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Trace element measurements in synthetic Al_2O_3

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Measurement sequence

1. Optical Absorption measurements
   (Stanford)

2. XRF, EXAFS and XANES
   (CAMD)

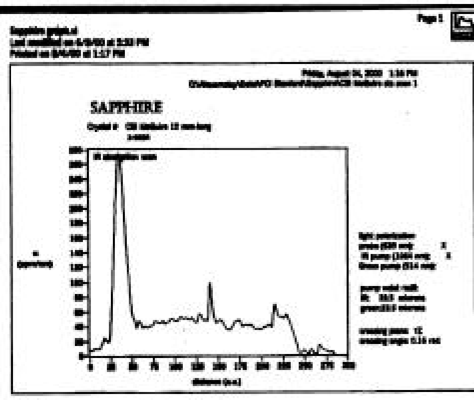
3. XRD
   (SUBR/LSU)

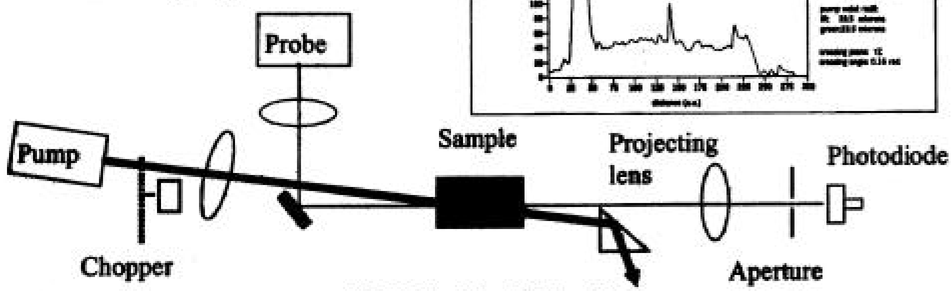
4. SANS
   (NIST)

5. INAA, PGNAA, NDP, ESR
   (NIST)

Absorption at 1064 nm in Sapphire

Starting material
Recycled material
Distribution Function - Position
Oxidation State
Annealing
Lattice Quality





Sapphire graph.vi
Last modified on 6/8/00 at 5:33 PM
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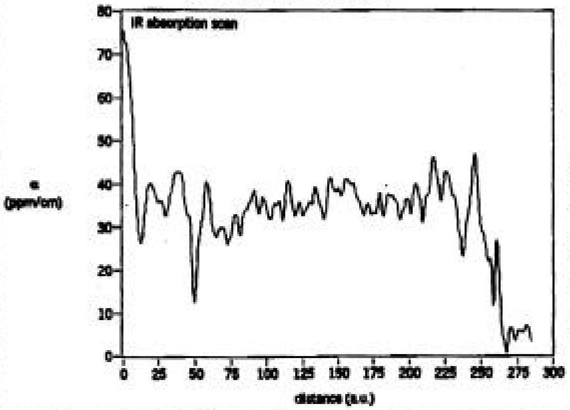
C:\Mesometry\Data\PCI Stanford\Sapphire\CSI McGuire transverse scan 1.dat

SAPPHIRE

Crystal # CSI McGuire 12 mm-long
transverse scan closer to the edge



light polarization
probe (633 nm): X
IR pump (1064 nm): X
Green pump (514 nm):

pump waist radii:
IR: 33.5 microns
green:23.5 microns

crossing plane: YZ
crossing angle: 0.16 rad

Prompt gamma activation theory:

$$N_\gamma = N \cdot f \cdot \sigma_{cap} \cdot \Phi \cdot p_\gamma \cdot \varepsilon_\gamma \cdot \Delta T_{count}$$

where

N_γ	=	number of observed prompt gamma rays
N	=	number of target atoms
f	=	isotopic abundance
σ_{cap}	=	neutron capture cross section (cm^2)
Φ	=	thermal neutron flux ($\#/cm^2 s$)
p_γ	=	gamma yield
ε_γ	=	photopeak detection efficiency
ΔT_{count}	=	counting time (s)

The number of atoms, N, of a particular element in the sample can be written

$$N = \frac{N_\gamma 100\lambda}{f I_\gamma \varepsilon_\gamma (\sigma\Phi_{th} + I_{res}\Phi_{epi})(1-e^{-\lambda t_I})e^{-\lambda t_d}(1-e^{-\lambda t_c})}$$

where

Φ_{th}	= thermal flux	($/cm^2\cdot s$)
Φ_{epi}	= epithermal flux	($/cm^2\cdot s$)
σ	= thermal activation cross section	(cm^2)
I_{res}	= resonance integral	(cm^2)
f	= isotopic abundance	
I_γ	= gamma-ray intensity	(γ's per 100 decays)
ε_γ	= photopeak detection efficiency	
t_I	= irradiation time	(s)
t_d	= decay time	(s)
t_c	= counting period	(s)
λ	= decay constant	(/s)

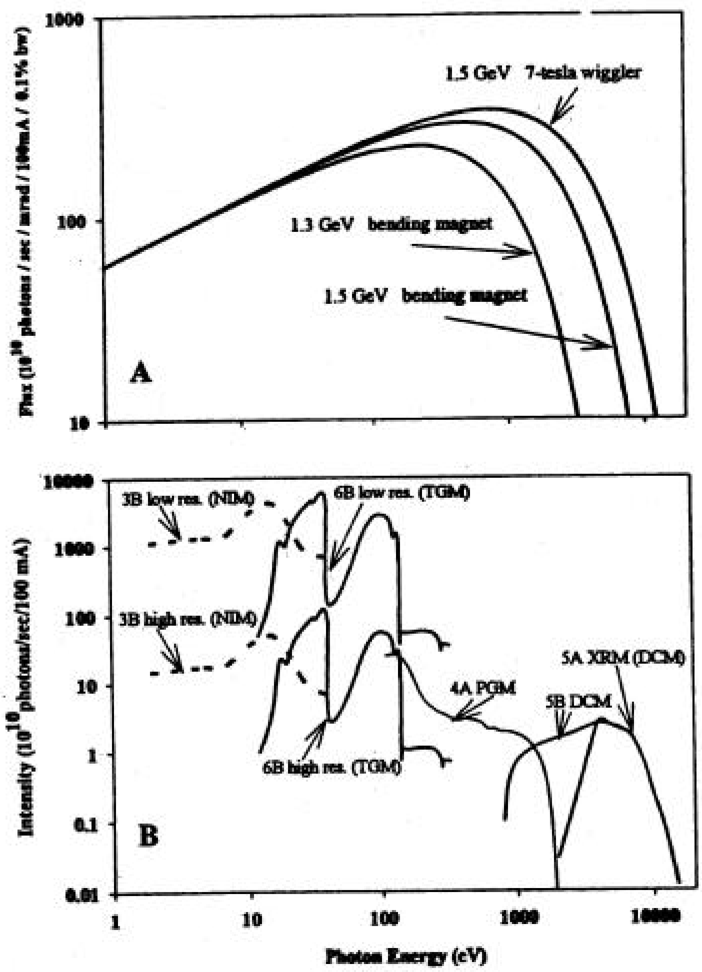


Figure 2 A. Photon flux produced by the CAMD electron storage ring operating at specified conditions, normalized to 100 mA current. The ring operates in excess of 150 mA at 1.5 GeV and 200 mA at 1.3 GeV. The 7-tesla wiggler is currently under construction. B. Output intensity of the CAMD basic- and analytical-sciences beamlines, normalized to 100 mA. See *Table II* for designation. Dashed lines are simulations. Port 6B beamline-intensity was recorded for the originally installed 1.8-meter TGM; the new 3-meter TGM is expected to provide similar intensity.

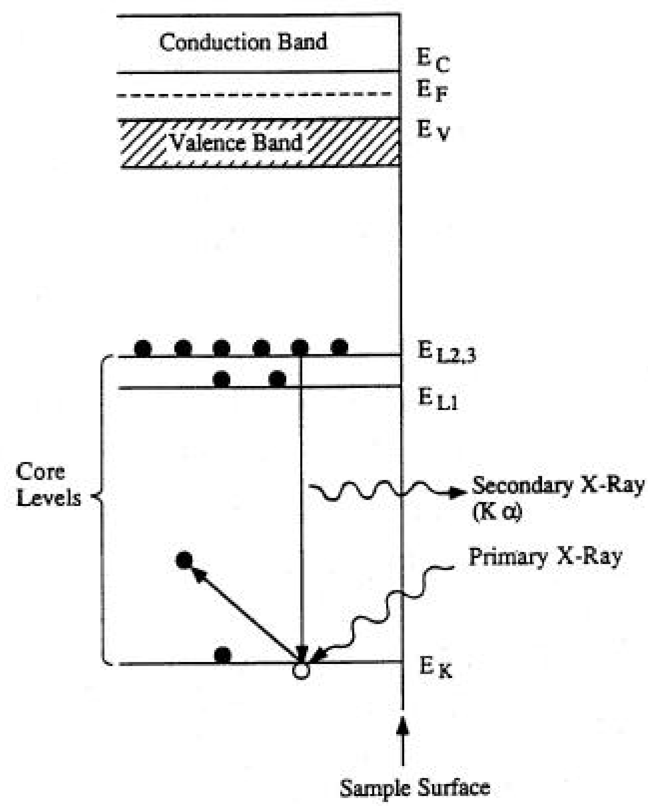


Fig. 10.28 Electronic processes in X-ray fluorescence.

Method (Basic Theory)

The amount of a particular element may be found from

$$m = (CR)_j(AW)_j / (N_A \Phi \sigma_\tau \omega_i \varepsilon) \qquad \text{(grams)} \qquad (1)$$

where $(AW)_j$ is the atomic weight of the *j*th element, N_A is Avogadro's number and CR is the background-subtracted, interference-corrected, photopeak count rate for the *j*th element in the specimen. Further,

Φ	=	flux of X-rays incident on the sample	$(\#/cm^2 \cdot s)$
σ_τ	=	photoelectric cross section per atom	(cm^2)
ω_i	=	fluorescence yield for the *i*th shell	
ε	=	absolute X-ray detection efficiency	

Atom ratios, R, may be calculated from

$$R = N_1/N_{ref} = [(CR_1/CR_{ref})][(\sigma_\tau \omega_i)_{ref}/(\sigma_\tau \omega_i)_1]\varepsilon_{rel}\ , \quad (2)$$

where

ε_{rel}	=	the relative X-ray detection efficiency,
N_j	=	the number of atoms of the *j*th element seen by the beam.

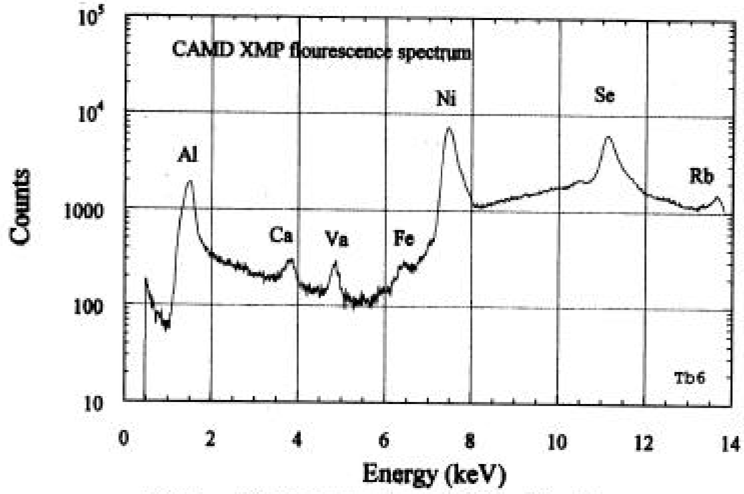


Figure ___. XRF spectrum of commercial sapphire using a "broadband" X-ray beam.

Attenuation, I/I_o, due to Self-Absorption

$$\frac{I}{I_o} = \frac{1 - e^{-\mu_m \rho x}}{\mu_m \rho x} \quad , \qquad (3)$$

where

ρ = is the sample's mass density,

μ_m = mass absorption coefficient for the sample, and

x = sample thickness.

The mass absorption coefficient is calculated via the equation,

$$\mu_m = \frac{\sum \omega_i \mu_i(E)}{\sum \omega_i} \quad , \qquad (4)$$

where

ω_i = percent concentrations by mass of the elements in the sample, and

$\mu_i(E)$ = energy-dependent mass absorption coefficients for each element.

Some Issues:

- Sapphire specimen availability
  - starting materials*
  - specimen sizes
- What impurities are most important?
- Staging/coordination of specimen testing
- X-ray irradiation effects on optical absorption?
- Interfacing with other groups
- Others ....