Impedance measurement of a gamma-ray TES calorimeter with a bulk Sn absorber

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1. Introduction

The response speed of gamma-ray calorimeter tends to slow by the huge absorber. Absorber physically supported by insulator like the epoxy to separate electrically. Because epoxy is an insulator, the thermal conductance is small. Therefore, for fabrication of gamma-ray calorimeter, it is necessary to consider the thermal conductance between TES and the absorber. It is essential to know the response speed of gamma-ray (time constant t) that shows thermalization speed of sensors. The optimum thermal conductance between TES and the absorber is closely related to not only the time constant of the calorimeter but also the thermal diffusion speed of absorber. From the above reason, the thermal conductance is an important parameter which shows a thermal characteristic of gamma-ray calorimeter.

Figure 1

2. Impedance measurement

Figure 2

3. Basic parameters ~ α, β, C, G, Gα ~

Figure 3a shows the obtained parameters, α, β, C, G, and Gα. Horizontal axis is relative resistance R/R0 at the bias point normalized by the normal state resistance, R0 = 63 mΩ. Thermal sensitivity α and current sensitivity β have two peaks due to two-step transition in R-T curve. Straight lines at C = 6.9 pJ/K, C = 40 nW/K, and G = 40 nW/K indicate the estimation by [1]. Result of this fit roughly agree with the estimation. Because it is unlikely that heat capacity of the Sn absorber, C, changes depending on the bias point, we fixed C = 6.9 pJ/K in the fit. Figure 3b shows the obtained parameters. Thermal sensitivity α increased compared with fig3a, while current sensitivity β did not change so much. Thermal conductance Gα became almost constant at about 10% higher value (~ 45 nW/K) than the estimation.

Figure 3

4. Noise contribution on energy resolution

Using parameters of TES which determined by impedance measurement (tab 1), we calculated the Johnson (Blue), phonon (Magenta), and the ITFN (Black) noise, and they are plotted in Fig. 4. We introduced three kinds of excess noise which have same frequency dependency with the Johnson, phonon, and the ITFN noise. Dotted line shows each excess noise spectrum, and they are 2.0, 2.2, and 0.8 times the Johnson, phonon, and the ITFN noise, respectively. Table 2 shows breakdown of the energy resolution. In this table, ΔE = (ΔEITFN^2 + ΔEphoton^2 + ΔEJohnson^2)^1/2, where ΔEITFN is the baseline energy resolution calculated from the observed overall noise spectrum, and ΔEJohnson is the contribution of the pulse variation.

Table 1: TES parameters at bias point which achieved ΔE = 38.4 eV @ 60 keV

<table>
<thead>
<tr>
<th>R0 (mΩ)</th>
<th>R (mΩ)</th>
<th>R0 (mΩ)</th>
<th>R (mΩ)</th>
<th>R0 (mΩ)</th>
<th>R (mΩ)</th>
<th>I (μA)</th>
<th>β (nW/K)</th>
<th>C (pJ/K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.41</td>
<td>26</td>
<td>0.5</td>
<td>3.1</td>
<td>154</td>
<td>130</td>
<td>5.6</td>
<td>0.7</td>
<td>75</td>
</tr>
<tr>
<td>0.67</td>
<td>75</td>
<td>0.49</td>
<td>1.74</td>
<td>6.9</td>
<td>45</td>
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</tbody>
</table>

Table 2: Contribution of each noise component to measured energy resolution

<table>
<thead>
<tr>
<th>ΔE (eV)</th>
<th>ΔEITFN</th>
<th>ΔEphoton</th>
<th>ΔEJohnson</th>
<th>ΔEITFN</th>
<th>ΔEphoton</th>
<th>ΔEJohnson</th>
<th>ΔEITFN</th>
<th>ΔEphoton</th>
<th>ΔEJohnson</th>
<th>ΔEITFN</th>
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<tbody>
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<td>38.4</td>
<td>8.1</td>
<td>37.2</td>
<td>4.7</td>
<td>9.2</td>
<td>10.5</td>
<td>16.4</td>
<td>7.39</td>
<td>10.4</td>
<td>13.2</td>
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</table>

5. Conclusion

We confirm parameter of the calorimeter obtained by impedance measurement correspond with estimation[1]. Using those parameters, we calculated the Johnson, phonon and ITFN noise. We found that the phonon-like excess (p-excess; 25.3 eV) and the ITFN noise (14.9 eV) are dominant components of the noise. The p-excess noise is probably originated in fluctuation of Tγ due to the irradiation of gamma-ray to the surrounding silicon substrate [4]. This can be reduced by attaching a collimator. The ITFN can be reduced by increasing the thermal conductance Gα. In the development of the gamma-ray microcalorimeter, an adhesive with good thermal conductivity is important.

6. Reference