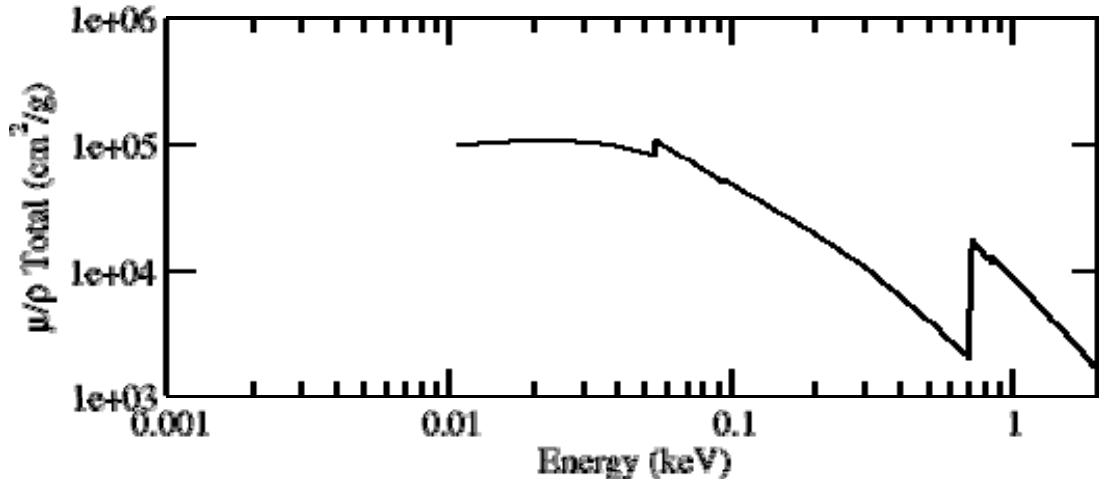


## Safety rule

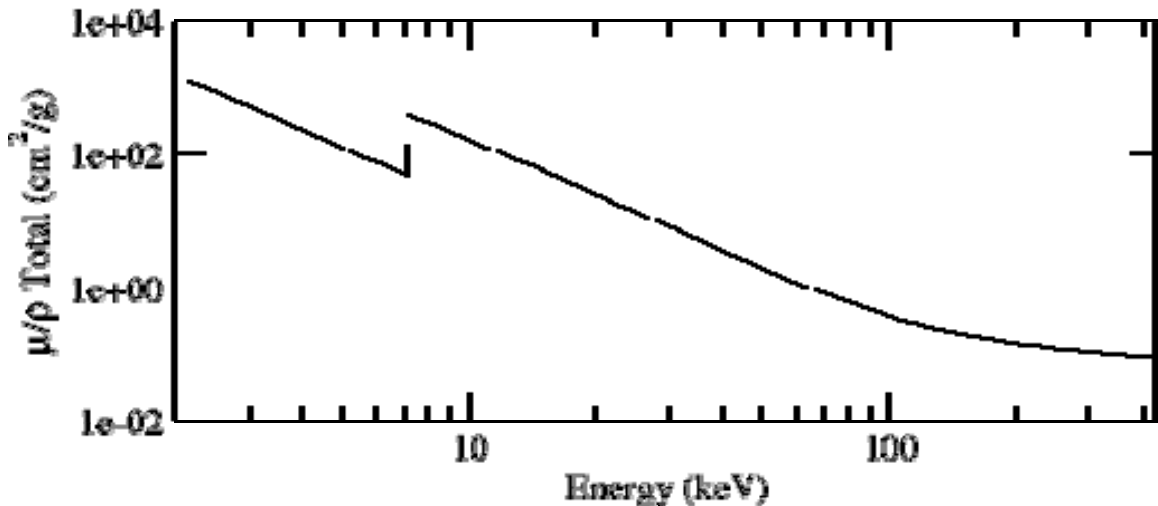
You are visiting the Swiss Light Source synchrotron radiation facility (SLS). The speaker acting as a guide is boring. You find an open access to the end station (the room containing the vacuum chamber where the experiment with x-rays is played) and by curiosity you decided to enter. Is it safe or not? Consider both the case of soft X-rays (1 Kev) and hard X-rays (400 keV).

The vacuum chambers are made in steel, which is principally iron ( $\rho = 7.9$  g/cm<sup>3</sup>), and their walls have a thickness of 3 mm.

**Z = 26, E = 0.001 - 2 keV**



**Z = 26, E = 2 - 433 keV**



## Solution: Safety rule

The X-rays absorption is described by an exponential decay following:

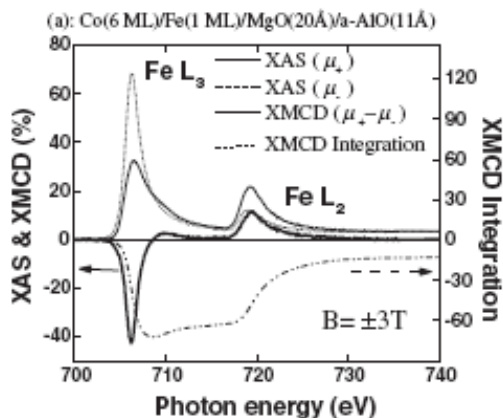
$I/I_0(h) = \exp(-\rho \mu/\rho h)$  where  $h$  is the material thickness. The ratio  $\mu/\rho$  (in  $\text{cm}^2/\text{g}$ ) is  $8.5 \cdot 10^3$  (1 keV) and  $9.3 \cdot 10^{-2}$  (400keV) which implies

$I/I_0(3 \text{ mm}) = 3 \cdot 10^{-8243}$  (1 keV), and 0.8 (400 keV)

This means that you can safely move inside the end stations using soft X-rays while the same behavior is not recommended in the case of end stations using hard X-rays. Actually, an automatic safety system stops the X-ray beam when the access door is opened

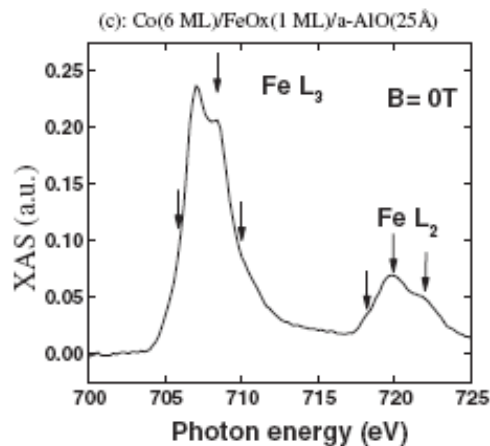
# X-ray absorption of a mono-atomic Fe(001) layer in tunnel barriers

The electronic state of a mono-atomic Fe(001) layer facing an oxide film in two different tunnel barrier was investigated by measuring the XAS at the  $L_3$  and  $L_2$  iron adsorption edges. In the first tunnel barrier (a) the Fe layer was covered by MgO deposited by electron-beam evaporation. In the second tunnel barrier (c) the Fe layer was covered by Al deposited by MBE in Oxygen atmosphere. By comparing the XAS spectra measured at the Fe edge for the two tunnel barriers and the XAS spectra measured at the Fe edge for pure and heavily oxidized Fe, what can you conclude?



a-AlOx(11 Å)	Reactive Evapo.
MgO(001)20 Å	MBE
Fe(001)1ML	MBE
bcc-Co(001)6ML	MBE
Cr(001)500 Å	MBE
Fe(001)500 Å	MBE

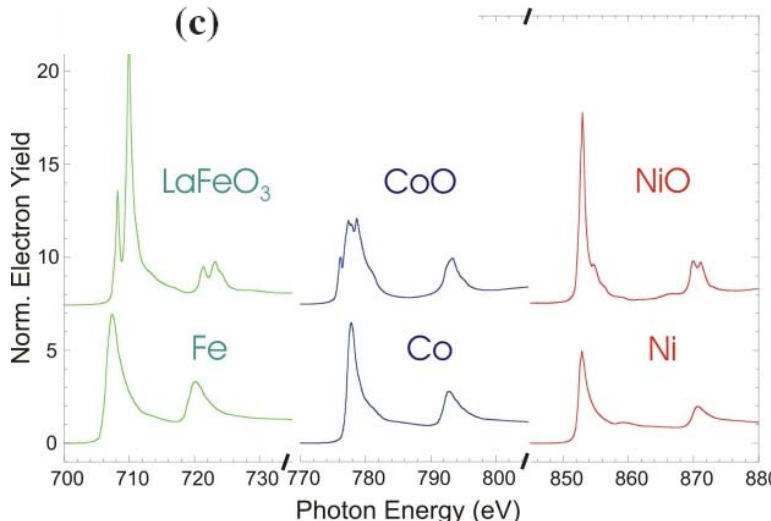
(a)



a-AlOx(25 Å)	Natural oxid.
FeO <sub>x</sub> 1ML	MBE
bcc-Co(001)6ML	MBE
Au(001)2000 Å	MBE
Cr(001)200 Å	MBE

(c)

Reference spectra for pure and heavily oxidized Fe



## **Solution: X-ray absorption of a monoatomic Fe(001) layer in tunnel barriers**

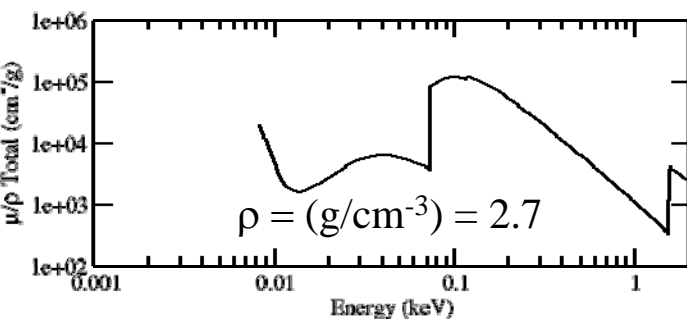
The XAS spectrum of the Fe monolayer covered by oxidized Al (barrier c) clearly shows a multi-peak structure characteristic of the oxidized Fe, while the XAS spectrum for the tunnel barrier (a) is comparable to the one measured on pure Fe. Thus in the tunnel barrier with MgO the Fe is not oxidized while in the tunnel barrier with AlO is strongly oxidized

K. Miyokawa *et al.*, Jpn. J. Appl. Phys. **44**, L9 (2005)

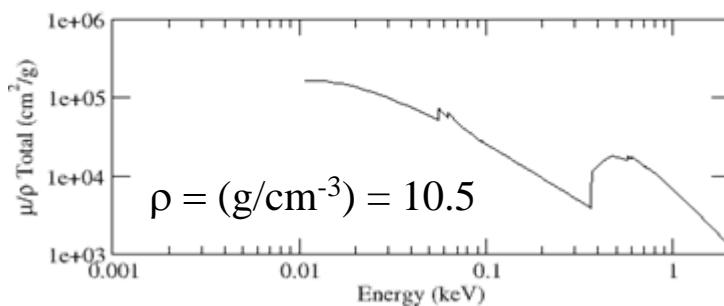
## Preparing your experiment

You want to characterize by XAS the iron oxidation at Fe-MgO interface of a Fe/MgO/Fe tunnel barrier you grew in your Molecular Beam Epitaxy chamber under vacuum conditions. To do that you have to transfer your sample in another vacuum chamber which comports the exposure of the sample to the air conditions. In order to avoid modifications of your sample you decide to cover your tunnel barrier by depositing a protecting capping layer with a thickness of about 100 nm. You can chose among silver (Ag), samarium (Sm) and gold (Au). Which element do you chose and why? Would using aluminum even better or not?

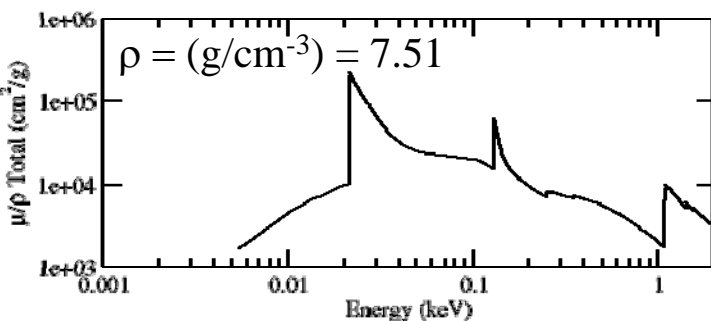
Al  $Z = 13, E = 0.001 - 2 \text{ keV}$



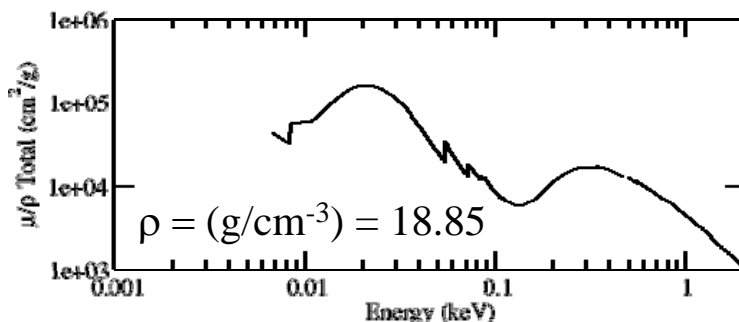
Ag  $Z = 47, E = 0.001 - 2 \text{ keV}$



Sm  $Z = 62, E = 0.001 - 2 \text{ keV}$



Au  $Z = 79, E = 0.001 - 2 \text{ keV}$



## Solution: Preparing your experiment

The X-rays absorption is described by an exponential decay following:  
 $I/I_0(h) = \exp(-\rho \mu/\rho h)$  where  $h$  is the sample thickness. Because we are interesting in studying the Fe oxidation we have to chose the x-rays energy in the range of the Fe adsorption edges, i.e. at about 700 eV. At this energy the ratio  $\mu/\rho$  (in  $\text{cm}^2/\text{g}$ ) is  $3.6 \cdot 10^3$  (Sm),  $1.3 \cdot 10^4$  (Ag), and  $7.8 \cdot 10^3$  (Au) which implies:

$$I/I_0(100\text{nm}) = 0.76 \text{ (Sm)}, 0.25 \text{ (Ag)}, 0.22 \text{ (Au)}.$$

This means that when using Ag or Au you have about a third of the x-rays intensity reaching your sample respect to case with Sm capping. Then, Sm is better even if it is not the lighter element among the three

In the case of Al  $\mu/\rho = 2.8 \cdot 10^3 \text{ cm}^2/\text{g}$  which gives  $I/I_0 = 0.93$ . Obviously, Al would be the best choice