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First measurement of an infrared dielectric bolometer with microwave readout and possible extension to a large-scale format X-ray microcalorimeter

Main author:

KIKUCHI Takahiro

Co-authors:

Hoshino Masatoshi, ISAS/JAXA
KIKUCHI Takahiro, ISAS/JAXA
Mitsuda Kazuhisa, ISAS/JAXA
Sato Kouske, ISAS/JAXA
Sekiya Norio, ISAS/JAXA
Yamasaki Noriko, ISAS/JAXA

Dielectric microcalorimeters (DMC) and dielectric bolometers are considered to be promising devices for a large format (~Mega pixel) array if the signals are read by microwave resonance like Microwave Kinetic Inductance Detectors (MKIDs) (Sekiya et al. 2012), because of the low heat dissipation per pixel and the possible large number of signal multiplexing at the cryogenic temperature. It is suitable for an X-ray spectrometer because the device can be designed so that the energy deposited by an X-ray photon heats up the X-ray absorber first then the energy gradually dissipated into the heat bath through a weak thermal link, which is a typical operations of X-ray mirocalorieters. Thus the final goal of our research is to develop X-ray spectrometers. However, in this paper we report the first attempt to measure infra-red energy flux with DMC in bolometer mode in order to characterize the thermal properties of the DMC. We plan to utilize SrTiO3 (STO) of which certain fraction of O is replaced with 18O. However, in this study we utilized STO with O in natural isotope fractions because it is more easy to obtain. As the consequence temperature dependence of dielectric constant appears in 4 K to 2 K range instead of 100 mK and the DMC is not suitable for X-ray photon detection.

We have fabricated a single pixel device consisting of a STO of 2.5x2.5x0.1 mm3 size and a micro-strip-line wave guide. The STO capacitor was placed on a stab structure coming out from the microstripline. GHz microwave was supplied to the one end of the wave guide and the output signal was amplified with an hetero junction bipolar transistor (HBT) amplifier at 4 K before it is sent to room temperature electronics through a semiridged cable.

We successfully observed a resonance of the stab and the STO at 7.5 GHz at 77 K then it moved to 2.308 GHz and 2.293 GHz at 4 and 2 K, respectively. We then supplied a bias frequency at the half maximum of the resonance dip at 2K and 4K respectively. We observed at both temperatures a shift of phase and amplitude in the output signal when the STO is illuminated with infrared photons. The difference of signal amplitude, rise and decay time constants are found to be consistent with the temperature dependence of heat capacity and thermal conductance. We thus consider that the device is working as a bolometer as designed.

We estimated the amplitude of signal to an X-ray photon assuming 18O STO working at 100 mK. It can be detected with the present experimental set up though the noise level will be limited with the room temperature electronics.