

# EDX Intensity

Identify primary factors influencing spectra:

$$I(E) = \alpha(E) \cdot D_e \cdot n \cdot T \cdot A(T, E) \cdot \sum_k x_k \cdot g_k(E)$$

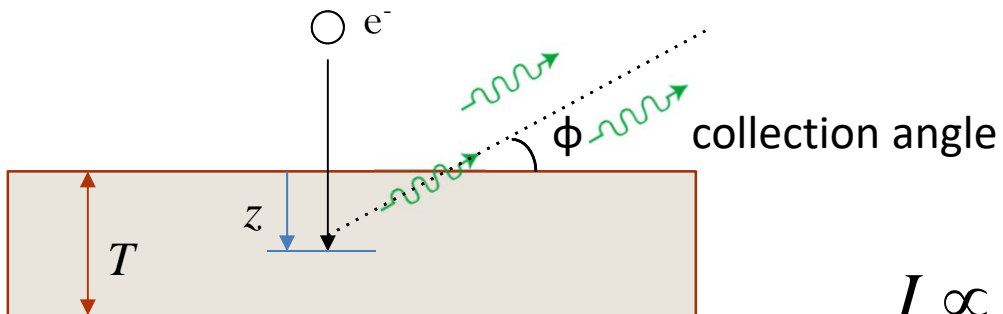
The diagram illustrates the primary factors influencing EDX intensity through the equation  $I(E) = \alpha(E) \cdot D_e \cdot n \cdot T \cdot A(T, E) \cdot \sum_k x_k \cdot g_k(E)$ . The factors and their corresponding terms are:

- energy** (points to  $\alpha(E)$ )
- electron dose** (points to  $D_e$ )
- thickness** (points to  $T$ )
- composition** (points to  $x_k$ )
- measured intensity** (points to  $I(E)$ )
- geometric factor** (points to  $\alpha(E)$ )
- atomic concentration** (points to  $n$ )
- absorption correction** (points to  $A(T, E)$ )
- elements** (points to  $x_k$ )
- generation rate** (points to  $g_k(E)$ )

# X-ray absorption

X-rays generated below the surface of the TEM foil can be absorbed before escaping.

Assume the electron beam is unattenuated.



$$I \propto \int_{z=0}^T e^{-\mu(E) \cdot \csc \phi \cdot z} \cdot dz$$

$$A(T, E) = \frac{1 - e^{-\mu(E) \cdot \csc \phi \cdot T}}{\mu(E) \cdot \csc \phi}$$

# Absorption correction

attenuation coefficient for an element

$$\mu(E) = n \cdot \sigma_k(E) = \frac{N_A \cdot \rho \cdot \sigma_k(E)}{M_k}$$

mass-attenuation coefficient for an element

$$\left( \frac{\mu(E)}{\rho} \right)_k = \frac{N_A \cdot \sigma_k(E)}{M_k}$$

attenuation coefficient for a composite

$$\mu(E) = \sum_k n_k \cdot \sigma_k(E)$$

concentration of an element in a composite

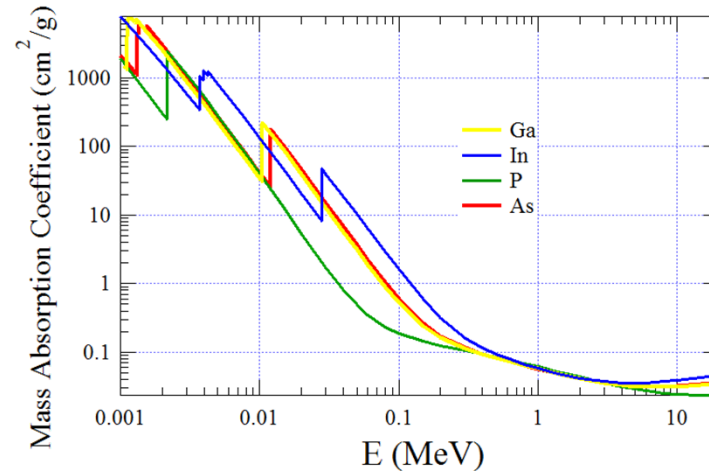
$$n_k = \frac{N_A \cdot \rho \cdot x_k}{\sum_{\ell} x_{\ell} \cdot M_{\ell}}$$

mass-attenuation coefficient of a composite

$$\frac{\mu(E)}{\rho} = \frac{\sum_k N_A \cdot x_k \cdot \sigma_k(E)}{\sum_{\ell} x_{\ell} \cdot M_{\ell}}$$

scattering cross-section for an element

$$\sigma_k(E) = \frac{M_k}{N_A} \cdot \left( \frac{\mu(E)}{\rho} \right)_k$$



<https://www.nist.gov/pml/x-ray-mass-attenuation-coefficients>

mass-attenuation coefficient of a composite

$$\frac{\mu(E)}{\rho} = \sum_k \left[ \frac{x_k \cdot M_k}{\sum_{\ell} x_{\ell} \cdot M_{\ell}} \cdot \left( \frac{\mu(E)}{\rho} \right)_k \right] = \sum_k y_k \cdot \left( \frac{\mu(E)}{\rho} \right)_k$$

mass ratios:

$$y_k = \frac{x_k \cdot M_k}{\sum_{\ell} x_{\ell} \cdot M_{\ell}}$$

# *k*-factors

Consider intensity at two energies associated with different elements:

$$I(E_1) = \alpha(E_1) \cdot D_e \cdot n \cdot T \cdot A(T, E_1) \cdot g_1(E_1) \cdot x_1$$

$$I(E_2) = \alpha(E_2) \cdot D_e \cdot n \cdot T \cdot A(T, E_2) \cdot g_2(E_2) \cdot x_2$$

$$\frac{I(E_2)}{I(E_1)} = \frac{\alpha(E_2) \cdot \cancel{D_e} \cdot \cancel{n} \cdot \cancel{T} \cdot A(T, E_2) \cdot g_2(E_2) \cdot x_2}{\alpha(E_1) \cdot \cancel{D_e} \cdot \cancel{n} \cdot \cancel{T} \cdot A(T, E_1) \cdot g_1(E_1) \cdot x_1}$$

$$\frac{I_2}{I_1} = \frac{1}{k_{12}} \cdot \frac{x_2}{x_1}$$

$$\frac{x_2}{x_1} = k_{12} \cdot \frac{I_2}{I_1}$$

//Cliff-Lorimer (1975)

# $\zeta$ -factors

$$\frac{I_2}{I_1} = \frac{x_2/\zeta_2}{x_1/\zeta_1}$$

Use known relationships among the constituent compositions:

$$x_1 + x_2 = 1$$

$$\frac{x_2}{x_1} = \frac{\zeta_2 \cdot I_2}{\zeta_1 \cdot I_1} \longrightarrow \frac{1 - x_1}{x_1} = \frac{\zeta_2}{\zeta_1} \cdot \frac{I_2}{I_1}$$

$$x_1 = \frac{\zeta_1 \cdot I_1}{\zeta_1 \cdot I_1 + \zeta_2 \cdot I_2}$$

$$x_2 = \frac{\zeta_2 \cdot I_2}{\zeta_1 \cdot I_1 + \zeta_2 \cdot I_2}$$

In general:

$$x_i = \frac{\zeta_i \cdot I_i}{\sum_j \zeta_j \cdot I_j}$$

//Watanabe-Williams (2006)

# Relating pairs of elements

$$\underline{A_{1-x}B_x}$$

$$\frac{x}{1-x} = \frac{\zeta_B}{\zeta_A} \cdot \frac{I_B}{I_A}$$

$$\frac{\zeta_B}{\zeta_A} = \frac{x}{1-x} \cdot \left( \frac{I_B}{I_A} \right)^{-1}$$

$$\underline{A_{1-y}C_y}$$

$$\frac{y}{1-y} = \frac{\zeta_C}{\zeta_A} \cdot \frac{I_C}{I_A}$$

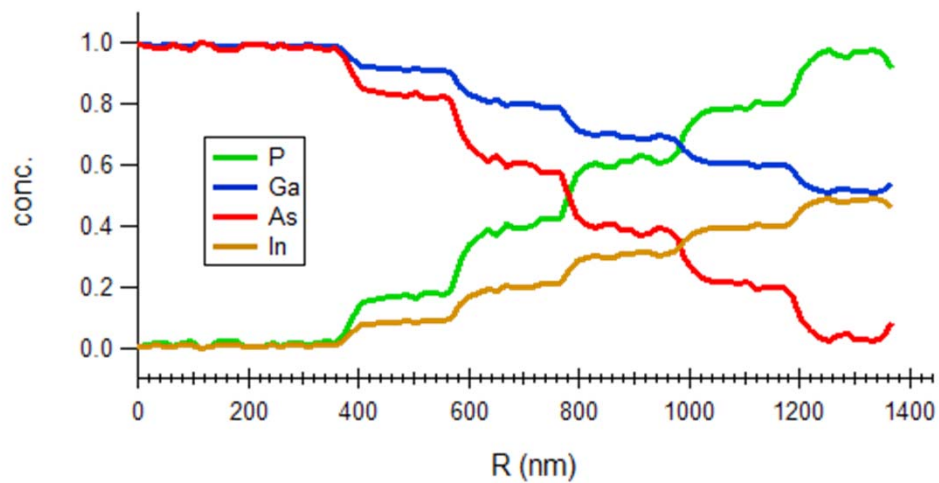
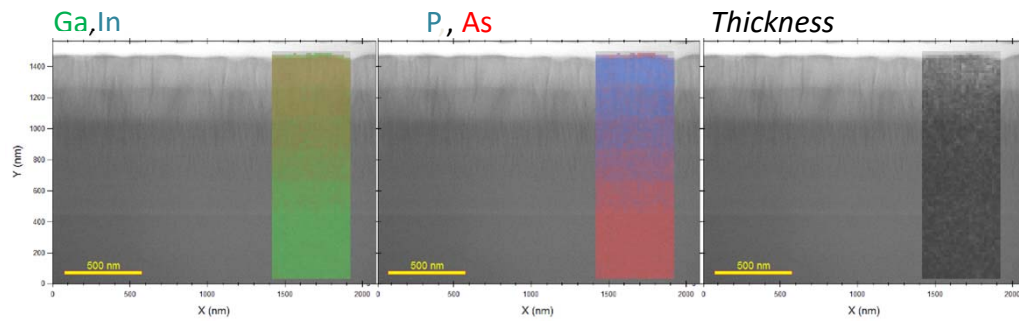
$$\frac{\zeta_C}{\zeta_A} = \frac{y}{1-y} \cdot \left( \frac{I_C}{I_A} \right)^{-1}$$

$$\underline{B_{1-z}C_z}$$

$$\frac{z}{1-z} = \frac{\zeta_C}{\zeta_B} \cdot \frac{I_C}{I_B}$$

$$\frac{\zeta_C}{\zeta_B} = \frac{\zeta_C}{\zeta_A} \cdot \frac{\zeta_A}{\zeta_B}$$

# EDX Mapping



The screenshot shows the 'Map' software interface. It includes a 'Map' dropdown menu, an 'Actions' dropdown menu, and three tabs: 'data', 'area', and 'line'. The 'line' tab is selected, showing a 'Line' dropdown menu. Below this are input fields for 'xi(pix)' (436), 'xf(pix)' (430), 'yi(pix)' (723), and 'yf(pix)' (143). There are checkboxes for 'show line' (checked) and 'show trans' (unchecked). Below these are 'long. bin' (1) and 'trans. bin' (8) input fields. A list box contains 'Ga', 'Ge', 'As' (checked), and 'thickness (nm)'. Below the list box are 'color' (red), 'max' (1), and 'min' (0.5) input fields. At the bottom, there is a 'T min. cutoff (nm)' input field (10) and an 'Actions' dropdown menu.