Metal-metal attachment of absorbers for Gamma-Ray TES

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Introduction

Transition Edge Sensor (TES) microcalorimeter gamma-ray detector arrays to be used in the focal plane of a future hard X-ray telescope (**ASCENT**) to study gamma ray emissions from supernova remnants (Fig. 1) with the aim to improve the energy resolution in the energy range 60-85 KeV, about 15 times better than NuSTAR

- For the focal plane instrumentation, ASCENT will use detectors similar to the system 'Spectrometer to Leverage Extensive Development of Gamma-ray TESs for Huge Arrays using Microwave Multiplexed Enabled Readout' (**SLEDGEHAMMER**) which comprises of an array of 256 detectors with an energy resolution of 55eV FWHM at 97KeV
- In this energy range, absorbers, composed of high Z-element tin (Sn), are used to improve the photon collection efficiency of the detectors
- One of the problems this work focuses on, is the insufficient thermal link due to glue attachment which can add complexity to the device behavior and affect accurate signal time measurements (Fig. 2)
- Development of a method to attach the absorbers using BiSn metal spheres to improve thermalization

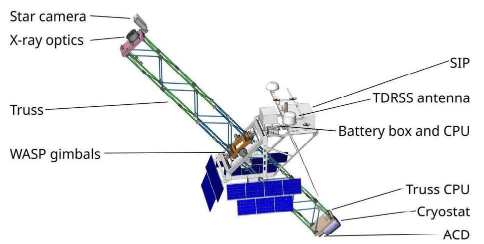

Fig. 1 : The proposed balloon-borne ASCENT telescope will flight-prove γ-ray TES microcalorimeter detectors, delivering new results on the ^{44}Ti distribution in Cas A with better energy resolution (From **[1]**)

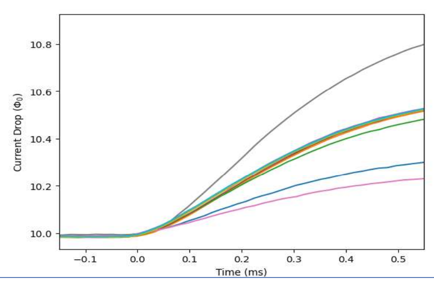

Fig. 2 : Plot showing the slow rise of a few sample pulses due to poor thermalization of the gamma-ray TESs.

Data collected using Am-241 source.

Die bonding

❑ Procedure :

Use of a die bonder to make the attachments

- Heater for the work stage was set to a particular temperature(95-100°C)
- Tweezer on the die bonder was used to pick up BiSn spheres and place on the gold chip on the work stage
- Force on the pickup tool was adjusted to attach the Sn absorbers
- Sn absorbers were picked up and pressed against the BiSn spheres on the chip with the pickup tool heater turned on for additional heat on the spheres
- Attachments with 1, 2 and 4 spheres (Fig. 3) have been tested by turning the chips upside down with a tweezer

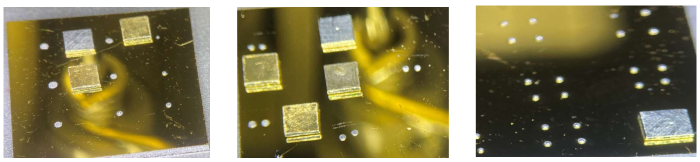

Fig. 3 : Left to right : Picture taken after testing absorber attachments with 1,2 and 4 spheres on a gold chip

❑ Observations :

- Various amounts of heat and forces were applied to attach the absorbers and the strength of the attachments with 1,2 and 4 spheres have been tested
- Absorber attachments using 2 and 4 spheres with 30g force came off easily whereas the attachments with 90g force stayed intact (temperature maintained at the same value for both cases)

❑ Conclusion :

Higher amount of force is required for attaching with 2 and 4 spheres than what is required to attach with 1 sphere

Higher values of temperature and force seemed to work better but no strict trend was observed.

Contact Resistance Measurements

❑ Procedure :

- Absorbers were attached using 2 spheres with 100g force, assembled on a PCB (Fig. 4) and installed inside a cryostat for 4-wire resistance measurements to check the change in resistance with temperature
- Resistance measurements were done using SIM921 AC Resistance Bridge at room temperature and as the cryostat was cooling down

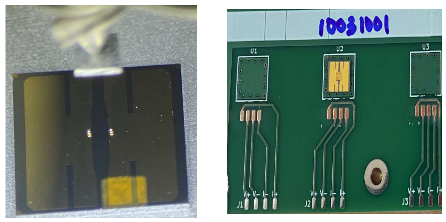

Fig. 4: *Left* : 2-sphere attachment of the absorber on the gold chip

Right : Assembled absorbers on the PCB for resistance measurements

❑ Observations :

❖ **Resistance Calculations :**

- The measurement of the chip gives us the total resistance of 2× some gold film resistance + 2× the SnBi sphere resistance + any contact resistance with the gold and the tin + 1× the Sn absorber resistance
- The resistance of a single SnBi sphere joint is likely (16.5-12)mΩ/2= 2.25 mΩ
- The resistance of the gold film contact is around 12mΩ/2= 6mΩ

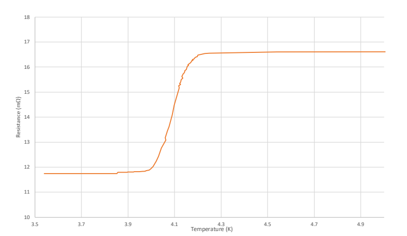

Fig. 5 : Plot showing the change in resistance measurements of the chip with temperature.

The sharp transition around 4.2 K is most likely due to the SnBi spheres and any part of it that alloyed with the Sn.

❑ Conclusion :

❖ **Thermal conductance** $G = T \times (\frac{L}{R_{el}})$ where T is the temperature, L is the Lorenz number and R_{el} is the electrical resistance.

- For R_{el} = 1Ω and T = 100mK, G = $2 \cdot 44 \times 10^{-9}$ W/K. For good contact, we want $G_{contact} > 10G \rightarrow R_{contact} < 10m\Omega$
- Since our absorber didn't fall off during the cooldown and our measured $R_{contact} = 6m\Omega$, we can conclude that it was a good attachment.

Future Measurements

- We will continue to experiment with different materials (e.g., SnBi paste, liquid metals etc.) to attach the absorbers and check the thermal conductivity.
- We will try various absorber thicknesses and cross-sectional areas to check for improvements.
- We also plan to check the glue attachment process for a better comparison.

Acknowledgements

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References

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[2] J. Ullom, D. Bennett, Review of superconducting transition-edge sensors for x-ray and gamma-ray spectroscopy, Supercond. Sci. Technol. 28 (2015) 084003 (36pp), doi:10.1088/0953-2048/28/8/084003

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