256x256 pixels active matrix photo detector combing an amorphous Silicon thin film transistor array with organic photo diodes

J. Fuerst*, D. Henseler, S. Tedde, E. Zaus

Siemens AG, Corporate Technology, Guenther-Scharowsky-Str. 1, 91058 Erlangen, Germany

(*email address: jens.fuerst@siemens.com)

Abstract

A hybrid approach for realizing a 256x256 pixels active matrix photo detector is presented. This approach combines conventional amorphous Silicon technology, well know from consumer products as TFT-LCD televisions or computer screens, with the advantages of organic semiconductor technology.

1. Introduction

In the last several years organic semiconductors have been used in a variety of electronic devices. The possibility to fabricate flexible, large area, light-weight and low-cost devices makes them attractive. Especially organic light emitting diodes [1,2] organic thin films transistors [3] and organic photodiodes have attracted much attention. An important step towards highly efficient charge separation in photovoltaic devices was the introduction of new concepts of an interpenetrating network of conjugated polymers as donor material and fullerene [4,5], or other molecules [6], with larger electron affinity as acceptor material. The absorption of an incident photon in the donor material of the bulk heterojunction blend results in the formation of an exciton. The exciton is dissociated by an electron transfer to the acceptor material. Charge separation times of less than 100 femtoseconds have been reported [7,8]. Because this process is more than 1000 times faster than the radiative or nonradiative decay of photoexcitations [4,9], the quantum efficiency of charge separation is almost 100 percent. These properties are very promising for the application of organic photodiodes as highly efficient solar cells [10] or very sensitive photodetectors [11].

In this paper, we describe the use of organic photodetectors (OPDs) in combination with amorphous Silicon (a-Si) technology to create a pixelated photodetector with 256x256 pixels.

2. Experimental Details

For the OPDs discussed in this paper a bulk heterojunction, consisting of a blend of poly-3-hexyl-thiophene (P3HT) as donor material and [6,6]-phenyl C_{61} butyric acid methyl ester (PCBM) as acceptor material is used. Starting from the bottom, the layer stack of the used OPDs is the following: 100 nm sputtered Au anode, 30 nm spincoated hole transport layer, 250nm bulk heterojunction layer and 3/10 nm thermal evaporated Ca/Ag semitransparent cathode. To achieve a fast response time and a high efficiency, photodiodes are reverse biased. Our OPDs are designed to operate at 5V reverse bias voltage and at room temperature, they show high external quantum efficiencies (EQE) up to 60% over a large part of the visible spectrum and very low dark current densities at 5V reverse bias. Taking into account the independently measured transmission of the cathode (approximately 60% at 550nm wavelength) the high EQE values reflect the high internal quantum efficiency close to 100% reported for this material system.

The OPDs were processed on top of a 0.7mm thick glass substrate on which a pixelated circuitry was created in a-Si technology. Two different pixel sizes with 98x98µm² and 154x154µm² were realized. Figure 1 shows an optical microscope image of the active area of the detector with 98µm pixel pitch. Each pixel can be addressed by an a-Si thin film transistor (TFT). In sum the detector consists of 256x256 pixels.

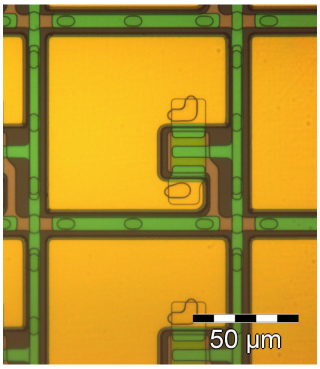

Fig. 1: Optical microscope image of the pixel structure.

The bottom electrode of the OPDs used in our approach is Au and can be seen in Fig. 1. This electrode is lithographically structured. On top of this circuitry, the organic layers as well as the top electrode are applied homogeneously as unstructured layers, resulting in a fill factor of nearly 100%. After top electrode deposition, the whole array was encapsulated with a 20µm thick film to prevent the sensor from degradation. With this encapsulation, a sensor lifetime of more than 1000hours in a climate chamber at 85°C and 85% relative humidity was achieved. The dark current of the OPDs was measured to be as low as $7*10^{-6}$mA/cm² at 5V reverse bias. With this value, we are close to that of a-Si diodes, which was measured to be about $1*10^{-6}$mA/cm²

The read-out procedure of the sensor is done by reading all pixels in one row simultaneously by opening all TFTs in one row. For reading out the information in the pixels, 2 highly integrated read-out chips with 128 inputs were chosen. The analog to digital conversion depth of these chips is 14bit. For illuminating the detector, a 10ms light pulse was chosen followed by a 20ms read-out time and a 3ms reset time. This results in a read out speed of 30fps. By reducing the read-out time, up to 60fps were shown.

3. Results

Figure 2 shows an image taken with this detector. The illumination was done by pulsed light of an LED at a wavelength around 520nm at a light intensity of 10µW/cm². As the whole active area of the detector is about 4x4cm² an image, printed on a foil was put above the active area. Illumination through this foil results in an image as can be seen in Figure 2.

Figure 3 demonstrates the signal linearity of the detector. At

