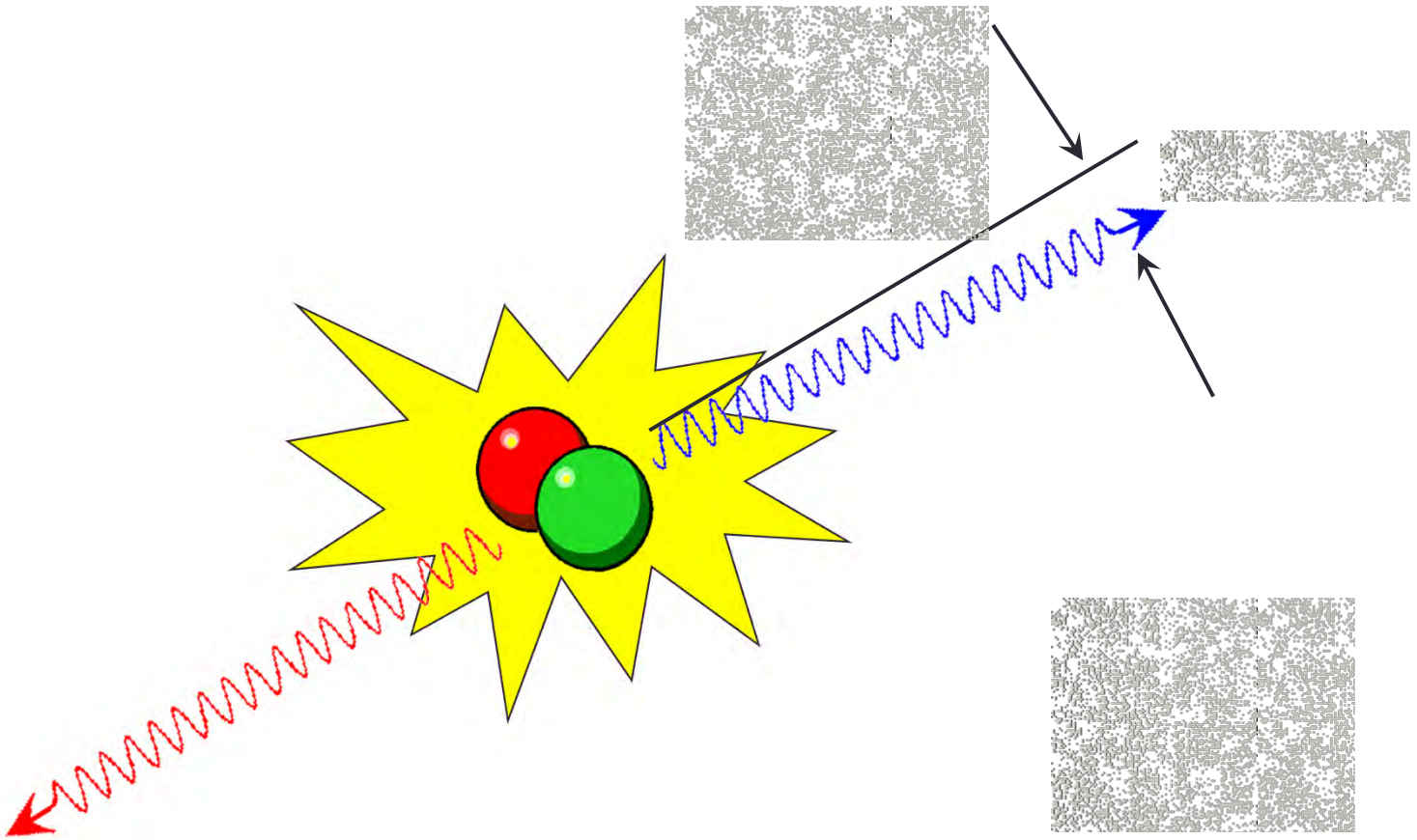
Outline

- Ion induced defects
- Positron annihilation
- Chemical “fingerprints”
- Migration energies

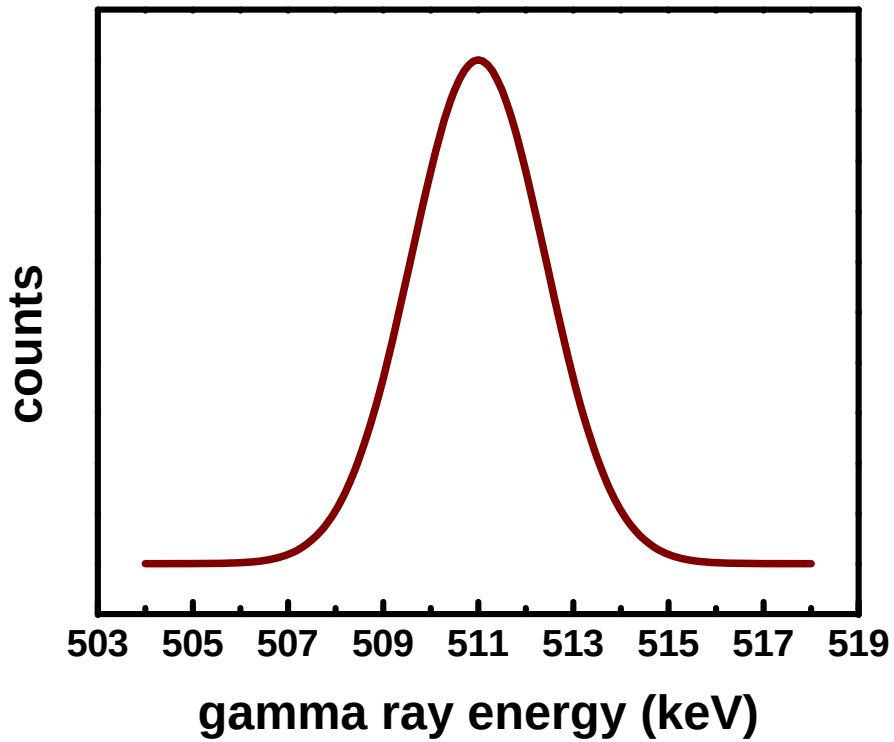
Vacancy production

- silicon implantation into silicon at 500keV generates ~2900 vacancy-interstitial pairs per ion (SRIM)
- silicon monovacancies are mobile at room temperature
- vacancies pair with each other or with impurities (dopants, oxygen)
- ~at room temperature, ~90% of the vacancies produced recombine with interstitials

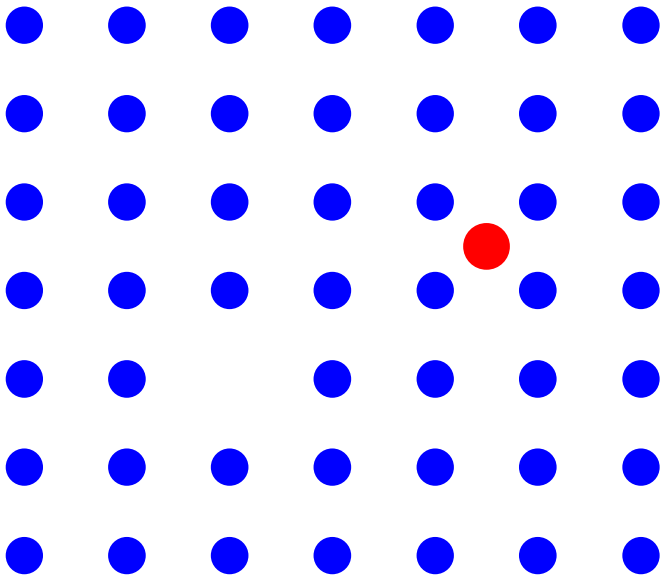
Positron Annihilation



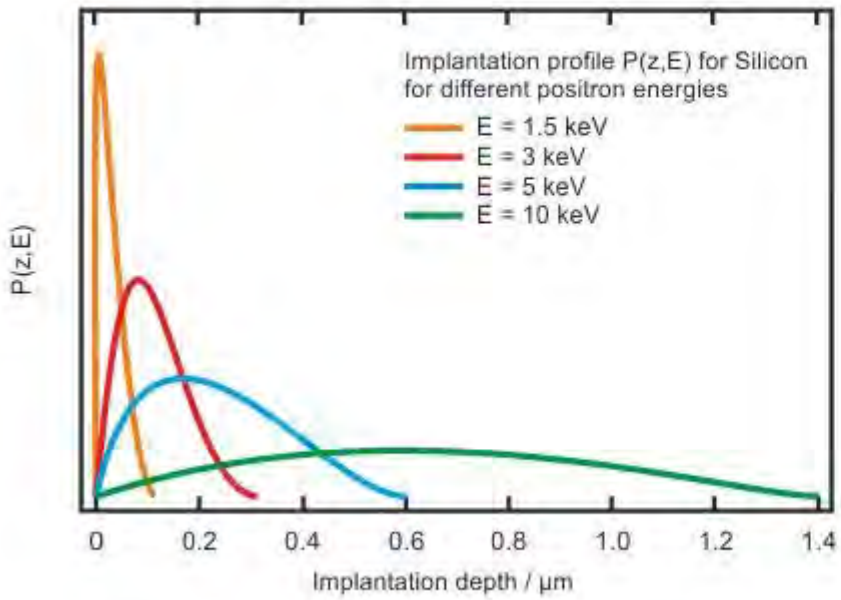
Gamma ray spectrum



Positrons are trapped by defects



“S”harpness parameter



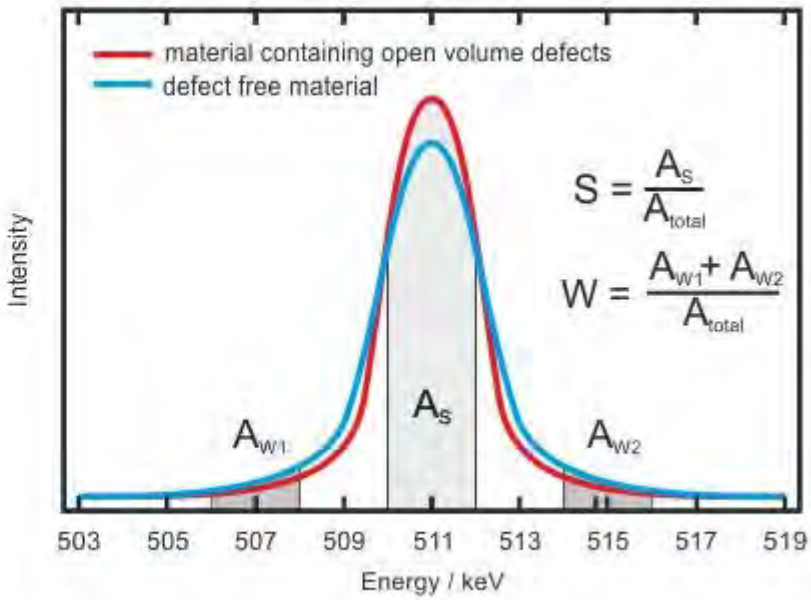
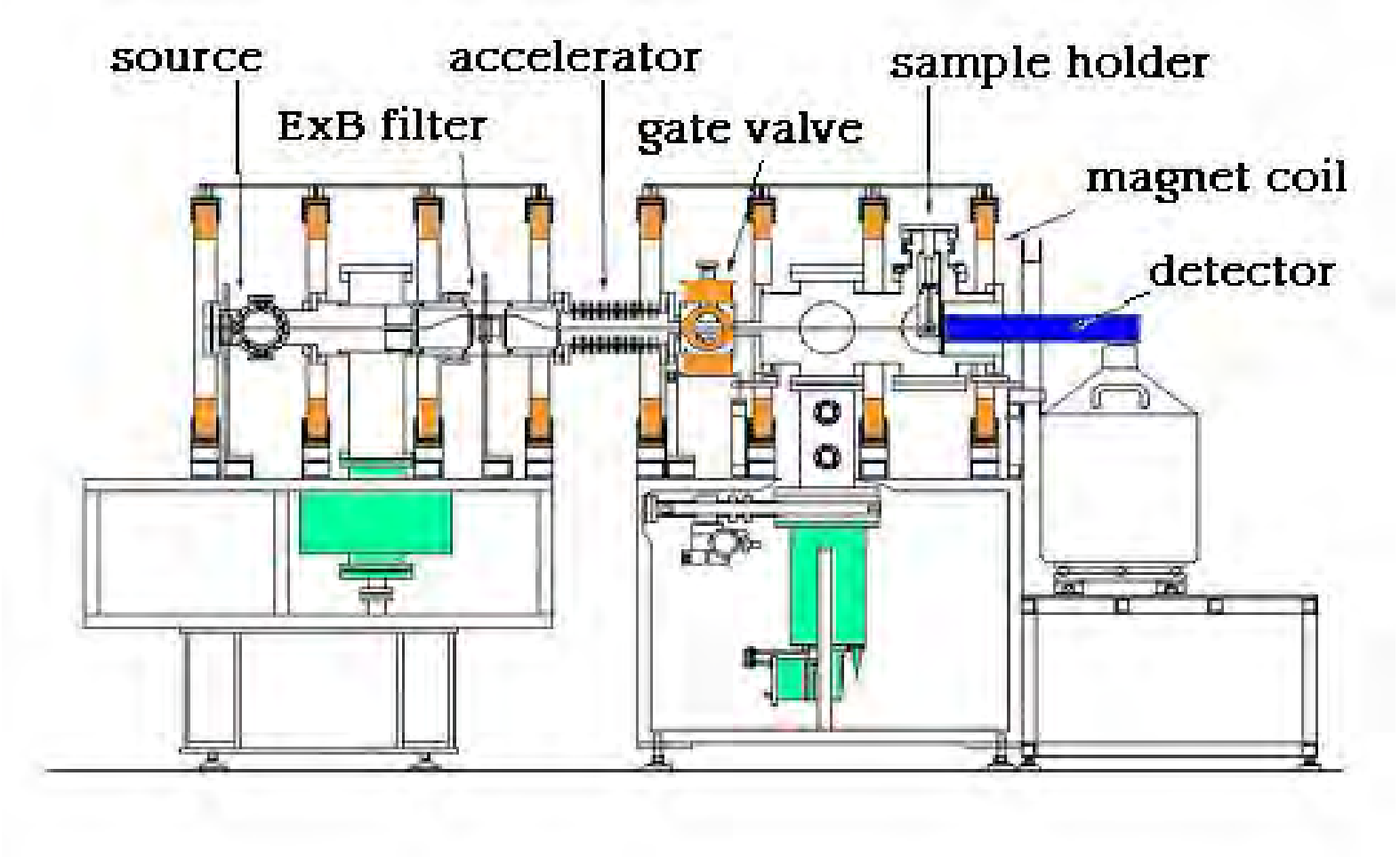
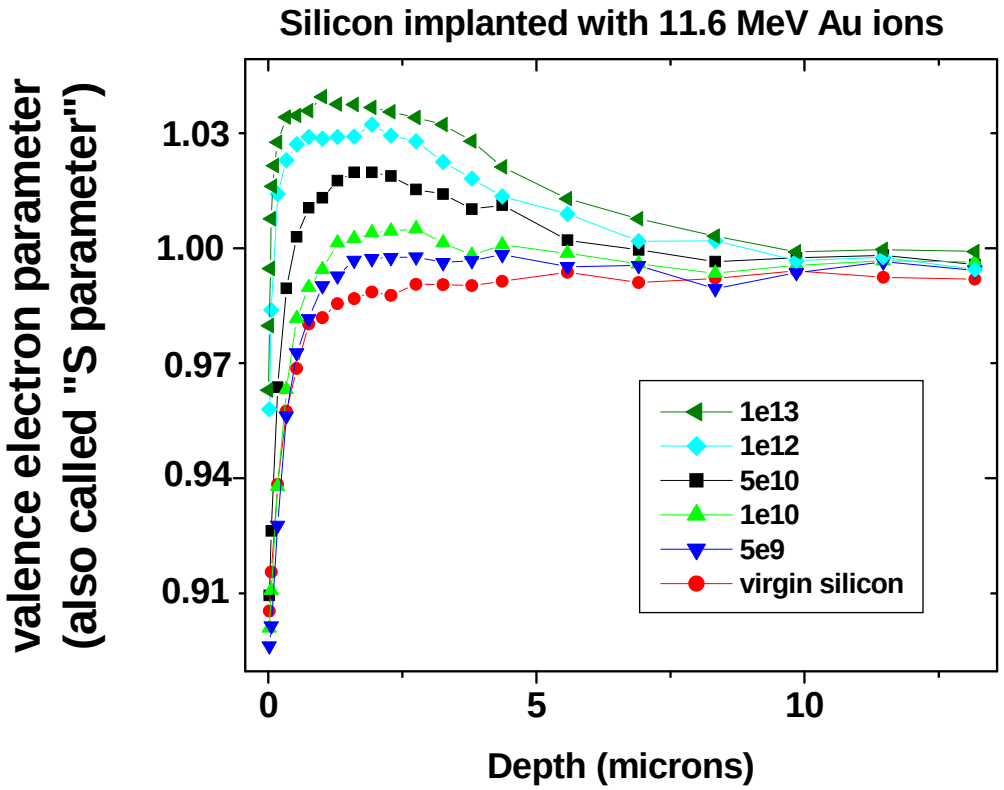


Figure by Maik Butterling

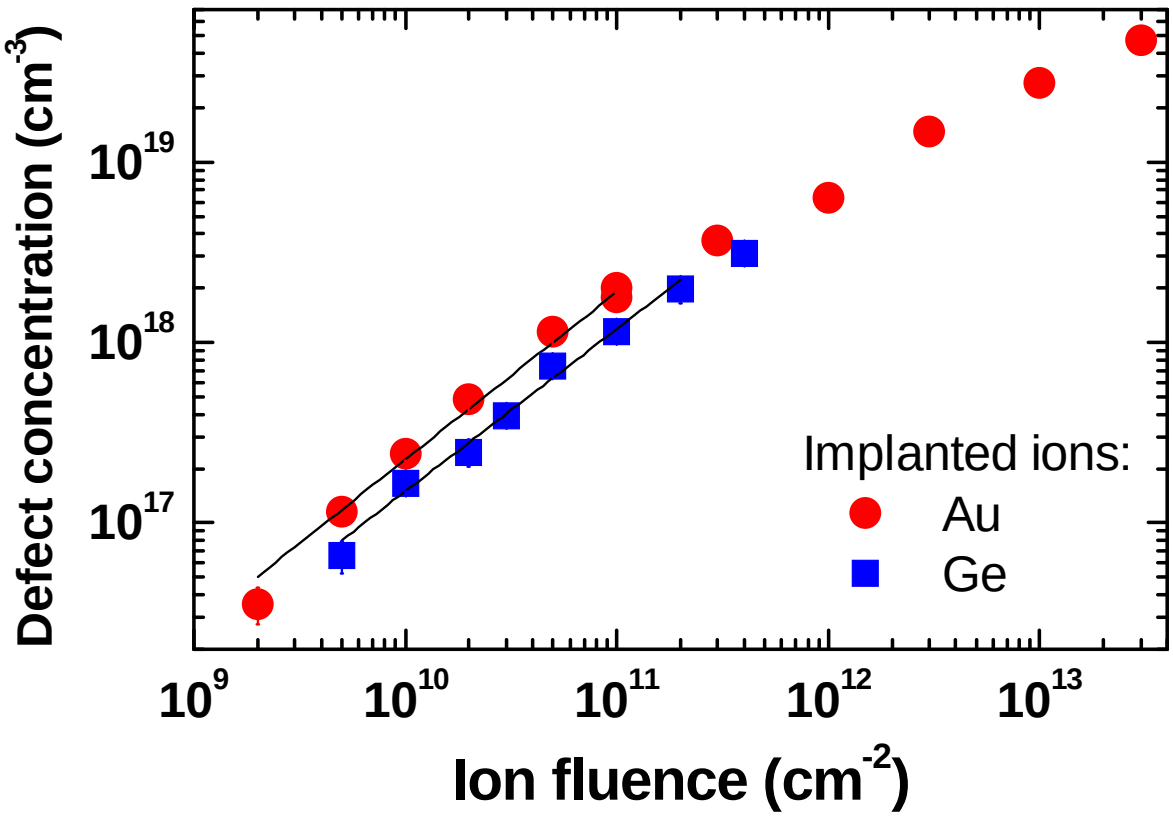
Positron accelerator



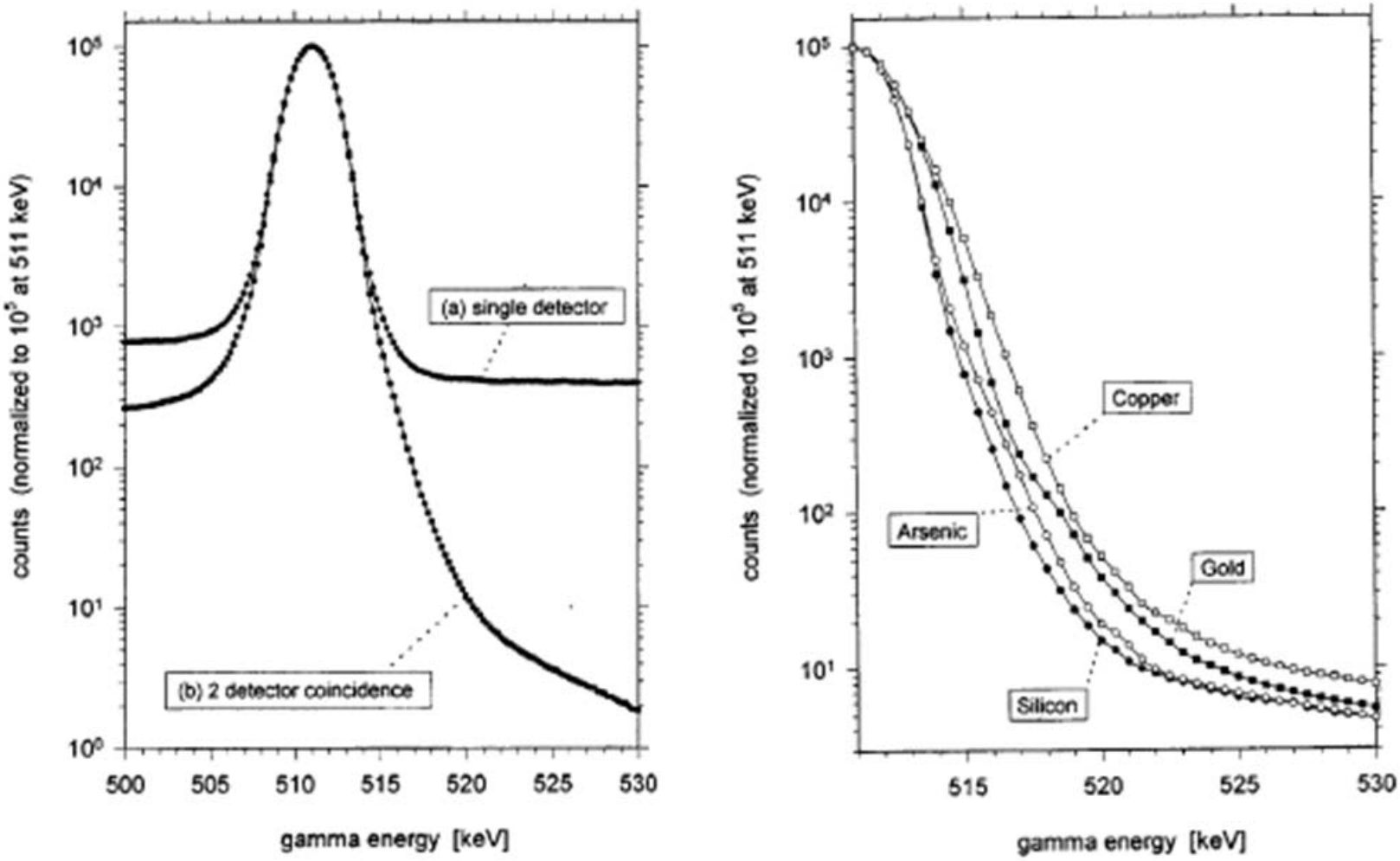
Example: ion-implanted silicon



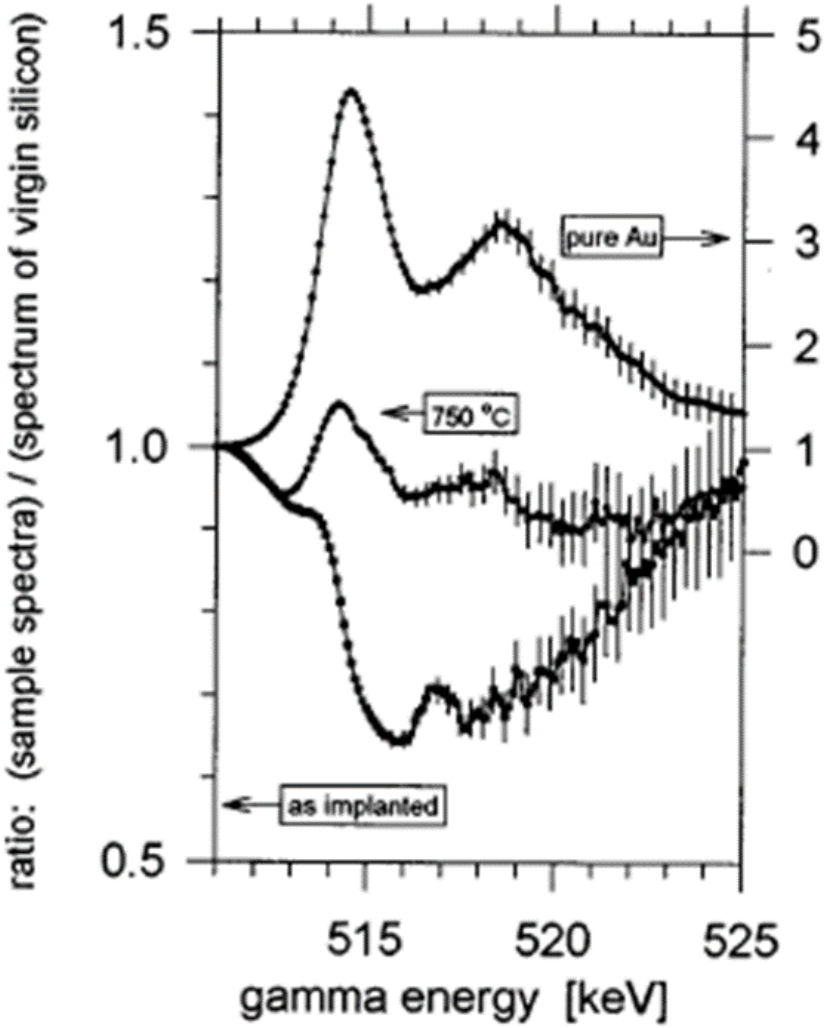
Measuring vacancy concentrations



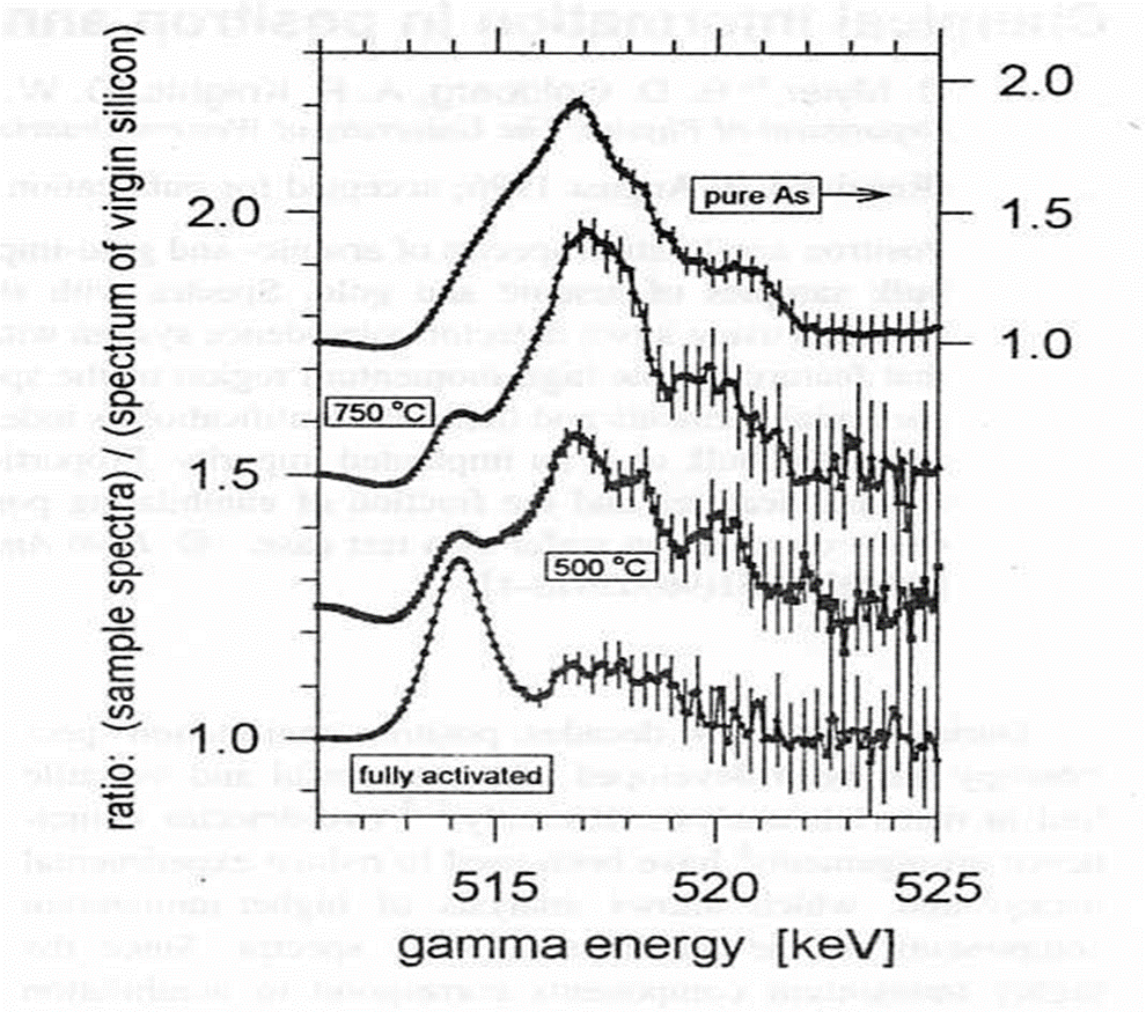
A closer look at annihilation spectra…



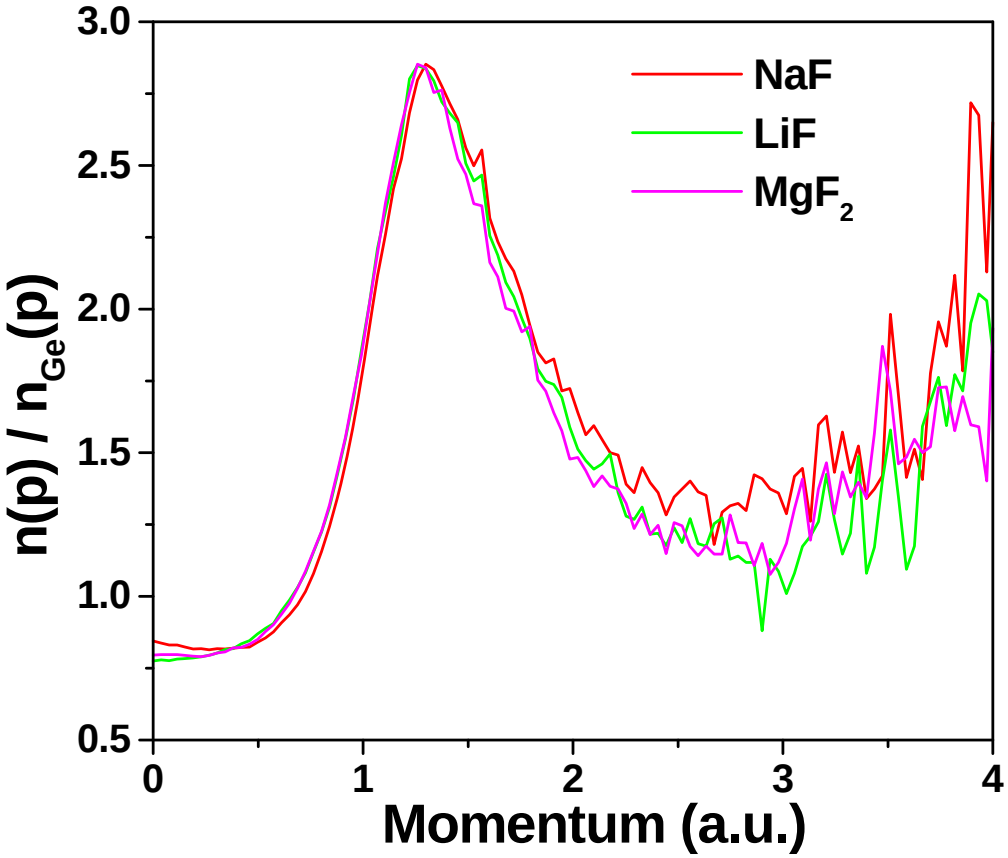
Chemical “fingerprints”



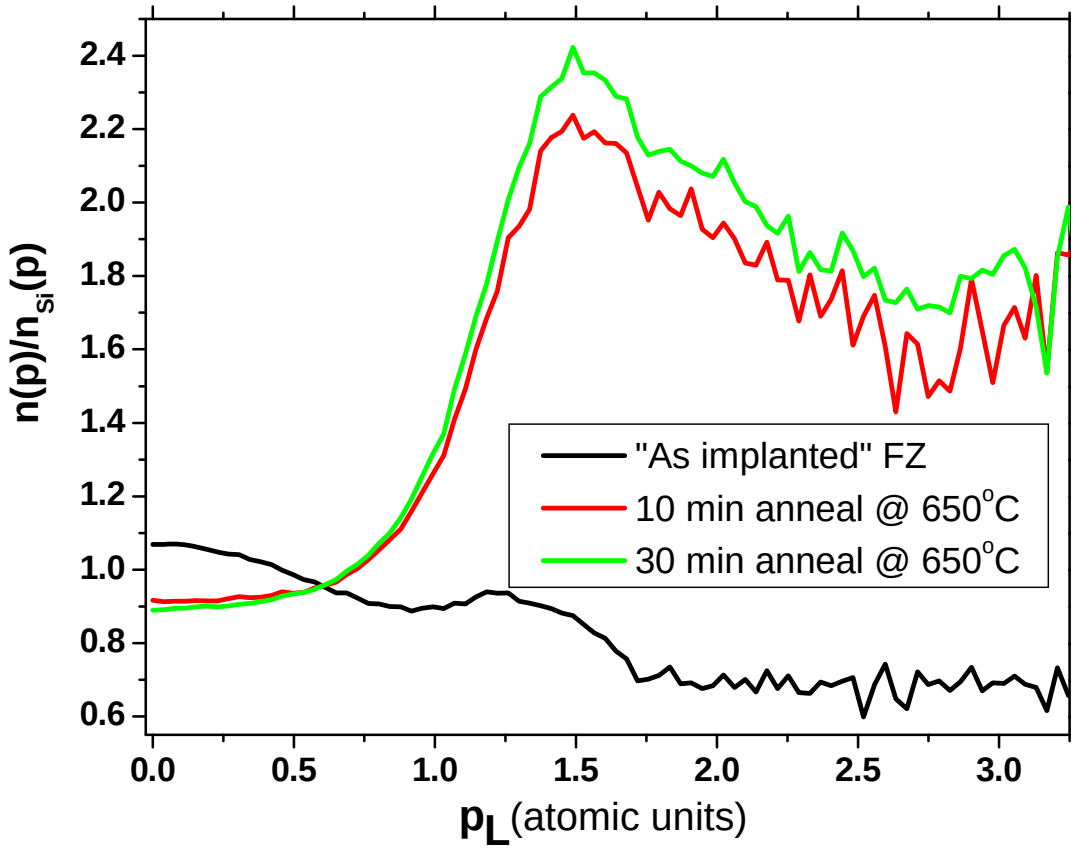
Arsenic in silicon



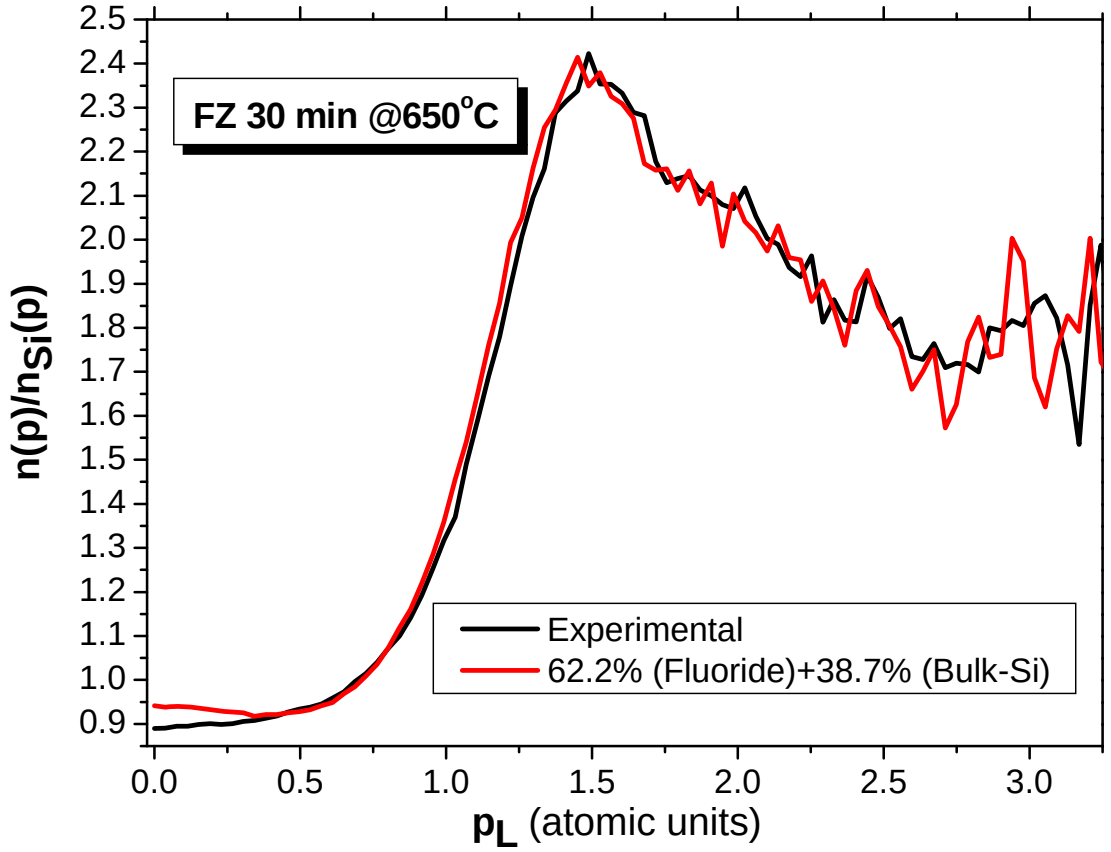
Various fluorides



F-doped silicon

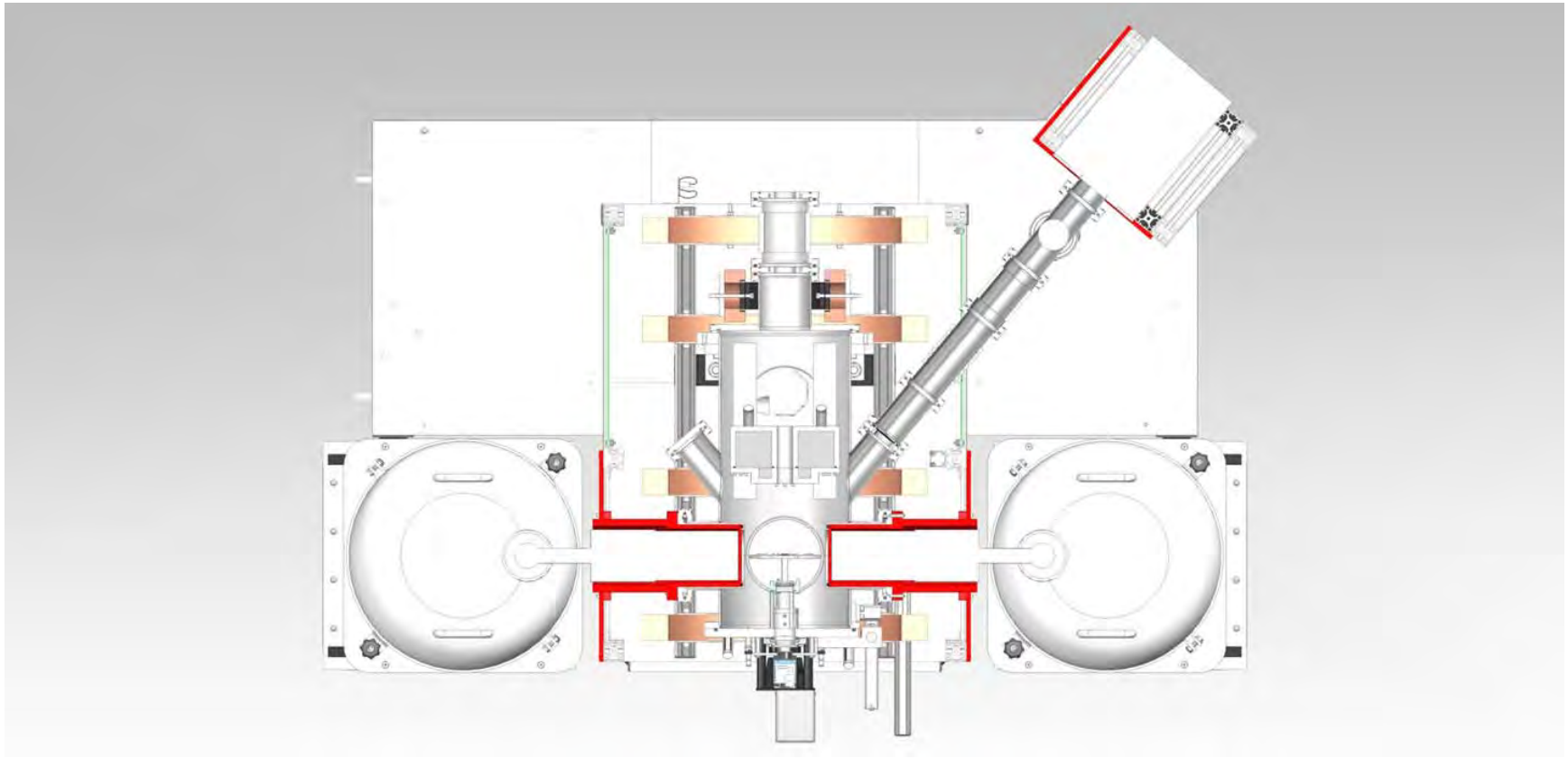


“Reconstruction”

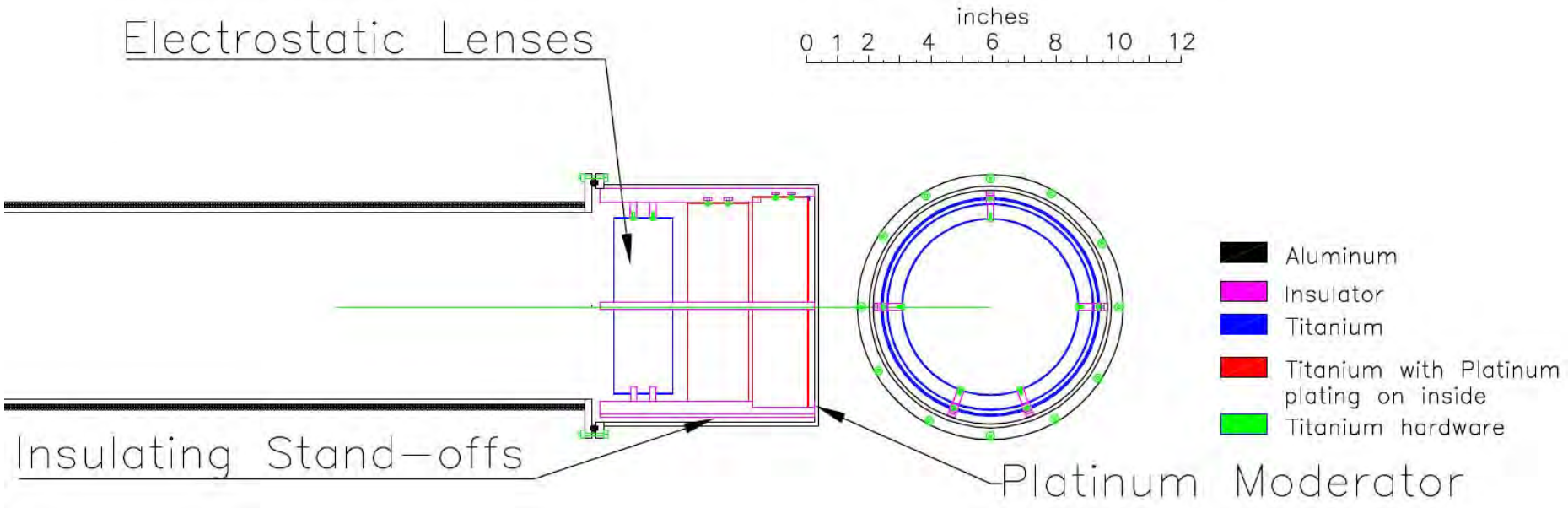


New apparatus

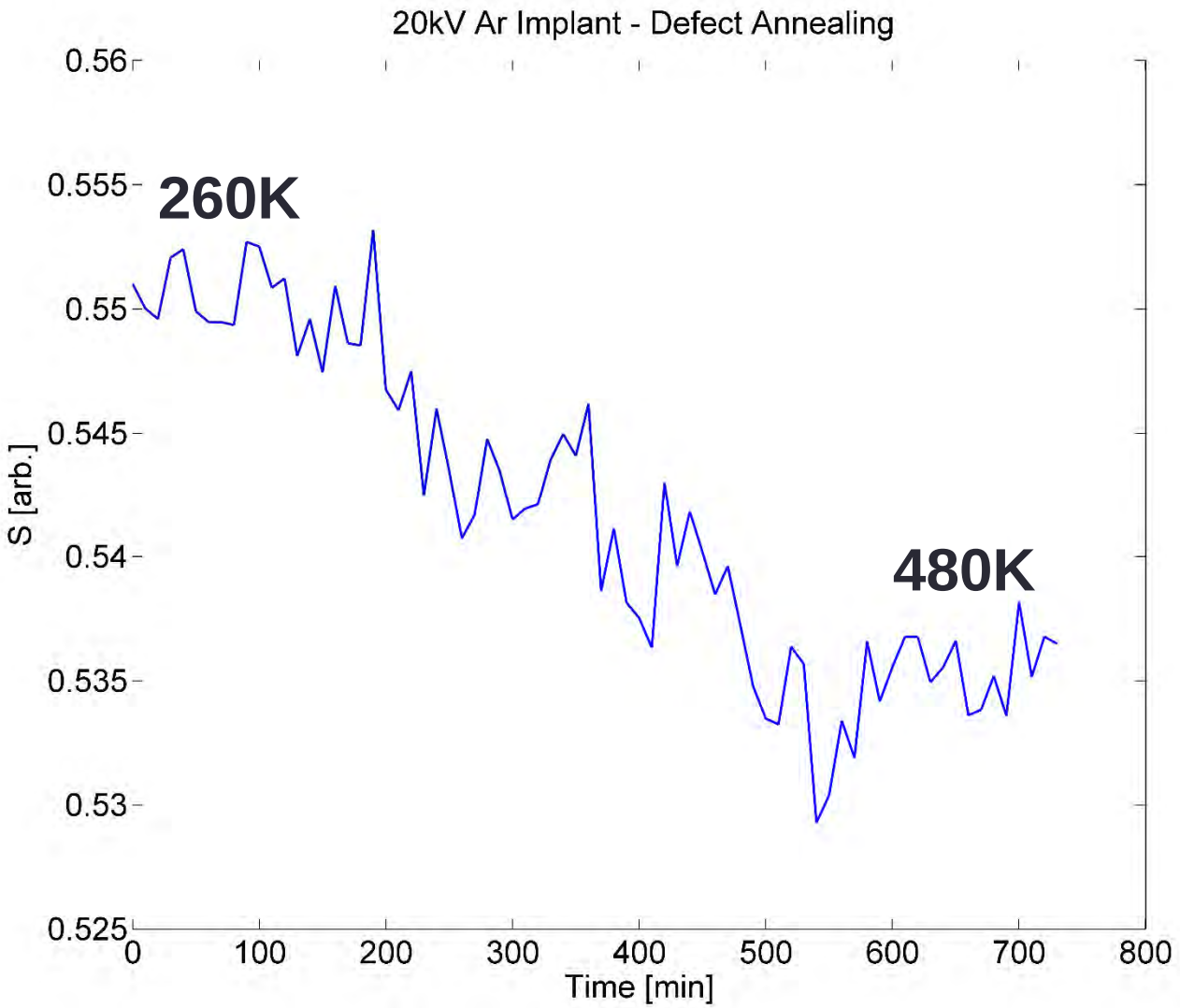
In situ ion implantation/positron spectroscopy



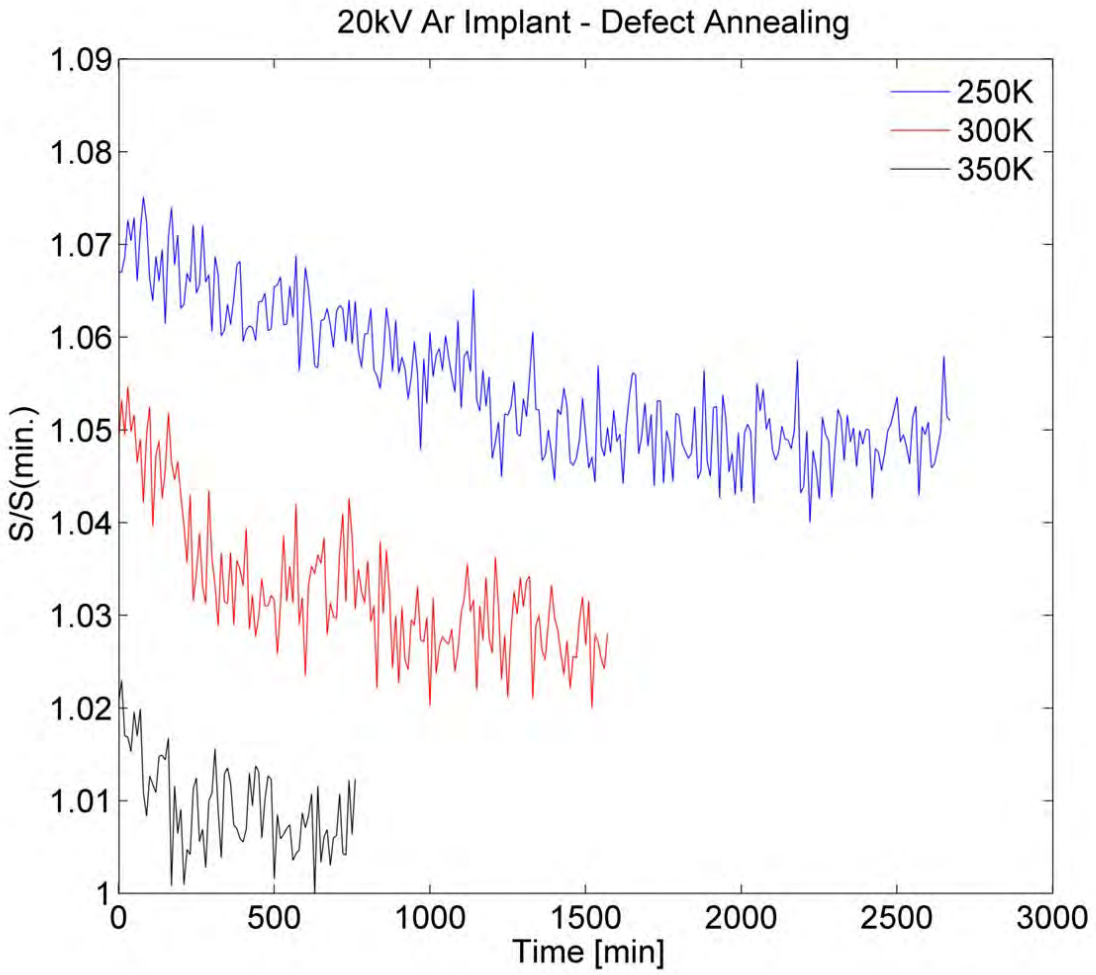
Positron Source and Moderator (Ti/Pt)



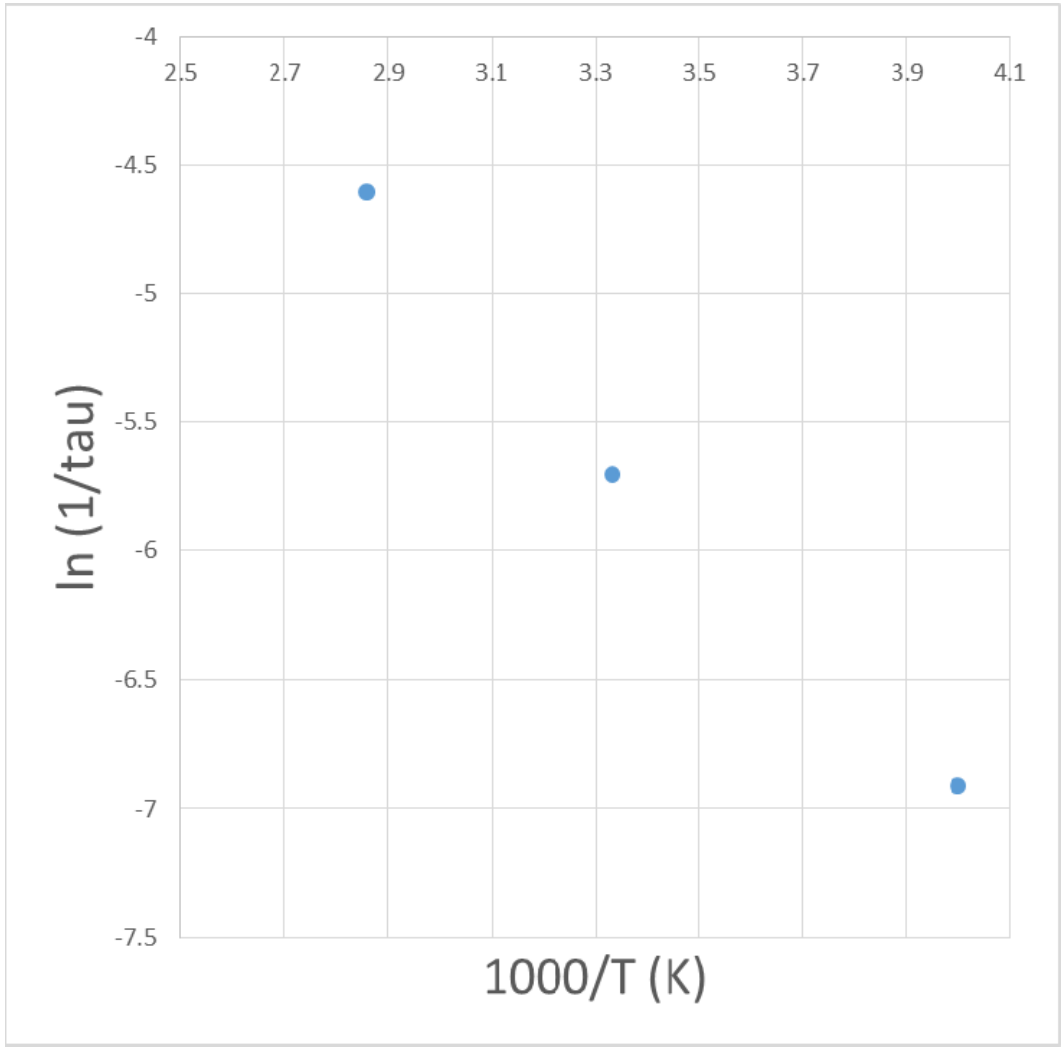
Ramp annealing of 10keV argon implant 1-5 ohm-cm boron-doped silicon



Isothermal annealing



Arrhenius plot



Ea ~0.2eV

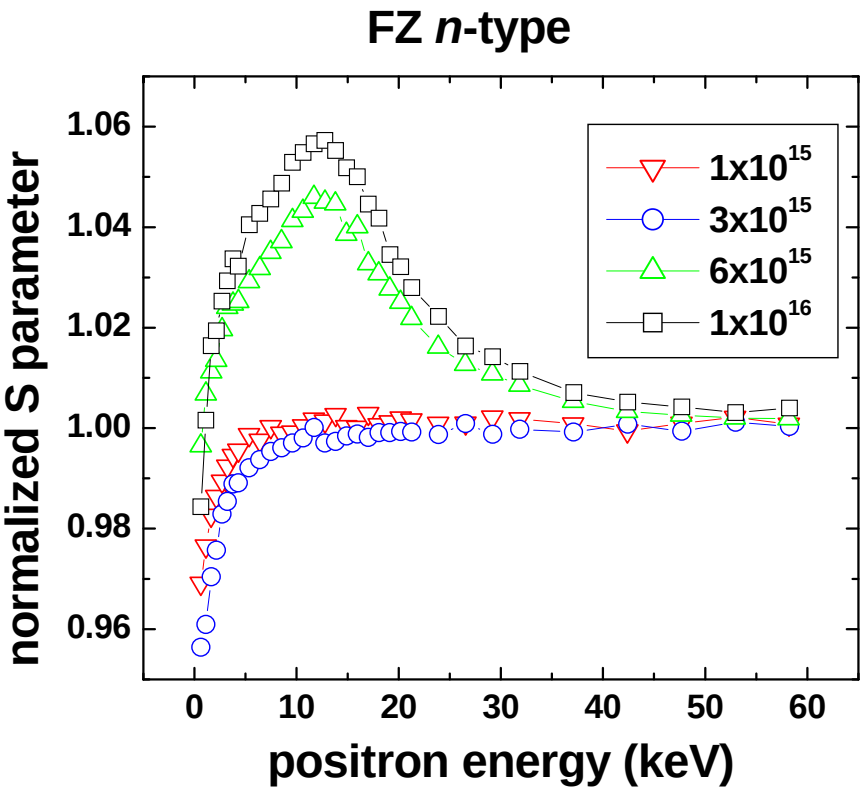
Summary

- Interplay among vacancies, interstitials and impurities provides complex microscopic behaviour that drives materials properties

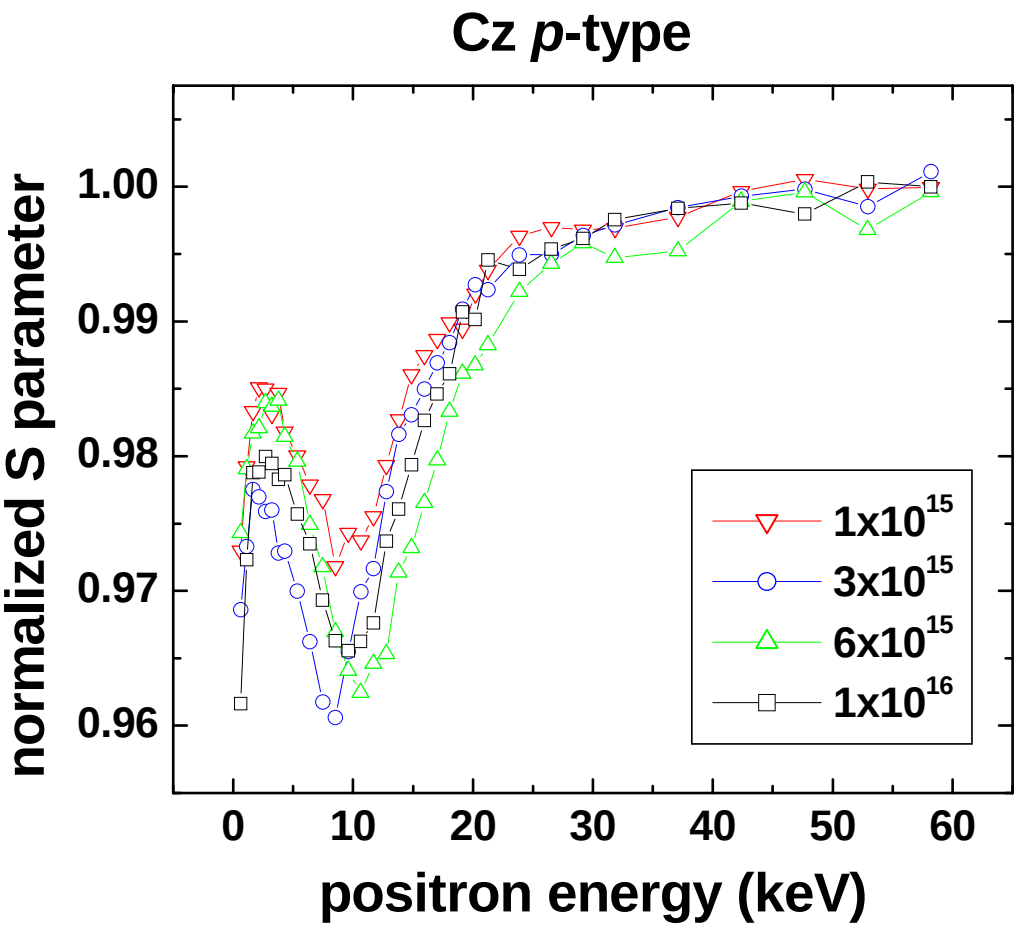
- Positron annihilation can provide pieces of the puzzle to understand this

Void formation threshhold:

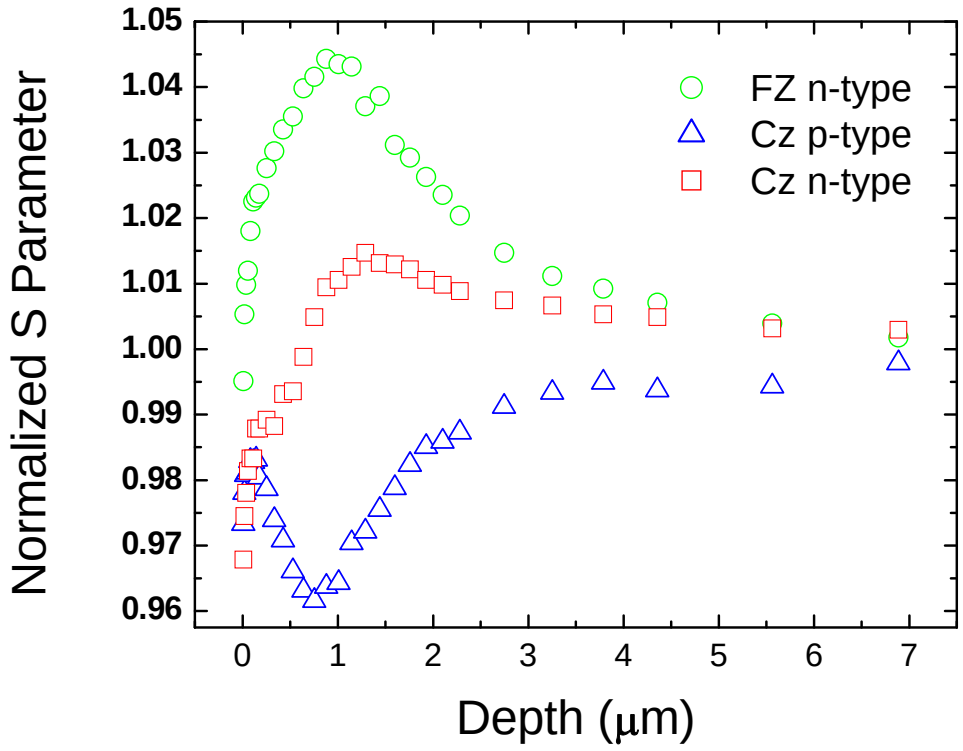
Implant 325 keV He, anneal 800°C.



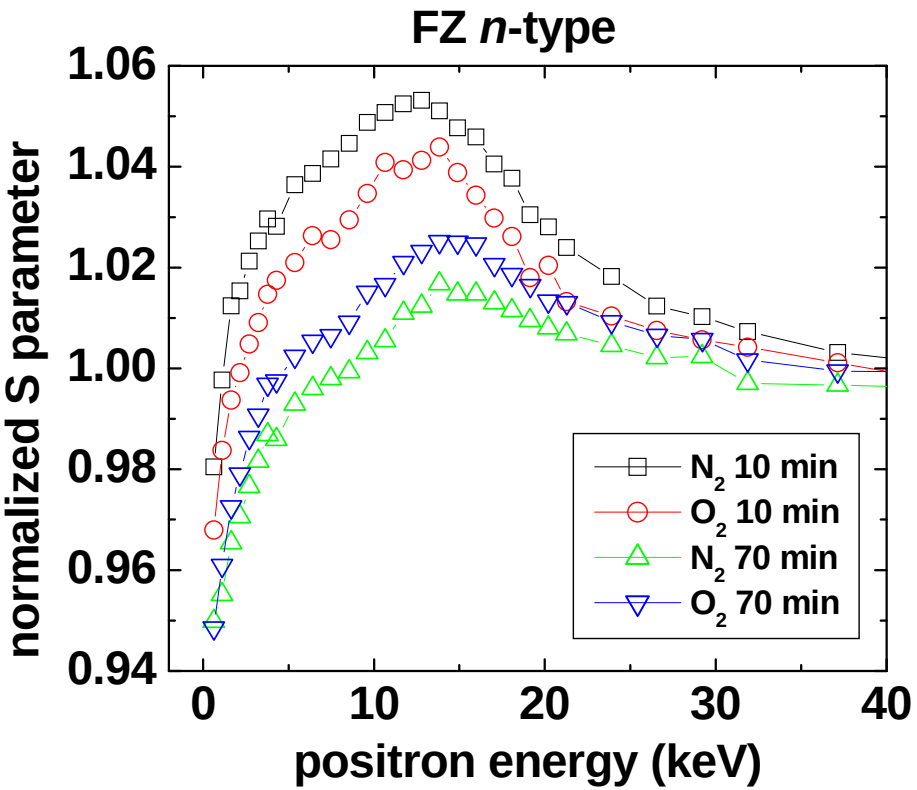
Void formation threshhold



Void formation threshhold



Annealing ambient



Applications

- Irradiation
- Aging
- Fatigue
- Thermal history
- Thin film growth
- Porosity
- Semiconductors
- Metals
- Polymers
- Ceramics

Ion implantation creates vacancies and interstitials, and introduces impurities