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Integration of epitaxial PZT thin film infrared detector array with JFET compatible CMOS process

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Abstract

In this research, epitaxially grown PZT thin film and JFET and MOSFET are integrated on Si substrate. To deposit epitaxial PZT film, epitaxial γ-Al_2O_3 thin film on Si is used. These material and circuit integration is achieved with process improvements for both PZT and circuit. Infrared absorbing film is also deposited on the detector to improve sensitivity.

1. Introduction

Surveillance, night vision, medical monitoring, and gesture interface are expected to be the application of infrared detector array. The trend of infrared detector array development is mainly miniaturization, high resolution, sensitivity improvement, and low cost fabrication.[1-3] However, miniaturization is reaching to technological limit, thus the cost reduction is no longer efficient. The device development of infrared detector needs to change its direction.

Today, value-added-device with appropriate structure needs to be researched for each application. Device with particular materials is the one of the way to achieve more functional device. Therefore material based development is required for breakthrough technology for infrared detector device and future prospects.

We have studied pyroelectric infrared detector array.[4] Pyroelectric detector has advantage of high sensitivity and is possible to integrate on Si substrate by MEMS technology which is suitable for low cost process and miniaturization. The device consists of two features, high sensitive epitaxial PZT thin film sensor and low noise integrated circuits. In this research we have developed fabrication process of JFET compatible MOS device with epitaxial grown PZT thin film sensor on a single Si substrate.

2. Device Concept

Epitaxial PZT thin film sensor with JFET and MOSFET integrated circuits on γ-Al_2O_3/Si substrate is the main concept of our proposal device (Figure 1). Epitaxial PZT thin film is the key material deposited for sensitivity improvement. To fabricate this device, γ-Al_2O_3 film is epitaxially grown on Si(001) substrate by metal organic chemical vapor deposition (MOCVD), and Pt electrode and PZT thin film are epitaxilly deposited subsequently. PZT film is sandwiched between electrodes on Pt/γ-Al_2O_3/Si substrate.

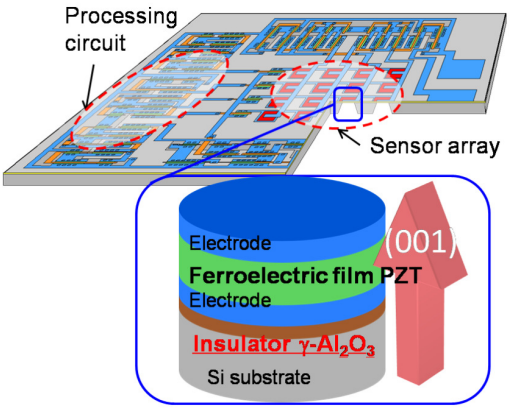

Fig.1 Schematic illustration of pyroelectric infrared detector array with epitaxial PZT film sensor

The purpose of this research is development of fabrication process to integrate epitaxial PZT thin film with JFET and MOSFET circuit. Pyroelectric infrared detector requires infrared chopper to obtain temperature change which is principle of pyroelectric effect. Typically chopping frequency is low, 10 to 30 Hz for instance. Then flicker noise will be dominant noise. The cause of flicker noise is the dangling bond and defect between SiO_2 and Si surface where the channel of MOSFET is formed. JFET's channel is formed away from Si surface in deep part of Si substrate that expected to reduce flicker noise in infrared detection.

3. Fabrication improvement

Integration of PZT film and JFET CMOS circuit has many difficulties because of the post-CMOS process of PZT film deposition and patterning that damage circuit characteristics. The PZT sensor is also damaged by plasma induced processes and is vulnerable to crack and peel off of the PZT film. Therefore new fabrication processes require characteristics of the ferroelectric PZT and circuitry to remain the original characteristics.

In this work, 3 processes have been improved as follows: 1) changing electrode material for preventing cracking and peeling off of PZT thin film, 2) reduction of leak current by changing p-well doping concentration of FET, 3) infrared absorbing film for improving sensitivity of detector. These changes are applied to a new fabrication process to achieve the integration of PZT thin film sensor, JFET and

MOSFET circuitry. Then the characteristics of the JFET the MOSFET and the PZT sensor are evaluated.

4. Results and Discussions

A microscopic image of the fabricated PZT detector integrated with nJFET and nMOSFET on a Si substrate as shown in Figure 2. Figure 3 and Figure 4 shows typical Id-Vgs characteristics of fabricated n-channel JFETs and nMOSFETs. Both transistors are successfully fabricated without large leak current and remain their original performance after all over PZT sensor fabrication processes. P-E hysteresis of the epitaxial PZT thin films detector exhibits no characteristics inferior as shown in Figure 5. The SiO_2/SiN double layer infrared absorbing film is deposited and patterned on PZT detector. The average infrared absorption has achieved 70% in wavelength between 8 to 14μm which is a target wavelength for human detection (Figure 6).

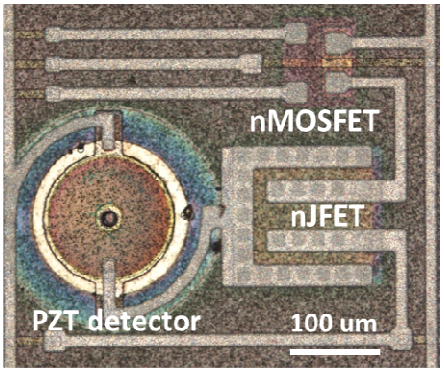

Fig.2 Fabricated PZT infrared detector with JFET and MOSFET circuit

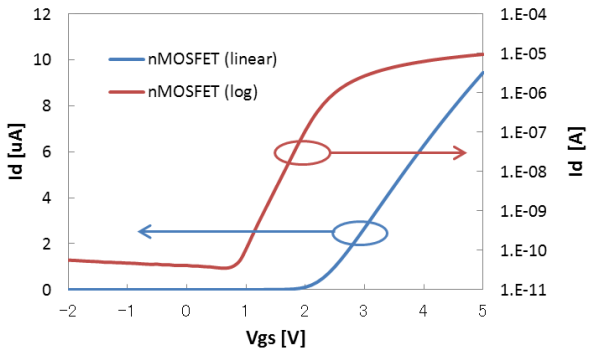

Fig.3 n-channel JFET Id-Vgs characteristics

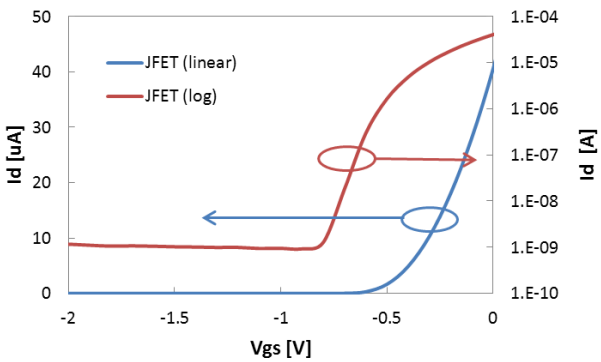

Fig.4 nMOSFET Id-Vgs characteristics

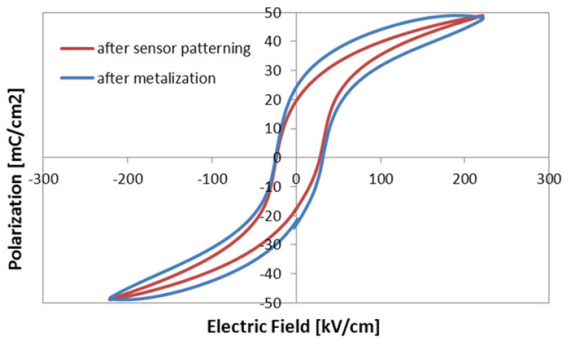

Fig.5 Polarization characteristics of PZT ferroelectric thin film, thickness of 450nm

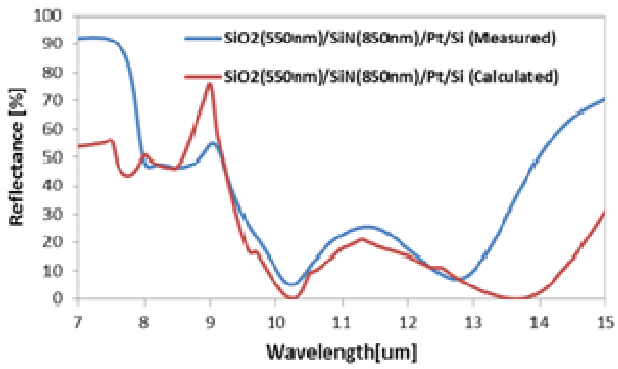

Fig.6 Reflectance of SiO_2/SiN infrared absorbing film

5. Conclusion

Epitaxially grown PZT thin film and JFET compatible MOS circuit are successfully integrated on Si substrate with γ-Al_2O_3 thin film. Several changes in fabrication processes have achieved to prevent characteristic inferior and improve infrared absorption. Consequently, fabrication of high performance PZT infrared detector with JFET MOSFET compatible circuit is prospected in near future.

References

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