Extended Abstracts of the 20th (1988 International) Conference on Solid State Devices and Materials, Tokyo, 1988, pp. 635-636 **LC-5-8**

Photovoltaic Infrared Sensor Arrays in Epitaxial Narrow Gap Lead-Chalocogenides on Fluoride Covered Silicon Substrates

H. Zogg, C. Maissen, J. Masek, S. Blunier
AFIF (Industry research unit) at Swiss Federal Institute of Technology, ETH-Hönggerberg, CH-8093 Zürich, Switzerland

Linear arrays of photovoltaic infrared (IR) sensors for thermal imaging applications have been fabricated for the first time in narrow gap semiconductor layers (PbTe and $Pb_{1-x}Eu_xSe$) grown heteroepitaxially on Si.

Heteroepitaxy and sensor fabrication were achieved using the fluoride buffer layer technique already demonstrated with single PbTe-sensors for the 3-5 µm, and $Pb_{1-x}Sn_xSe$-sensors for the 8-12 µm atmospheric window [1]. The intermediate stacked ≈2000 Å thick epitaxial CaF_2-BaF_2 buffer layers allow to overcome the lattice mismatch up to 20% as well as the large thermal expansion mismatch between lead chalcogenides and Si [2], and can also be applied to other largely mismatched systems like CdTe on Si [3].

The fluorides were grown by molecular beam epitaxy (MBE) on (111)-oriented Si-substrates as described elsewhere [2]. (111)-orientation was chosen because epitaxial fluoride growth is easiest with this surface. However, we recently have been able to grow high quality BaF_2(100) on CaF_2 covered Si(100) despite its strongly preferred (111)-growth mode and 14% lattice mismatch.

PbTe-layers of ≈3 µm thickness were grown onto these fluoride covered Si-substrates using hot wall epitaxy (HWE), while the ternary lead chalcogenides were grown by MBE (the MBE growths were performed at the Fraunhofer-Institut in Freiburg, FRG).

Photovoltaic IR-sensors were formed following the technique developed for PbTe on bulk BaF_2 using blocking Pb-contacts on p-type layers [5]. Staggered 66 x 1 sensor arrays with 50x100 μm^2 active areas of the individual elements were fabricated in the layers as shown schematically in Fig. 1. Pt is used as a common ohmic contact and an insulating layer isolates the fan-out pattern to the Si-substrate. Illumination is from the backside through the IR-transparent substrate and fluoride buffer.

At present, our development for PbTe-arrays on Si is most advanced. Fig. 2a) shows I-V-characteristics and spectral response of a typical sensor at 90K. Its resistance-area product R_0A is ≈400 $\Omega\,cm^2$, while the mean R_0A of the whole array is ≈150 $\Omega\,cm^2$. This value is much above the background noise limit for room temperature radiation with 180° field of view (FOV), and would correspond to a sensitivity D^*_λ = $1.1\cdot10^{12}$ cm $sec^{-1/2}$ W^{-1} in a strongly reduced FOV. Typical quantum efficiencies are around 70% up to the cut-off wavelength of ≈5.6 µm.

As shown in Fig. 2b), R_0A = 0.3 Ωcm^2 (corresponding to D^*_λ = $2.6\cdot10^{10}$ cm $sec^{-1/2}$ W^{-1}) is achieved at 200K, and the cut-off is shifted to somewhat

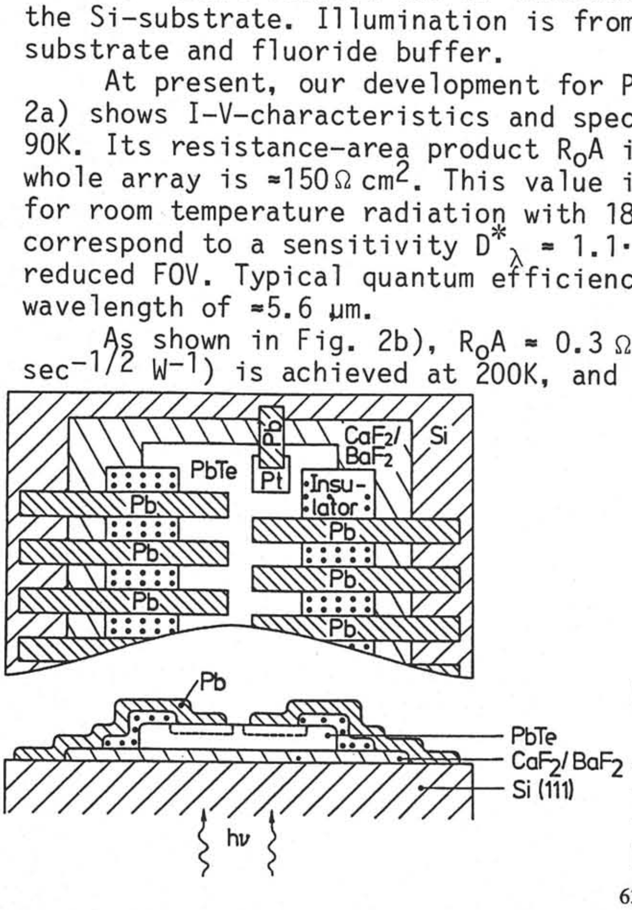

Fig. 1. Layout of a linear photovoltaic IR-sensor array on Si-substrate with epitaxial PbTe layer and step graded fluoride buffer. The active areas below the Pb-blocking contacts are indicated by dashed lines.

shorter wavelength (≈4.5 µm) due to the positive temperature dependence of the band gap energy. R_0A ≈ 0.04 Ωcm^2 (corresponding to $D^*_\lambda \approx 7\cdot10^9$ cm $sec^{-1/2}$ W^{-1}) and λ_{co} ≈ 4.0 µm is achieved at room temperature. Although our growth- and fabrication procedures are still far from being optimized, these values are already significantly higher than those of commercial photoconductive (polycrystalline) PbSe-sensors with comparable cut-offs and at comparable temperatures. In addition, photovoltaic narrow gap PbTe-sensors allow operation at higher temperature, have higher quantum efficiencies and the cut-off extend to higher wavelengths than platinum-silicide Schottky-barrier IR-sensors.

The Pb-blocking contact technique works also with $Pb_{1-x}Eu_xSe$ on Si [7], where increasing Eu concentration shifts the cut-off towards lower wavelength [6]. In contrast, $Pb_{1-x}Sn_xSe$ is used for sensor fabrication for the 8-12 µm range [1].

Growth temperatures are below 700°C for deposition of the buffer, and below 400°C for growth of the narrow gap semiconductor layer and the further fabrication steps. The processing appears compatible to be applied with active silicon substrates which contain signal processing electronics, thus opening the way to a heteroepitaxial, but fully monolithic approach of staring IR-focal plane arrays.

[1] H. Zogg, P. Norton, Techn. Digest Int. Electron Devices Meeting IEDM, Washington D.C. Dec. 1985, p. 121.
[2] H. Zogg, S. Blunier, H. Weibel, Proc. 2nd Int. Symp. on Silicon Molecular beam epitaxy, Proc. Vol. **88-8**, 1988, 321; J. Electrochem. Soc., XXX, 1988.
[3] H. Zogg, S. Blunier, Appl. Phys. Lett. **49**, 1531, 1986.
[4] S. Blunier, H. Zogg, H. Weibel, Mat. Res. Soc. Symp. Proc. **116**, XXX, 1988.
[5] H. Holloway, Physics of Thin Films **11**, 1980, 105.
[6] J. Masek, C. Maissen, H. Zogg, S. Blunier, H. Weibel, Proc. ESSDERC 88, Montpellier F, Sept. 1988., to be published.

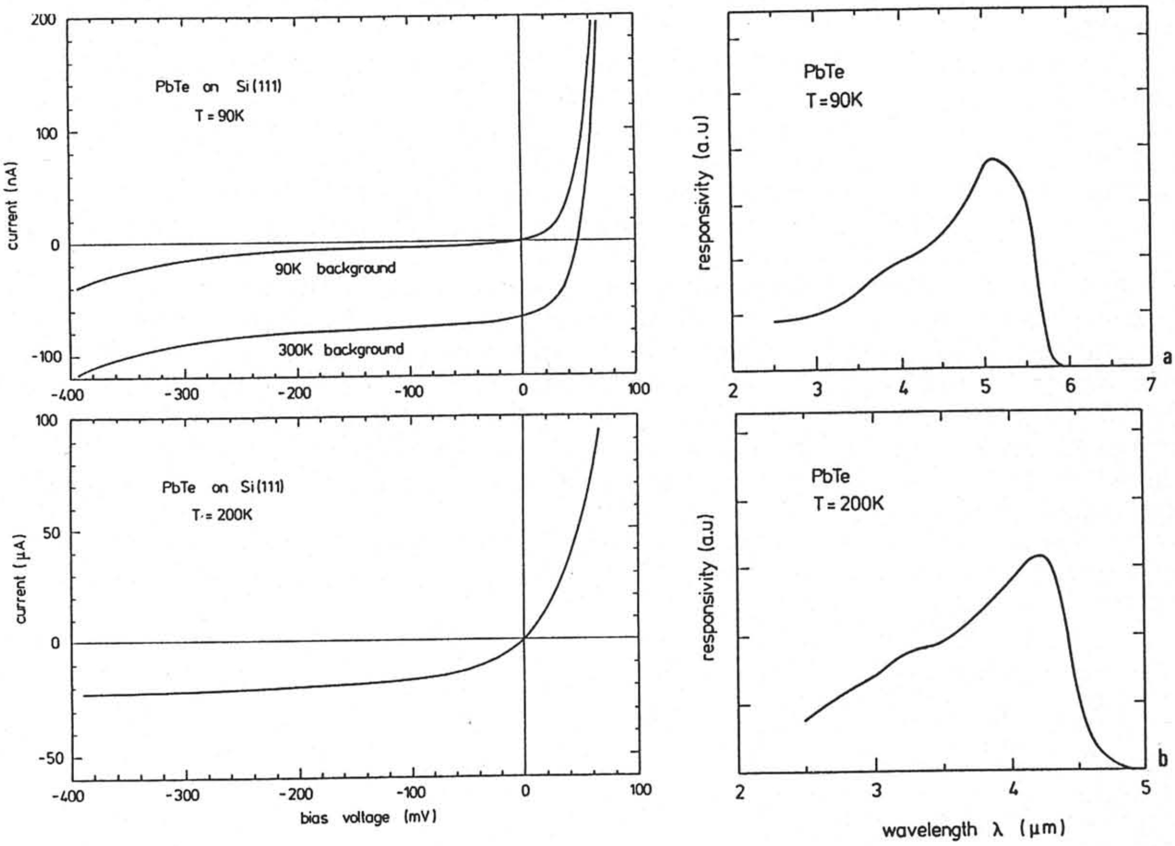

Fig. 2. I-V-characteristics and spectral response (Amps/Watt scale) for a typical photovoltaic PbTe IR-sensor on Si of the array shown in Fig. 1 at 90K (a) and 200K (b).