B-1-2 Pyroelectric Si-monolithic Sensor Using $PbTiO_3$ Thin Film

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Recently much attention has been paid for infrared sensors from a viewpoint of wide applications to infrared sensing technology such as remote sensing, biomedical thermography and gas detection. Pyroelectric infrared sensor has many attractive points as compared with photon type sensors like HgCdTe and Ge;Cu operated at low temperature, because the pyroelectric can be operated even at room temperature and has basically no wavelength dependence of the response over wide infrared range. By utilizing the pyroelectric effect, we have recently developed IR-OPFET(Infrared Optical FET) which is an infrared-sensitive Si MOSFET having $PbTiO_3$ ferroelectric thin film gate[1]. This Si-monolithic sensor showed large responsivity(390 V/W at 20Hz) and fast response(rise time ∿3.5 μsec) in wide infrared region. However, the response decreases with chopping frequency of infrared light because the pyroelectric output amplified by high-input-impedance amplifier is inversely proportional to the frequency, and its value is still small because absorbed infrared energy (heat) spreads in the whole volume of Si wafer and fractional temperature change of the pyroelectric film is reduced very much. In this paper, we have prepared a Si-monolithic infrared sensor which amplifies the pyroelectric current by a bipolar transistor in order to improve the responsivity at high frequency, and increased the responsivity by reducing the thermal capacity with etching of Si layer beneath the sensitive area.

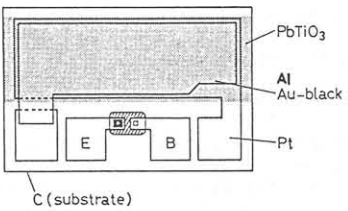

Fig. 1 Device structure.

Figure 1 shows a sample structure proposed here. $PbTiO_3$ thin film is deposited on Pt-coated SiO_2-Si substrate by rf sputtering, and Al and Au-black are formed on the $PbTiO_3$ film as an infrared-absorbing electrode. Pyroelectric current of the $PbTiO_3$ film is amplified by a bipolar transistor fabricated on the same Si wafer and infrared signal can be detected as a collector current.

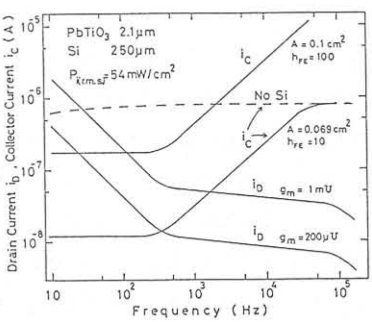

Fig. 2 Calculated frequency dependence of pyroelectric current amplified by a bipolar transistor(i_C) and by an FET(i_D).

Frequency dependence of pyroelectric signal can be calculated from an analysis of thermal conduction, and a comparison between the pyroelectric currents amplified by a bipolar transistor (i_C) and by a FET (i_D) are shown in Fig. 2. i_C little changes at low frequency, but increases with frequency above ∿200 Hz as thermal conduction to the Si wafer can't follow the chopping frequency at high frequency. On the other hand, i_D is almost inversely proportional to the frequency at low frequency and become flat at high frequency because of large CR time constant. So the response can be improved at high frequency by using the bipolar. Pyroelectric response was measured under a chopped infrared light coming through a Ge filter from an incandescent lamp. Figure 3 shows the frequency dependences of output voltage V_O, noise voltage V_N and detectivity D* of the fabricated device of Fig. 1. V_O increases with the frequency as well as i_C of Fig. 2 and is lager than that of IR-OPFET(V_{FET}) at high frequency under infrared irradiation with the same intensity. V_N decreases with the frequency due to the noise of the bipolar transistor and so D* increases abruptly with the frequency.

Moreover an attempt to raise the responsivity has been done by reducing a heat capacity of the infrared-sensitive area. Si beneath a part of the SiO_2 film is etched off from narrow SiO_2 holes of width ∿25 μm using a preferential etchant of ethylenediamine, pyrocatecol and water. SiO_2(∿5000 Å thick) and $PbTiO_3$(∿2 μm thick) membrane bridged between Si plateau is floated over the Si substrate (∿250 μm) as illustrated in Fig. 4. The pyroelectric current of this structure is shown in Fig. 5 and Si under one third of the sensitive area is etched off. This current is one order of magnitude larger than that of the film attaching directly to the Si. The improved result of the device with the structure of Fig. 1 will be given in the presentation.

1) M. Okuyama, Y. Matsui, H. Seto and Y. Hamakawa: Proc. of the 12th Conf. on Solid State Devices, B-4-9, p.315, Tokyo, 1980.

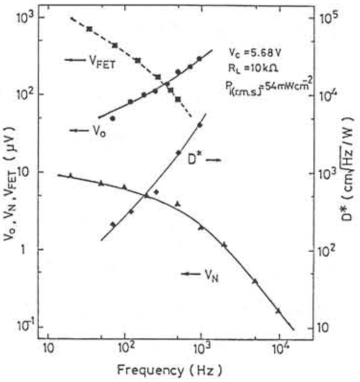

Fig. 3 Frequency dependence of output voltage V_O, noise voltage V_N and detectivity D of the fabricated device and output voltage of IR-OPFET V_{FET}.*

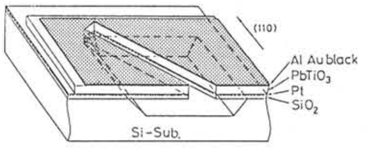

Fig. 4 Improved sample structure with floating SiO_2.

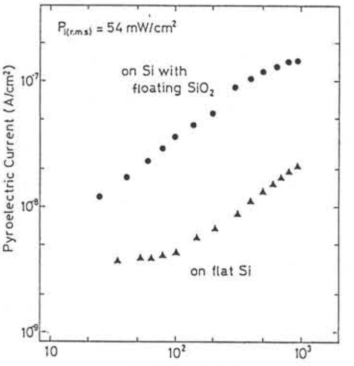

Fig. 5 Frequency dependence of pyroelectric current of the sample with and without floating SiO_2.