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Considerations on the ^{163}Ho implantation on the Au absorber for HOLMES

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HOLMES is a project funded by the European Research Council aiming to realise the calorimetric measurement of the neutrino mass from the electron capture spectrum of ^{163}Ho. HOLMES will deploy a first large Kilo-pixel large array of low temperature microcalorimeters containing about 18 μg of implanted ^{163}Ho nuclei. The resulting mass sensitivity of the pilot experiment will be as low as 0.4 eV.
The total activity will be given by about $6.5*10^{16}$ ^{163}Ho nuclei, that allows to achieve a neutrino mass sensitivity as low as 0.4 eV.
However the relatively high concentration of holmium (J = 7/2) could cause an excess heat capacity in the metallic absorber, due to hyperfine level splitting of the implanted ion.

WIP

- Au-absorber C
- Ho purity
- Ho metallic state
- Ho implantation
- G
- τ
- ΔE

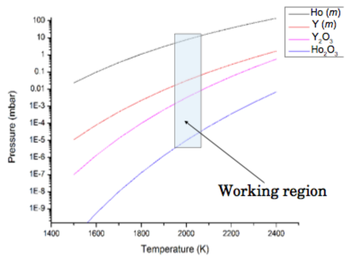
...

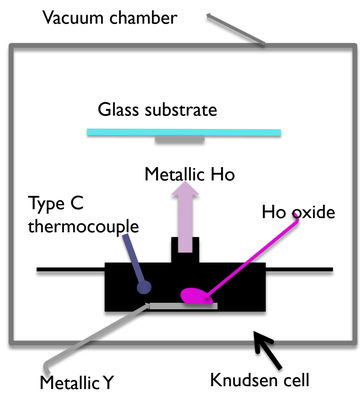
Production of Pure Metallic Holmium

Methodology: heating a mixture of metallic yttrium and holmium oxide above the mealting point. Due to the different std enthalpy of formation oxygen is captured by yttrium, leaving pure metallic holmium by means of the reaction:

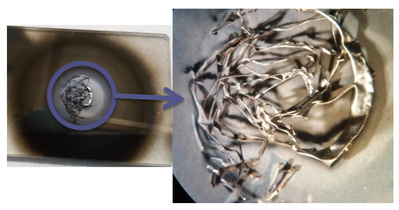
$$Ho_2O_3 + 2Y(m) \rightarrow 2Ho(m) + Y_2O_3$$

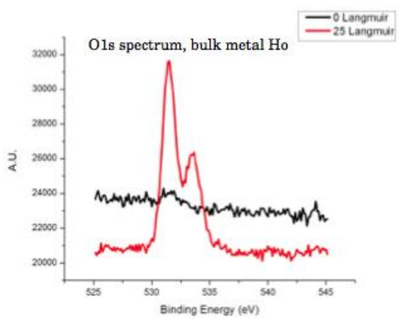
Process	ΔH (kJ/mol)
$Ho(m) \rightarrow Ho_2O_3$	-1880
$Y(m) \rightarrow Y_2O_3$	-1905

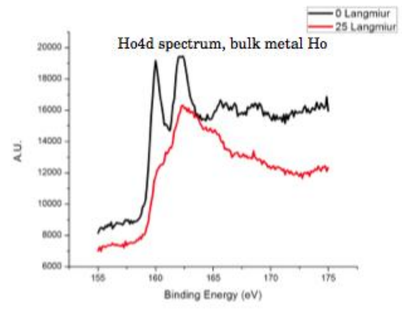


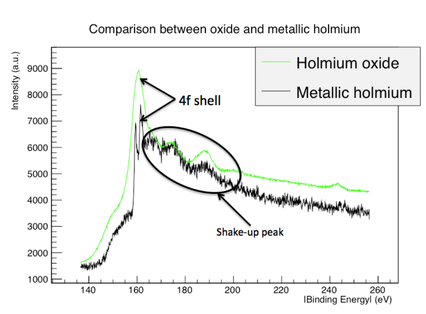


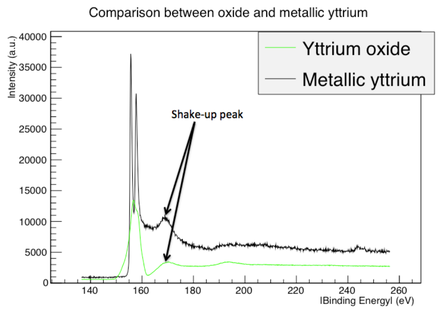
First metallic holmium obtained











Implantation of non-radioactive Ho and Er

The samples were produced by PLD in the University and INFN of Genoa and made of a silicon substrate with orientation (111) and an Ir/Au bilayer. The iridium, used as an adhesion layer for the Au film, as a thickness of 60 nm; the Au film is 1.3 micron thick.

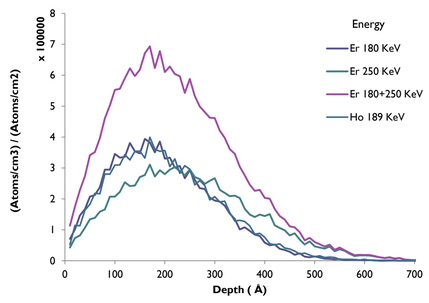
Implantation conditions

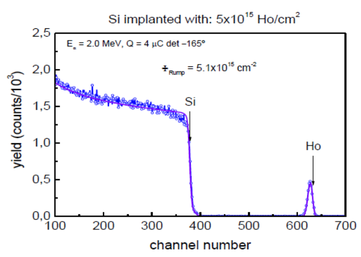
Ho^+ nas amostras de SiAu	Er^+ nas amostras de SiAu
Mass: 165 a.m.u.	Mass: 168 a.m.u.
Charge: 1	Charge: 1
Molec.: 1	Molec.: 1
Extraction: 40 kV	Extraction: 40 kV
Acceleration: 140 kV	Acceleration: 140 kV
H.Sweep: 4,0 cm	H.Sweep: 5,0 cm
V.Sweep: 4,0 cm	V.Sweep: 5,0 cm
Dose: 4,E+15 at/cm2	Dose: 9,6E+15 at/cm2
Beam: 35 uA	Beam: 30 uA
Magnet: 94,9 A	Magnet: 95,8 A
Energy: 180 keV	Energy: 180 keV
Focus: 5,51	Focus: 5,56
Astig.: 0,38	Astig.: 0,38
SweepX: 1,00	SweepX: 1,26
SweepY: 1,14	SweepY: 1,44
Total Charge: 10253 uC	Total Charge: 38448 uC
Time: 0:04:52 h:m:s	Time: 0:21:21 h:m:s
Power Dens.: 0,394 W/cm2	Power Dens.: 0,216 W/cm2

IST-ID 210 kV **Ion implanter** has a chamber allowing the implantation of an area of 20x20 cm^2, and to carry on implantation samples in the temperatures range of 77 K up to 1273 K, in a controlled way.

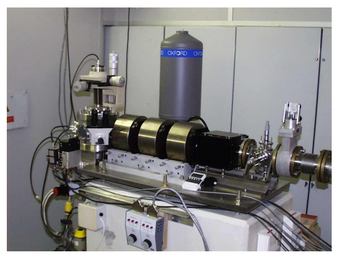
Er^+ 180 keV	190,2 Å
Er^+ 250 keV	245,3 Å
Ho^+ 180 keV	186,0 Å
Ho^+ 250 keV	244,0 Å

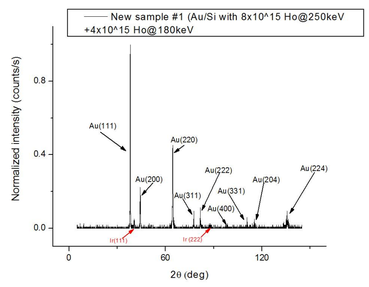
250 keV	$8x10^{15}$ Ho^+/cm^2
	$1.9x10^{16}$ Er^+/cm^2
	$8x10^{15}$ Ho^+/cm^2 + $1.9x10^{16}$ Er^+/cm^2
180 keV	$4x10^{15}$ Ho^+/cm^2 + $8x10^{15}$ Ho^+/cm^2 (250 keV)
	$9.6x10^{15}$ Er^+/cm^2 + $1.9x10^{16}$ Er^+/cm^2 (250 keV)
	$4x10^{15}$ Ho^+/cm^2 + $9.6x10^{15}$ Er^+/cm^2 + $8x10^{15}$ Ho^+/cm^2 (250 keV) + $1.9x10^{16}$ Er^+/cm^2 (250 keV)



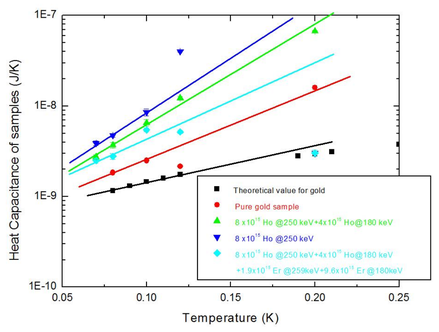


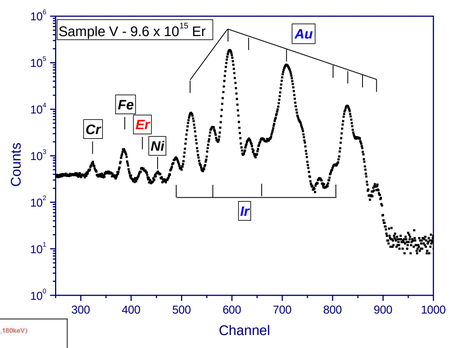
PIXE (Particle Induced X-ray Emission) line at the 2,5 MV **Van de Graaff accelerator** at IST-ID with three experimental beam lines, with all the relevant ion beam techniques available: RBS (Rutherford Backscattering Spectrometry), PIXE, NRA, Channeling, ERDA and NRB with (p, γ)

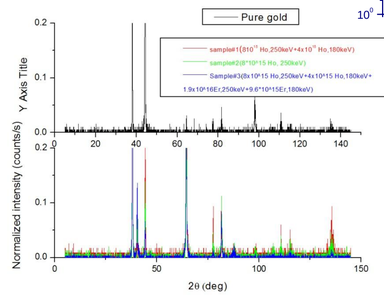




Sample A, black: Pure gold
Sample B, red: $4x10^{15}$ ions of ^{163}Ho + $9.6x10^{15}$ ions of ^{163}Er
Sample C, green: $4x10^{15}$ ions of ^{163}Ho

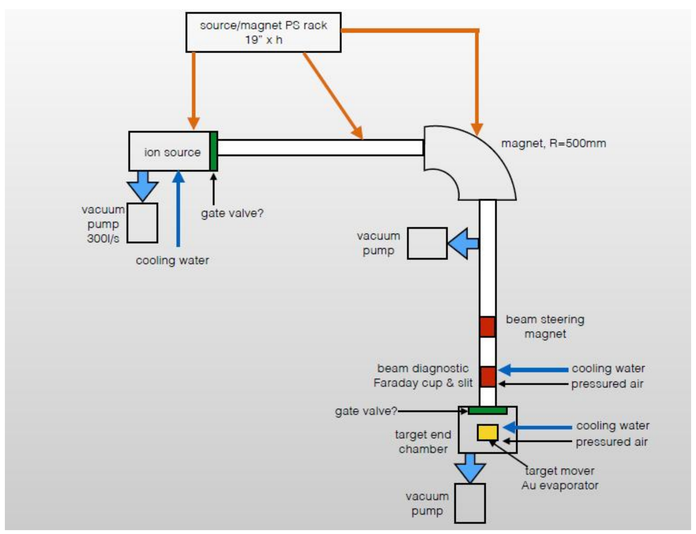






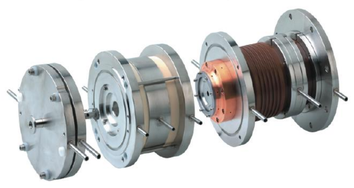
No effect of the implantation on the crystal structure of the films

Implantation of radioactive Ho



Custom-made system:

- sputtering source (metallic target)



- isotopic mass selection
- Ho shallow implantation
- thermal evaporation chamber

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