PROCEEDINGS OF SCIENCE

HOLMES: The Electron Capture Decay of ^{163}Ho to Measure the Electron Neutrino Mass with sub-eV sensitivity: TES detector and array production.

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The HOLMES experiment aims to directly measure the neutrino mass with a final resulting mass sensitivity as low as 0.4 eV exploiting the energy released in the Electron Capture (EC) decay of the radioactive isotope ^{163}Ho with the calorimetric technique. An array of low temperature microcalorimeters will be used. Specifically, the microcalorimeters two step microfabrication process carried on by NIST and INFN-Genoa laboratories will be presented in this proceeding. Moreover the problem of the effective heat capacity of the microcalorimeters absorber will be discussed. Effectively, the relatively high concentration of Ho could cause an excess heat capacity in the metallic absorber, due to hyperfine level splitting of the implanted ion.

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1. Introduction

The HOLMES experiment aims to directly measure the neutrino mass with a final resulting mass sensitivity as low as 0.4 eV doing a calorimetric measurement of the energy released in the Electron Capture (EC) decay of the radioactive isotope ^{163}Ho using an array of low temperature microcalorimeters. HOLMES will be an important step forward in the direct neutrino mass measurement with a calorimetric approach as an alternative to spectrometry in order to eliminate the systematic uncertainties arising from the use of external beta source. We outline here the project with its technical challenges and perspectives. HOLMES will deploy a large array of low temperature microcalorimeters with implanted ^{163}Ho nuclei. Its optimal experimental configuration has been defined through extensive Monte Carlo statistical analysis and it is based on the present knowledge of the^{163}Ho decay parameters [1] [2] . In its baseline configuration HOLMES will collect about $3 \cdot 10^{13}$ decays with an instrumental energy resolution ΔE of about 1 eV FWHM and a time resolution τ_R of about 1 μs. To obtain this energy resolution, 3 years of measuring time t_M and a total Ho activity of about $3 \cdot 10^5$ Bq is required. Using an array of 1000 detectors, each pixel must contain a ^{163}Ho activity of about 300 Bq which gives a pile-up fraction of about $3 \cdot 10^{-4}$.

2. TES detectors and array

The detectors used for the HOLMES experiment will be Mo/Cu bilayer TESs on Silicon Nitride (SiN) membrane (Fig. 1) on which bismuth/gold (Bi/Au) absorbers will be deposited. The detectors will be fabricated in a two steps process. The first step will be carried out at the National Institute for Standard and Technology (NIST, Boulder, Co, USA) [3] [4] where the devices will be fabricated up to the deposition of the bottom half of the absorber, i.e a 1.5 μm Bi layer. The devices will be further processed in the Genoa INFN laboratory (Fig. 2). Here, a thin (few than 100 Å) layer of Ho will be be implanted in Au, then a first thin layer of Au and a second 1.5 μm Bi layer will be deposited to fully encapsulate the ^{163}Ho source. GEANT4 simulations show that with this Bi thickness only a few part (0.3 ppm) of the highest energy electrons (between 2.2 and 2.8 keV) emitted in the ^{163}Ho decay will escape from the detector. Deep Reactive Ion Etching (DRIE) of the back of the silicon wafer will follow in order to suspend the membranes with the TES microcalorimeters . The TES array is presently being designed with the aim of achieving an energy resolution ΔE_{FWHM} for a single detector of about 1 eV at the spectrum end-point and a time resolution τ_R as close as possible to 1 μs. This requires an optimal thermal design of all detector components. To minimize the stray electrical inductance L which limits the pulse rise time, the TESs will be arranged in 2×32 sub-arrays.

3. The microcalorimeters heat capacity measurement

The resolution of a microcalorimeter is defined, as a first approximation, by the following formula: $\Delta E = \sqrt{k_B T^2 C_{eff}}$ [3], ΔE the energy resolution, k_B is Boltzmann constant, T is the temperature and C_{eff} is the effective heat capacity. Because of this, an important point to analyze in order to perform the resolution of the microcalorimeters is to have a precise measurement of C_{eff}. Moreover, because of the relatively high concentration of Ho included in the gold absorbers

($\sim 10^{16}$ Ho implanted ions), it would be possible to observe an excess in the total heat capacity. This effect is due to nuclear hyperfine level splitting of the Ho ions at low temperatures [3][4]. Measurements have been already carried out in the framework of the MARE project [5] to assess the gold absorber heat capacity at temperatures below than 150 mK, both with Ho and erbium (Er) implanted ions. Those tests did not show any excess heat capacity, but further more sensitive investigations should be done. In The INFN laboratory of Genoa is installing the new cryogenic system set up for the measurement of the total heat capacity of Ho implanted gold films. If the results will show a contribution by the Ho ions, it could be necessary to dilute Ho:Au samples concentration by co-evaporation of gold during the implantation process.

4. Conclusions

This work has shown the new TES microcalorimeters array fabrication steps, that will be carried on by NIST and the INFN Genoa Group. The first microfabrication one will be pursued by NIST, then, in Genoa, ^{163}Ho implanted ions will be included in the absorber and the microcalorimeters will be suspend by DRIE technique. Moreover a new set up for the low temperature heat capacity measurement is under construction in order to have a better estimation of the resolution of the detectors.

5. Acknowledgments

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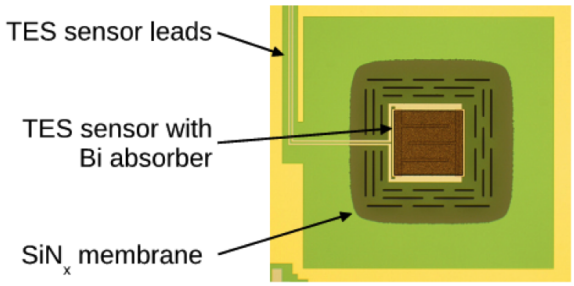

Figure 1: TES sensor with Bi absorber fabricated by NIST.

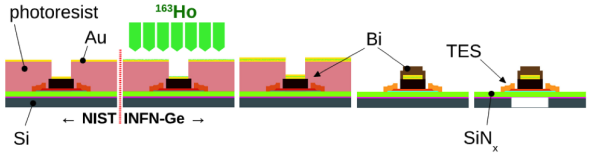

Figure 2: Ho implantation in the microcalorimeters absorbers and final suspension.

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