Microfabrication of TES microcalorimeters for the HOLMES experiment

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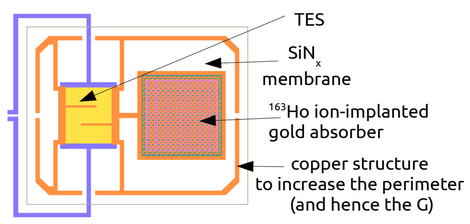
HOLMES is an experiment aiming at pushing down the sensitivity on the smallest neutrino mass at the order of ~ eV performing a calorimetric measurement of the Electron Capture decay spectrum of 163Ho. For reaching its goal, HOLMES will deploy an array of 1000 microcalorimeters based on Transition Edge Sensors with gold absorbers in which the 163Ho will be ion implanted. A major challenge is represented by the fabrication of the microcalorimeters with the required amount of 163Ho (300 Hz/det). Therefore, the fabrication process needs to be compatible with ion implantation without impairing the detector performances. The gold absorber will be fabricated in more steps: before, during and after the ion implantation. In particular, the gold deposition during the embedding process is intended to compensate for the absorber atom sputtering caused by ion implantation and to control the 163 Ho concentration in the detectors. The implanted area will finally be encapsulated in-situ to ensure the fully containment of the decay energy and to avoid oxidation of the holmium.We describe here the multi-step microfabrication process, mainly focusing on the last steps..

Detector design

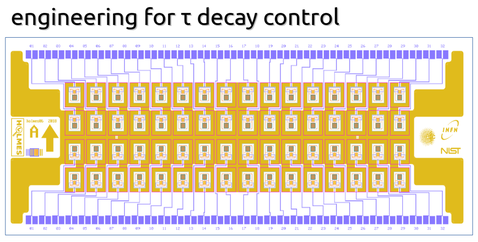
Detectors: Transition Edge Sensor (TES) with ^{163}Ho implanted in Au absorbers

Activity: 6.5x10^{13} nuclei per detector
→ 300 dec/s

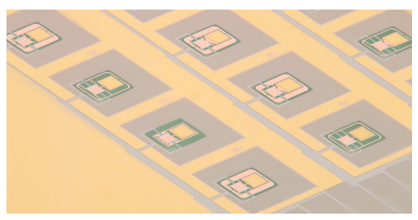
Performances: $\Delta E \approx 1$ eV and $\tau_R \approx 1$ µs



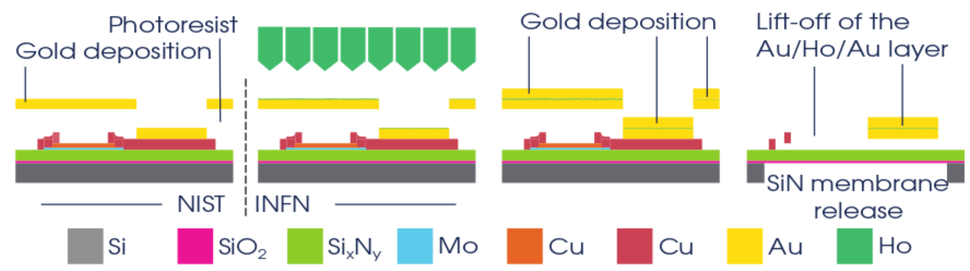
Design: side-car design to avoid TES proximitation and G engineering for τ decay control



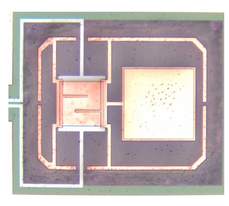
4 x 16 linear sub-array
for low parasitic L and
high implant efficiency
7x19 mm in size



Detector array fabrication

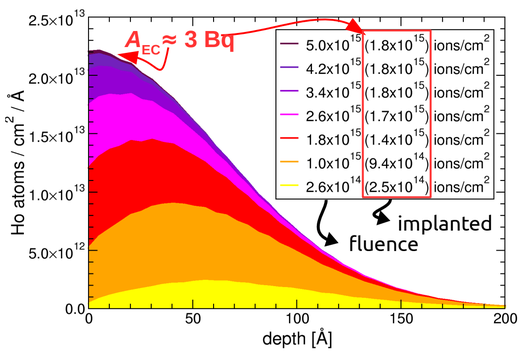


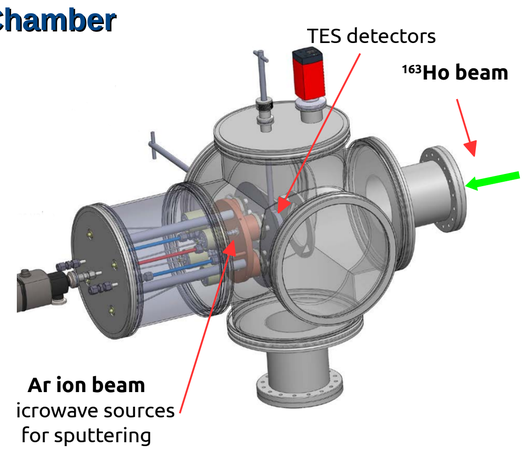
- TES originally fabricated at NIST, Boulder, CO, USA
- ^{163}Ho implantation and final 1 µm Au layer deposition at INFN, Genova, Italy
- final fabrication processes: SiN membrane release & lift-off



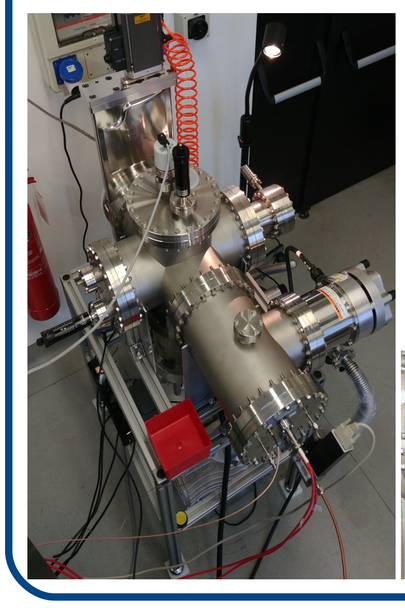
Target Chamber

ion implant simulation with SRIM2013
^{163}Ho ions on Au (E_{ion} = 50 keV)



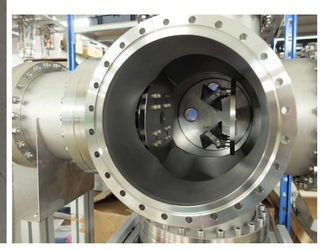


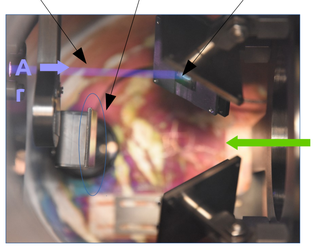
- ^{163}Ho concentration in absorbers saturate because ^{163}Ho sputters off Au from absorber
- effect compensated by Au co-evaporation (also for heat capacity reasons)
- final 1 µm Au layer deposited in situ to avoid oxidation

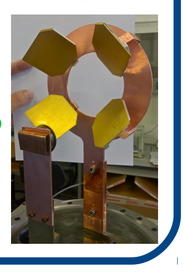


Ion Beam sputter system for on-line deposition

- 4 ECR ion beam sources
- Testing/optimization in progress with 4 ECR sources
  → Au deposition rate control and maximization
  → Au film quality and uniformity characterization
- Deposition rate ≈ 50nm/h



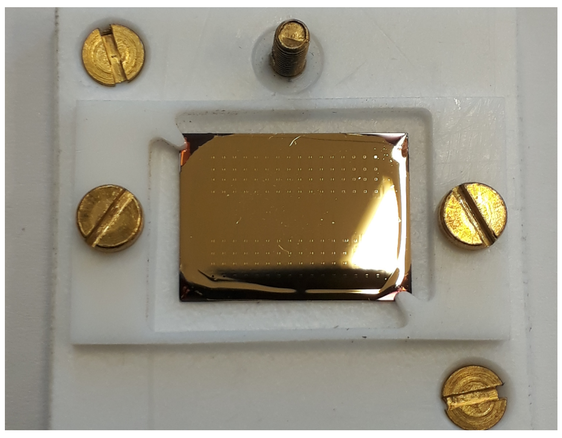




Lift off step

Patterning of Gold Absorber

Deposition of 1 µm of Au (~20 h)
Photoresist mask → 7 µm thickness



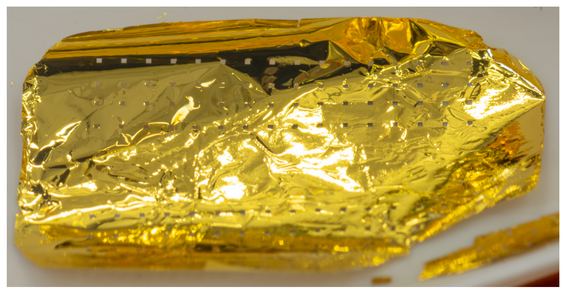
Zoom of a single absorber

Dimension:
- 200 x 200 µm
- 2 µm thickness

Minimal crowning
Almost isotropical deposition thanks to the 4 ion beam sources

- Sample in acetone for 24 h
- Acetone @ 40°C

After the lift-off, the Au dopisited remains only on the Absorber



SiN membrane release

two options for membrane release (i.e. final array fabrication step)

- Silicon Deep Reactive Ion Etching (DRIE)
- best for close packing and high implant efficiency
- not yet properly tuned → work in progress

- Silicon KOH anisotropic wet etching
- requires more spacing between pixels
- succesfully tuned → **HOLMES baseline**

calculated ^{163}Ho beam FWHM width

In summary

Deposition of 1 µm Au →

→ KOH etching →

→ Lift-off

Final result

The first processed HOLMES array without 163Ho is in measurement now!

Poster presented at LTD18, 22-26 July 2018, Milan