High Energy Resolution Pixel Detectors Based on Boron Oxide Vertical Bridgman Grown CdZnTe Crystals

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***Abstract*–CdZnTe crystals are used for the realization of X-ray detectors. In particular, pixel detectors can be exploited for many application fields such as medical diagnostics, security, and industrial inspection. In the last years, CdZnTe crystals have routinely been grown by the boron oxide encapsulated vertical Bridgman technique. In this work, it is shown that linear array detectors have been prepared based on this material. The detectors show low leakage current and have been coupled to a specifically designed research-grade low noise ASIC. The detectors show good spectroscopic characteristics and no polarization effects, meeting the requirements for the realization of high throughput, multi-energy scanners.**

I. Introduction

PIXEL detectors can be exploited for many application fields such as medical diagnostics, security, and industrial inspection [1]. Usually, for low energy applications (up to 100 keV) CdTe is also used. CdTe ensures a better homogeneity, but suffers some problems of polarization. In this frame two Italian companies, X-NEXT srl and due2lab srl, together with Polytechnic of Milan and CNR-IMEM, have started a cooperation for the realization of linear array detectors on CdZnTe crystals grown by the boron oxide vertical Bridgman method at IMEM-CNR [2, 3]. The idea is to study the response of pixel detectors based on CdZnTe grown by boron oxide vertical Bridgman method to operate in the low-medium energy range (10 keV-160 keV) for applications such as security, food inspection, industrial monitoring.

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II. Detector preparation

2-inches CdZnTe crystals are routinely grown at IMEM-CNR lab by boron oxide Vertical Bridgman technique [2, 4]. CdZnTe polycrystalline material is obtained by direct synthesis of high purity elements [5]. Before growth, material is annealed in order to precisely control stoichiometry [6]. Thanks to the use of boron oxide, it is not necessary to seal the growth ampoule, being material evaporation prevented by boron oxide itself and by a moderate argon pressure (about 5 bars). This growth procedure presents several advantages: i) there is no risk of ampoule explosion, ii) there is no free volume, so that material stoichiometry is preserved, iii) a liquid boron oxide layer fully surrounds the quartz ampoule so that the contact between the quartz ampoule and the growing crystal is prevented [2, 4].

Detectors are obtained by routine cutting procedures and by polishing all the surfaces. By means of chemo-mechanical process is possible to polish the surfaces with a final roughness lower than 1 nm.

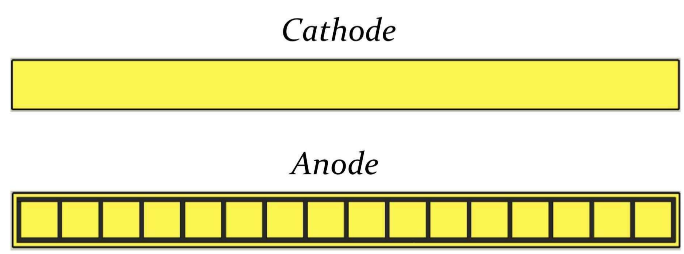

Fig. 1. Cathode and Anode detector geometry.

Gold contacts are deposited after standard photolithography process by electroless deposition.

Geometry of the contacts are shown in Fig. 1.

After contact deposition, surfaces were passivated in order to reduce the leakage current and to ensure detector stability.

Then, detectors were flip-chip bonded on PCB (two detectors for each PCB, see Fig. 2).

PCB shows also housing for ASICs and some passive electronic components.

Fig. 2. 32 pixels array detector bonded on PCB with housing for ASICs.

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III. READ OUT ELECTRONICS

The pixels were connected to a Research-Grade low noise ASIC designed to readout semiconductor pixel detectors. The ASIC can process signal of photons up to 300 keV, with processing times from 170 ns up to 2.2 µs, and with a count rate up to 1 Mcps. The measured Equivalent Noise Charge of the ASIC (with no detector connected) is shown in Fig. 3: the minimum intrinsic noise at room temperature is equivalent to 450 eV FWHM in CZT.

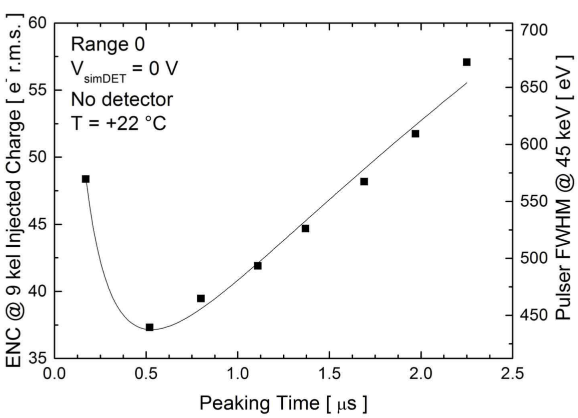

Fig. 3. Intrinsic noise of the readout ASIC measured at room temperature as function of the processing peaking time.

IV. DETECTOR CHARACTERIZATION

Detectors were firstly characterized by current-voltage measurements. The I-V characterization of the detectors has been performed with Source Measurement Units Keithley 2410, Keithley 6430, and Keithley 236.

Currents at the back contact of the detector, at the guard ring of the pixels, and at each pixel were measured at room temperature (+24 °C). In Fig. 4 both pixel current and pixel current density are reported for several pixels as a function of bias voltage. I/V characteristics are typical of a blocking contact, as previously reported for gold contacts on CdZnTe [7]. In all the cases, the dark current density is lower than 5 nA/cm^2 at the detector operating voltage of 200 Volts.

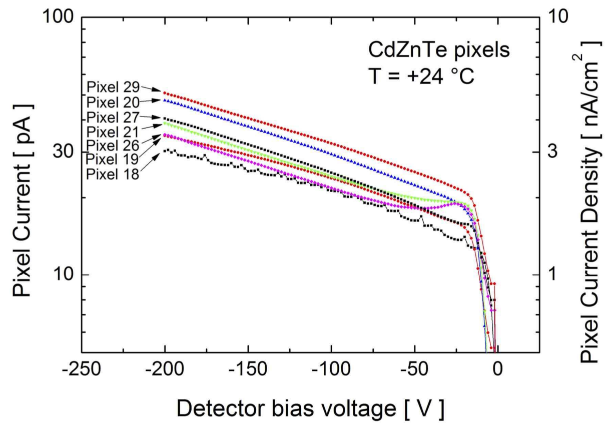

Fig. 4. Pixel dark current density as a function of detector bias voltage. The dark current is always lower than 5nA per square centimeter at 200 V (detector operating voltage).

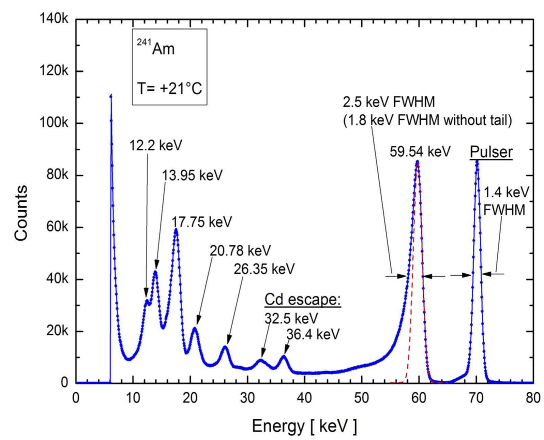

Fig. 5. Energy spectrum obtained with an uncollimated ^{241}Am source at +21°C. A linewidth of 2.5 keV FWHM @ 59.54 keV is measured.The pulser width is 1.4 keV FWHM.

Fig. 5 shows the typical energy spectrum obtained with an uncollimated Am^{241} source at 21°C, with a pulser line-width of 1.4 keV FWHM. All the main peaks are very well resolved and the FWHM at 59.54 keV is 2.5 keV. The spectrum is not corrected and a low-energy tail is apparent in the case of the main 59.54 keV peak. No polarization effects were observed during detector characterization.

V. CONCLUSIONS

CdZnTe crystals grown by the boron oxide Vertical Bridgman method has been used for the realization of linear array detectors.

Pixels show leakage current as low as 5 nA/cm^2.

A research-grade low-noise ASIC has been specifically designed to readout CdTe/CZT pixel detectors, showing a minimum intrinsic noise at room temperature equivalent to 450 eV FWHM in CZT.

Detectors showed good spectroscopic performances at room temperature, with an energy resolution of 2.5 keV @59.54 keV, and no polarization effects.

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