Characterization of an Al-STJ based X-ray Detector with Synchrotron Radiation

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Motivation

Application of STJ based detectors in X-ray fluorescence analysis (e.g. semiconductor industry)

STJ’s advantages over TES:
• higher count rate capability
• insensitivity to temperature changes

Picture:
Cryogenic spectrometer Polaris (TES based) attached to SEM at laboratory of semiconductor company Infineon Technologies

additional info:
Session F (material science)
talk F02 - C. Hollerith
poster F07 - M. Huber
STJ Detector

Al-STJ with Pb absorber on membrane:

- **Si$_3$N$_4$ membrane (300 nm)**
- **Pb absorber (1.3 µm)**
- **phononic read-out** by STJ over natural Al$_X$O$_Y$

**top view:**

- Pb 90x90 µm$^2$
- 100 µm
STJ Detector

Working principle:

• breaking of Cooper pairs

top view:

Pb
90x90 µm²

100 µm
STJ Detector

Working principle:

- breaking of Cooper pairs
- quasiparticle lifetime
STJ Detector

Working principle:

- breaking of Cooper pairs
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- recombination, phononic energy transport
STJ Detector

Working principle:

- breaking of Cooper pairs
- quasiparticle lifetime
- recombination, phononic energy transport
- phonon absorption, STJ signal
STJ Detector

Picture of STJ detector chip (3x5 mm²), glued on chip holder

2 detectors on membrane (1x1 mm²)
Electron Storage Ring *BESSY II* (Berlin, Germany)
PTB operates several beamlines at *BESSY II*

ADR cryostat and STJ preamplifier
(designed and supplied by LLNL)
available at PTB beamline
Energy scan:

X-ray energy: 3 keV to 10 keV in steps of 1 keV

electrochemical pulser for stability control

pulse height only; no pulse shape discrimination
Linearity Investigations

Relation of detector pulse height - X-ray energy:

![Graph showing the relation between pulse height and X-ray energy. The x-axis represents X-ray energy in keV ranging from 0 to 10, and the y-axis represents pulse height in channel numbers ranging from 0 to 2000. The data points are scattered along a linear trend.]
Linearity Investigations

Relation of detector pulse height - X-ray energy:

Best fit: polynomial function with small quadratic term (blue line)
Relation of detector pulse height - X-ray energy:

Best fit: polynomic function with small quadratic term (blue line)

for comparison: same function w/o quadratic term (red dashed line)

quadratic deviation due to escape of recombination phonons
Linearity Investigations

qualitative confirmation from pulse shape data:

slight energy dependence of signal rise and signal decay due to energy dependence of QP lifetime in Pb & Al

normalized templates (average of 2000 pulses) for 3keV-10keV
Artefact Investigations

Detector top view:

- STJ
- membrane
- Pb absorber

X-ray beam

50 µm

100 µm

Idea:
- constant X-ray energy of 10 keV
- spatial scan in steps of 25 µm
- measurement of detector response
Artefact Investigations

- pulse height spectrum (semilog. scale)
- absorber peak normalized

artefacts are more than two orders of magnitude smaller than absorber peak!
Artefact Investigations

red: + 25 µm
black: center position

no change!
yellow: + 100 µm
green: + 75 µm
blue: + 50 µm
black: center position

membrane hits far from STJ
membrane hits below STJ
Summary

- detector was successfully operated at BESSY synchrotron
- low deviation from linearity detected, can be corrected easily
- detector artefacts more than two orders of magnitude smaller than X-ray line, origin understood (further suppression via PSD)

Thank you for your attention!