Abstract—We have carried out a terahertz (THz) passive measurement of high-Tc superconductive materials down to liquid nitrogen temperature at 1.5-2.5 THz using a 4 K-cryocooled stressed Ge:Ga photoconductive detector. Using the calibration line, which gives the relation between THz signal emitted from sample, emissivity and temperature, we have derived the temperature-dependent THz emissivity of superconductive materials. The result shows that emissivity of superconductive materials steeply change around each superconductive transition temperature. We also demonstrated the THz passive imaging of superconductive wires and successfully obtained THz passive images before and after superconductive transition.

I. INTRODUCTION

TERAHERTZ (THz) imaging has been drawn intense interest in research because of their potential in application to nondestructive inspection in many fields [1, 2]. THz imaging is classified into active method detecting transmitted or reflected radiation from a sample using an external THz source and passive method detecting thermal radiation emitted the sample. THz passive imaging has a great advantage that it needs no extra source. However, it requires sensitive THz detectors such as cryogenic detectors or heterodyne mixers to receive weak thermal THz radiation. Uncooled thermal infrared camera (8-14 µm) is widely used for nondestructive inspection. However, the infrared camera is difficult to measure a cold object since the blackbody radiation from low temperature objects drastically reduces in infrared region. In contrast to the infrared, THz passive imaging can measure the cold object because the blackbody radiation has a linear temperature dependence even the liquid-nitrogen (liq. N₂) temperature in THz region. Therefore, we are conducting THz passive imaging to measure the cold object.

Owing to its outstanding electric conducting properties, high-Tc superconductive materials have been studied in many fields. Especially, high-Tc superconductive wire has been manufactured for demonstrations of transmission cables, motors and other electrical power components [3]. To fabricate uniform and high quality superconductive layer is important to manufacture practical wire [4] because defects in the superconductive layer cause to decrease the critical current and to occur the quench effect. Therefore, it is necessary for the technique to monitor the status. THz passive imaging is suitable for these applications because the emissivity and temperature changes which caused by defects and quench effect can detected even the liq. N₂ temperature.

In this study, we measured the THz radiation from superconductive materials at from room temperature to 77 K using the THz passive imaging apparatus with a 4 K-cryocooled stressed Ge:Ga photoconductive detector at 1.5-2.5 THz.

II. THZ PASSIVE IMAGING APPARATUS

For this measurement, we used the 4 K-cryocooled stressed Ge:Ga photoconductor with background limited performance (NEP=7.7×10⁻¹⁵ W/√Hz, NETD=11 mK) in 1.5-2.5 THz [5]. The detector assembly comprises a stressing mount containing a Ge:Ga detector chip, a Winston cone condenser [6], a low-pass filter for THz wave and a 200 µm pinhole placed in front of the condenser. The passive imaging apparatus also consists of two off-axis parabolic mirrors and a sample stage on the raster scan stage. THz radiation emitted from the sample is collected and collimated with the first off-axis parabolic mirror and is focused on the pinhole just before the detector by the second off-axis parabolic mirror. THz radiation is condensed by the Winston cone condenser after passing through the pinhole and then detected by the stressed Ge:Ga detector. To perform the measurement at down to liq. N₂ temperature, we employed the sample stage made of gold-plated oxygen-free copper which is soaked in liq. N₂ in a vacuum flask for the THz passive imaging apparatus [7] as shown in Fig. 1. A platinum thermometer (EL-701-TN) is fixed on the top of the sample stage to monitor the temperature of samples down to 77 K. We have performed all measurements under dried nitrogen atmosphere inside the acrylic case in order to prevent cold samples from the frost and reduce the influence from background radiation.

![Experimental setup for emissivity measurement of high-Tc superconductive materials down to liq. N₂ temperature with the 4K-cryocooled stressed Ge:Ga photoconductive detector.](image-url)
III. EMISSIVITY MEASUREMENT OF SUPERCONDUCTOR

We measured signals of THz radiation from three samples as a function of temperature, which are YBCO thin film \(T_c=92\,\text{K}\), GdBCO superconductive wire \(2\,\text{GHTS}, T_c=92\,\text{K}\), and BSCCO superconductive wire \(\text{DI-BSCCO}, T_c=110\,\text{K}\). GdBCO and BSCCO wires covered with the protection and/or stabilization layers. Therefore, we measured signals of THz radiation from the samples after we etched these layers selectively. Using the calibration line, which gives the relation between THz signal emitted from sample, emissivity and temperature, we have derived the emissivities of the samples as functions of temperature as shown in Fig. 2. Due to method for calculating emissivity, the accuracy of calibration to reduce emissivity is poor at the vicinity of 240 K. As can be seen from Fig. 2, THz emissivities of samples steeply change around each superconductive transition temperature. This is due to the emissivity, which is identical with absorptance, is a little smaller for normal conducting state than for superconducting state in THz region \[8, 9\].

IV. THZ PASSIVE IMAGING OF SUPERCONDUCTIVE WIRE

We have measured the high-\(T_c\) superconductive materials change around each superconductive transition temperature from the temperature dependent emissivity measurement and THz passive imaging. THz passive imaging will be implemented for the application to the nondestructive inspection of superconductive materials in the near future.

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