Cryogenic X-ray Detectors for Material Analysis

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cryogenic detectors

- transition edge sensors
- superconducting tunnel junctions
- neutron doped thermistors
- magnetic calorimeters

single photon detection with

- excellent energy resolution
  (some eV @ 5.9 keV)
- low energy threshold (some eV)
- moderate count rates
  (~ 1000... 10 000 /sec)
- size ~ 100 x 100 μm^2

cryogenic detectors for fluorescence analysis

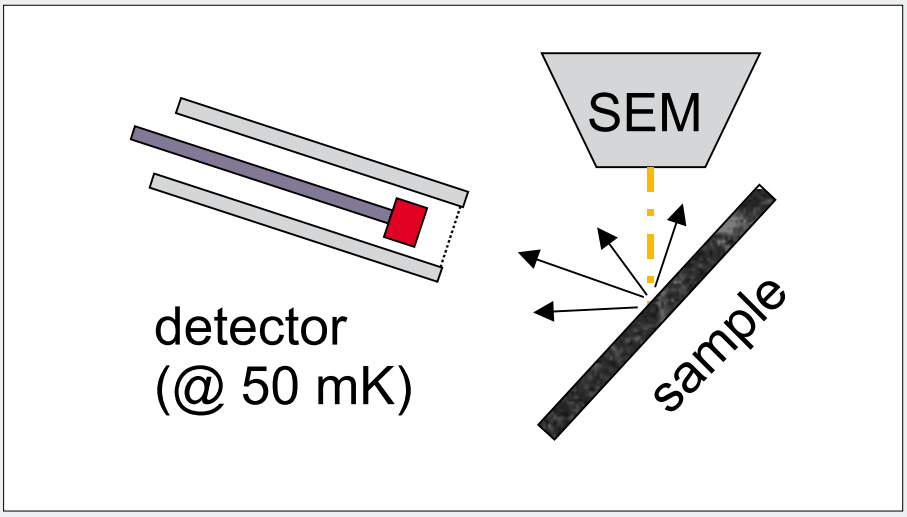
- element identification in surface sensitive analysis (low excitation energy)

  light elements: K-lines
  heavy elements: L/M-lines

- particle identification

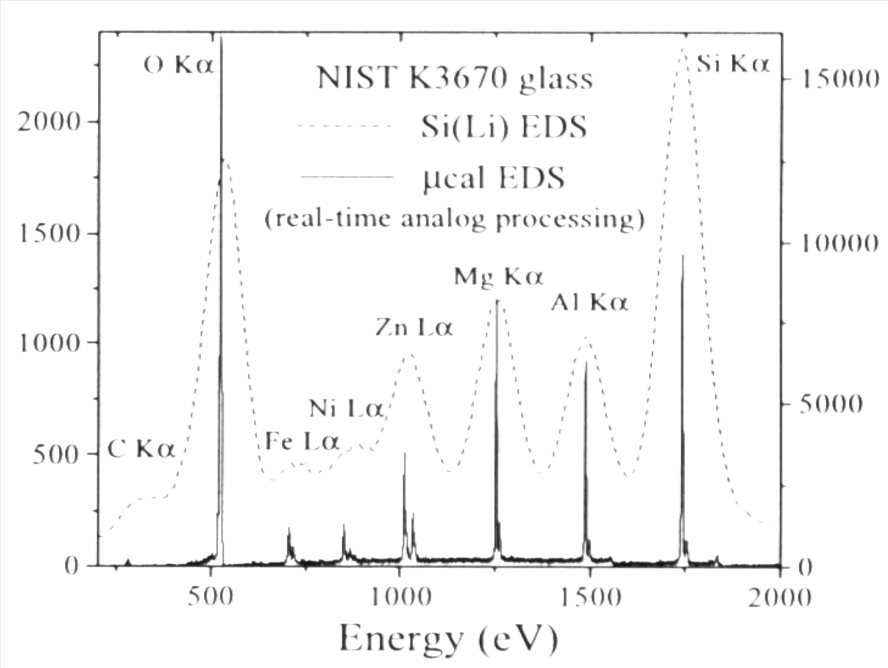
- measurement of chemical shifts

experimental setup



combination of cryogenic detector and scanning electron microscope

analysis of multielement sample



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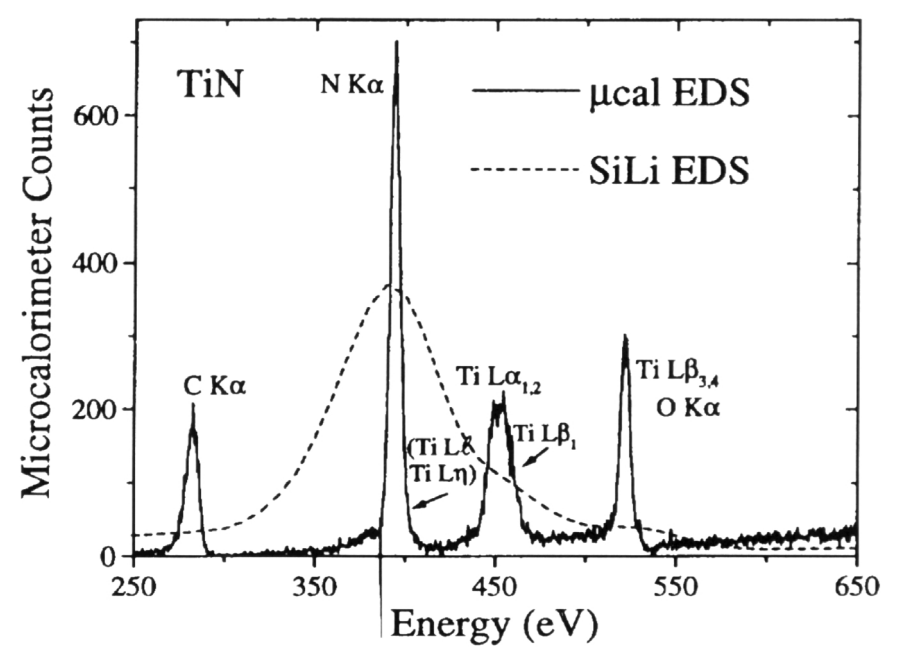
analysis of TiN



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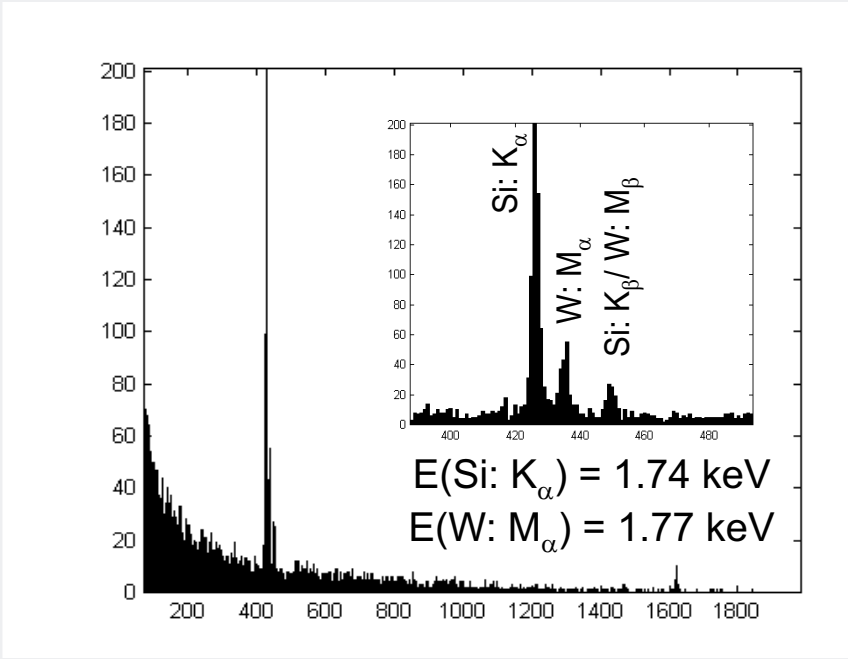
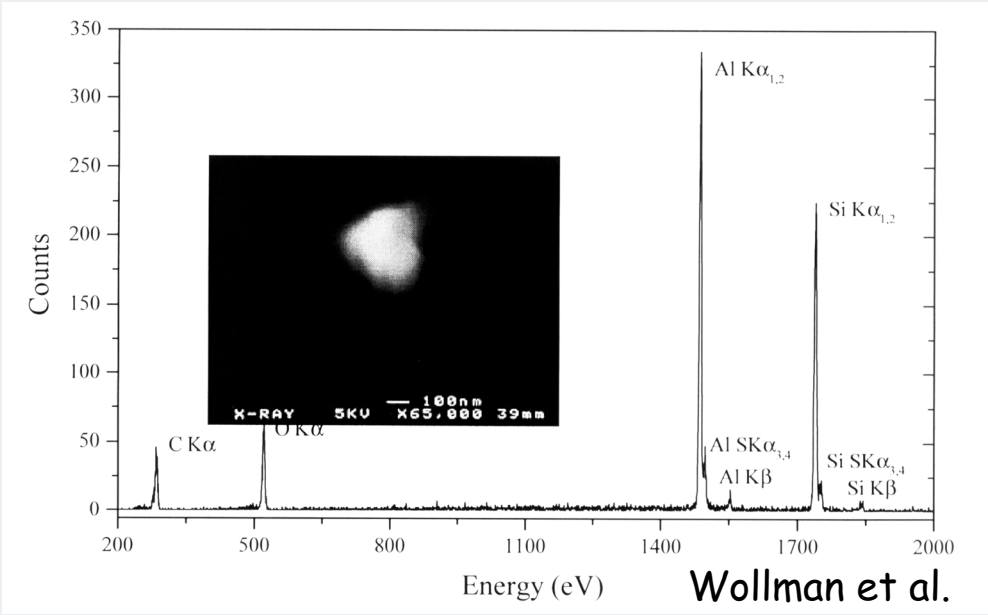
separation of N: K_α and Ti: L_α

analysis of W in presence of Si



separation of Si: K_α and W: M_α

Al_2O_3 particle on Si layer



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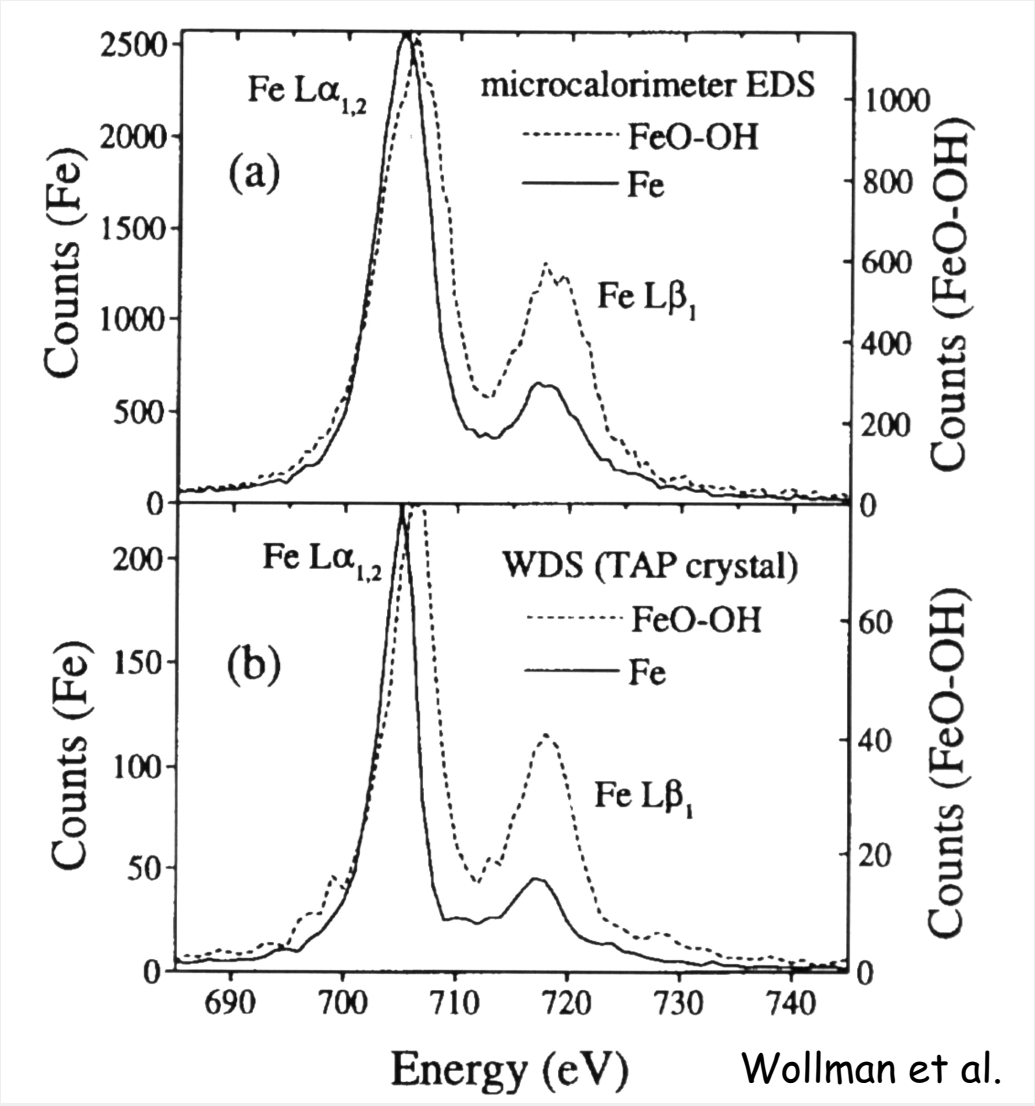
particle detection crucial for scaling semiconductor structures down

future development



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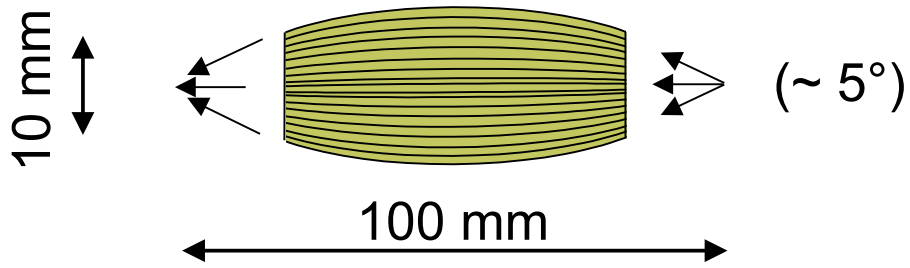
identification of chemical bonds by measurement of chemical shifts

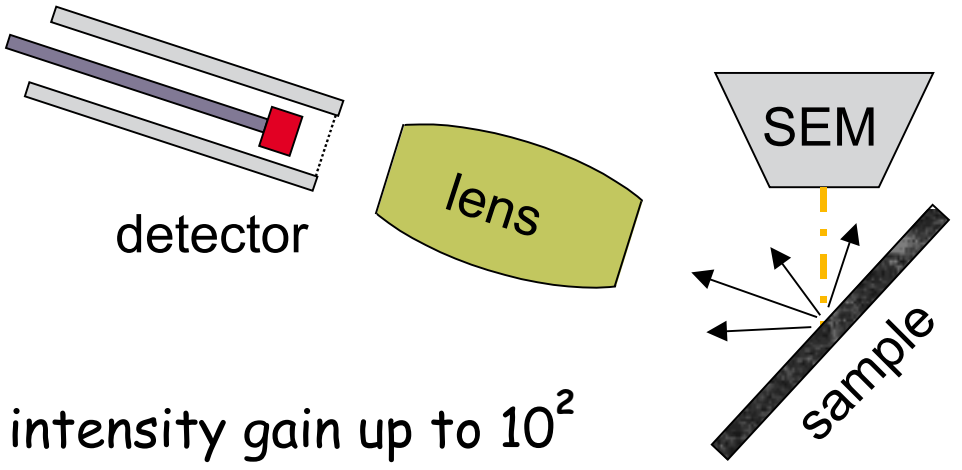
drawback #1:
detector size very small
(typical 100 x 100 μm^2)

remedy:



polycapillar X-ray lens (Kumakhov)

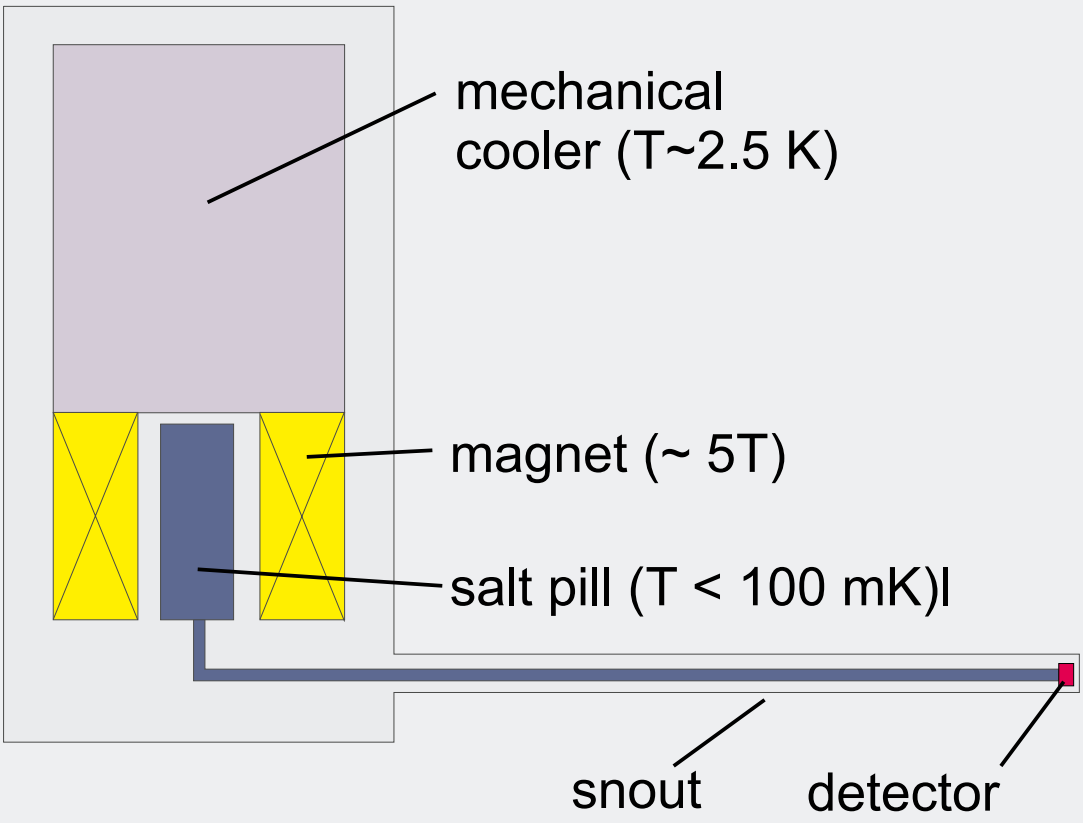
multiple total reflection inside polycapillars
allows two-dimensional collimation of X-rays
by very compact lenses



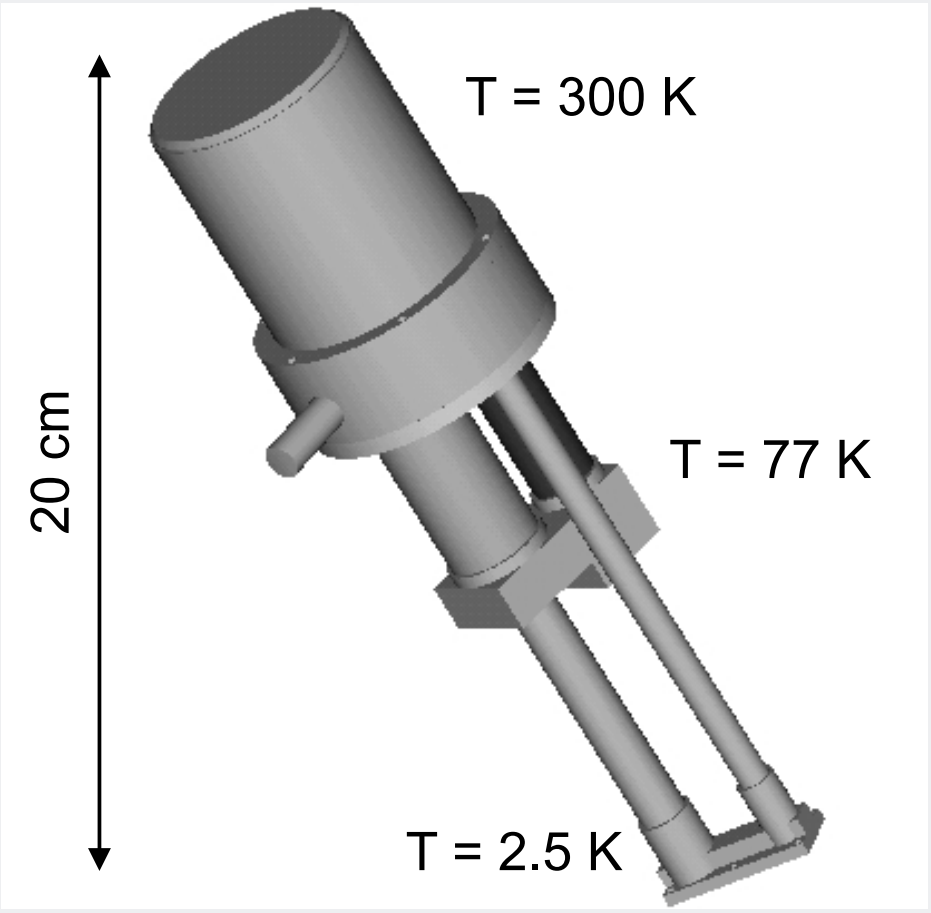
intensity gain up to 10^2

drawback #2:
operation temperature < 100 mK

remedy:
combination of mechanical cooler
and demagnetization refrigerator
(CSP GmbH, Ismaning)



mechanical cooler



pulse tube technique:

- no refrigerant liquids (safe & cheap)
- fully automatic, at base temperature within ~ 10 h
- cooling power 0.5 W @ T = 4 K
- little vibrations (no movable parts)

application of cryogenic detectors in X-ray fluorescence analysis

- important improvement in sensitivity
- reasonable detection efficiency by use of Kumakhov lenses
- new refrigerator technique: simple & easy to use