Development Of TES Microcalorimeter Array For DIOS Mission

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Abstract

We are developing TES microcalorimeter array for DIOS (Diffuse Intergalactic Oxygen Surveyor) mission, to perform survey observations of Warm-Hot Intergalactic Medium (WHIM) using O_{VII} and O_{VIII} emission lines. The superior energy resolution close to 2 eV FWHM will enable us to measure the WHIM lines and their redshifts, separately from the Galactic lines. The TES calorimeters are processed in our group using MEMS technology. We achieved $\Delta E = 2.8$ eV (FWHM) at 5.9 keV with a single pixel device, and trial models of 16 × 16 pixel arrays have been produced for the DIOS emission.

Key words: Microcalorimeter,-TES,-Warm-Hot Intergalactic Medium-Future mission

1. Introduction

Based on several N-body simulations of cosmological large structure formation, a significant (30-50%) fraction of baryons is thought to reside in the form of gas in a "warm-hot" phase ($T = 10^{5-7}$ K) (Fukugita et al.), which is hard to detect with currently operating missions. This warm-hot gas is called Warm-Hot Intergalactic Medium (WHIM). The importance of the observational study of WHIM can be summarized as follows:
1: Direct detection of WHIM will solve the problem of "missing baryons".
2: WHIM is the best tracer of the large scale structure gorverned by dark matter.
3: WHIM is an important probe for the chemical and thermal history of the universe.

Table 1. Parameters of the observing instruments on board DIOS

Effective erea	> 100 cm^2
Field of view	$50'$ diameter
$S\Omega$	> 100 cm^2 deg^2
Angular resolution	$3'$ (16×16)
Enerrgy resolution	$<$ 5eV FWHM (0.1-1.5 keV)
Observing life	> 5 yr

2. DIOS: Diffuse Intergalactic Oxygen Surveyor

Japanese small X-ray mission DIOS is designed to explore WHIM using emission kine for first time. The structure and performance of DIOS are shown in the fig 1 and table1. DIOS aims to detect the WHIM signal and to reveal the large scale structure of universe through the WHIM distribution. It is expected that WHIM is bright in the oxygen lines (Chen & Ostriker). A clean confirmation for the existence of WHIM to detect the redshifted ionized oxygen emission lines (O_{VII}: 574 eV, O_{VIII}: 654 eV in the rest frame). To detect the oxygen lines, the X-ray sensor needs to have superior energy resolution close to 5 eV FWHM for separation of lines from our galaxy. DIOS will use TES microcalorimeters to realize such energy resolution.

3. TES (Transition Edge Sensor) microcalorimeters

Microcalorimeters are X-ray detectors that absorb X-ray photons with the absorber, and produce signals by temperature rise. The energy resolution of microcalorimeters depends on operating temperature T, thermal capacity C and the temperature sensitivity α of thermometer. Microcalorimeters can achieve excellent performance at an extremely low temperature below 100 mK. The energy resolution of 7 eV at 5.9 keV was achieved in the orbit with Suzaku XRS which employed semiconductor thermometers (Kelley et al.). Using TES for the thermometer, it is possible to achieve the energy resolution $<$ 2 eV at 5.9 keV.

3.1. Single pixel performance

We produced TES calorimeters with in-house sputtering and dry etching processes. Our TES consists of Ti/Au thin film to control the transition temperature through proximity effect. The device is shown in fig 1(Yoshino et al.), which consists of TES with a size of 200×200×0.135

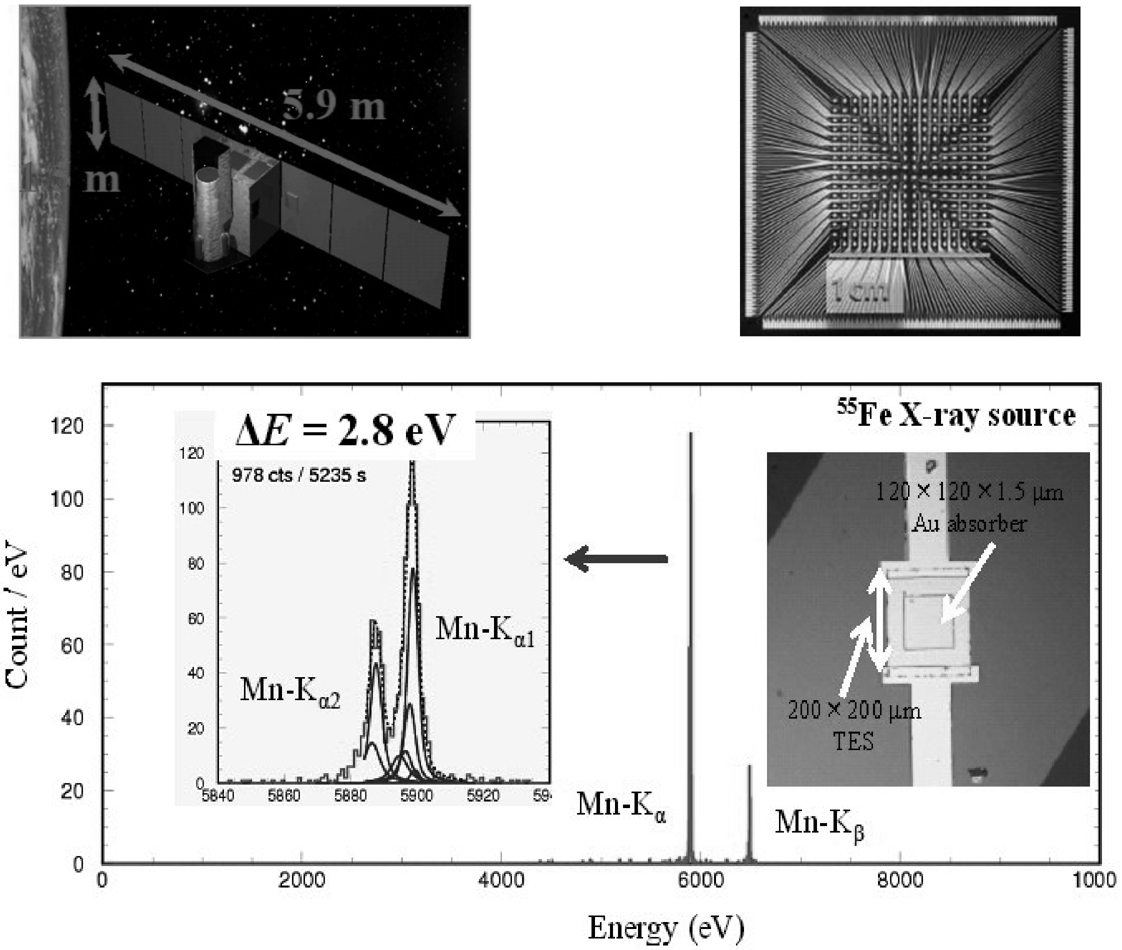

Fig. 1. Upper left: The DIOS spacecraft. Upper right: A picture of the 16×16 TES array. Lower left: Energy spectrum for ^{55}Fe X-ray source by a single pixel TES calorimeter. Lower right: the fabricated Ti/Au TES calorimeter with Au absorber.

μm^3 and Ti/Au thickness of 100/35 nm. The calorimeter is eqoipped with an Au absorber to stop X-rays, with thickness of 1.5 μm. This TES calorimeter showed good energy resolution of ΔE = 2.8±0.3 eV (FWHM) at 5.9 keV. The spectrum was fitted with seven lorentzians. The natural widths of the lorentzians, their intensities, and energy ratios are fixed based on the parameters by Holzer et al.

3.2. Multipixel array performance

To observe the spatial structure of WHIM, detector size of 1 cm^2 or more is required. We are developing a 16×16 pixel array with large absorbers to meet the requirement. Such a number of pixel with complete wiring has been only fabricated in Japan, so far. In this 16×16 array (Ezoe et al., Yoshitake et al.), each TES pisel has a size of 180 ×180μm^2 with no absorber. We achieved energy resolution ΔE = 4.4±0.2 eV at 5.9 keV.

4. Prospects

In near future, we hope to achieve energy resolution ΔE < 2 eV at 2 keV with 16×16 pixel array attached with large absorbers. We plan to formally propose DIOS to ISAS/JAXA as a small satellite mission around 2013, aiming for launch in 2015-2016.

Reference

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