RADIOGRAPHY IMAGING BY 64/128 MICROSTRIP CRYSTALLINE DETECTOR AT DIFFERENT X-RAY ENERGIES

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Abstract

This paper summarizes some results obtained in the study of position sensitive detectors developed for experiments of high energies physics with the objective of evaluating its possible application to obtain X-ray digital images. A crystalline silicon microstrip detector with 64/128 channels coupled to two RX64 chips was used to obtain radiographic images of different objects. The more relevant figures for spectrometry applications were measured and reported. Two-dimensional images were obtained by scanning the object with a collimated beam using different source-target-detector positioning and three sources of X-rays (6.4, 8.04 and 22.16 keV). The counts acquired by each strip correspond to a particular collimator position during the scan, thus serving to reconstruct the image of the exposed to X-ray object and to reveal its internal structure. The preliminary results obtained using in-house made mammography phantoms allow to infer that such kind of detectors could be successfully introduced in the digital mammography practice.

Key words: phantoms, biomedical radiography, si semiconductor detectors, digital systems, mammary glands, pathology, nondestructive testing, collimators

IMAGENOLOGÍA RADIOGRÁFICA CON DETECTORES CRISTALINOS DE MICROBANDAS 64/128 Y RAYOS X DE DIFERENTES ENERGÍAS

Resumen

El presente trabajo resume algunos de los resultados obtenidos en el estudio de detectores sensibles a posición desarrollados para experimentos de física de las altas energías con el objetivo de evaluar su posible aplicación para la obtención de imágenes radiográficas digitales. Un detector de silicio cristalino del tipo microbandas con 64/128 canales acoplado a dos chip RX64 se utilizó para obtener imágenes digitales de diferentes objetos de interés. Se midieron y reportaron en el texto los parámetros espectrométricos más relevantes del sistema de detección. Las imágenes bidimensionales se obtuvieron mediante el barrido del objeto con un haz colimado de rayos X (6,4; 8,04 y 22,16 keV) utilizando diferentes configuraciones geométricas fuente-blanco-detector. Los conteos adquiridos por cada microbanda en una posición particular del colimador dan lugar a un perfil, y la yuxtaposición de todos ellos posibilitaron la conformación de la imagen del objeto radiografiado y el revelado de su estructura interna. Los resultados preliminares obtenidos, utilizando maniquíes mamográficos fabricados en el laboratorio permitieron inferir que este tipo de detectores pudiera ser en un futuro introducido en aplicaciones prácticas de mamografía digital.

INTRODUCTION

The advantages of the digital X-ray radiography are significant when this technique is compared with the conventional screen-film systems. Among these advantages are the exposure time reductions, elimination of film waste, enhancement in image analysis, improvement in data management, image archiving and transmission, etc. [1 ,2]. Due to this, there are immense resources and efforts dedicated to the investigations related with the development of the digital radiography, specifically applied to the medical imaging [3 ,4].

In this context, the present paper represents a contribution to the effort oriented to the evaluation of semiconducting position sensitive detectors used thoroughly in the experiments of High Energy

Physics, as possible X-ray detector for imaging purposes.

A 64/128 microstrip crystalline silicon detector (designed and manufactured by ITC-IRST, Trento, Italy) was tested. The reported images, obtained using three X-rays energies and different source-sample-detector configurations, belong to a group of objects with small dimensions selected by their density characteristics, and to a couple of mammographic phantoms where the presence of small pathologies (microcalcifications) in the glandular tissue are simulated.

EXPERIMENTAL DETAILS

A 64/128 micro-strips silicon detector with strip length of 1 cm and pitch of 100 mm was employed [5], see figure 1.

The charge from the strips is collected by RX64 ASIC chip with 64 channels each featuring a low noise preamplifier followed by a shaper, a discriminator and a counter [6].

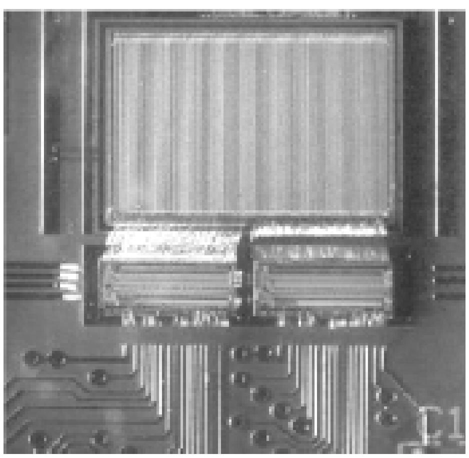


Figure 1. 128 micro-strips c-Si detector with two RX64 chips.

Measurements have been taken with the microstrips oriented both orthogonal (front configuration) and parallel (edge-on configuration) to the beam axis.

Three different X-ray sources has been employed. Its energies and mean characteristics are presented in table 1.

Two-dimensional images are obtained by scanning method. In the experiments with calibrations sources the test object was placed directly on the detector in front configuration. Using a step motor coupled to the collimator and synchronized with the data acquisition system, the collimated X-ray beam is sweeping along the strips. The step width coincides with the collimator slit width.

When the Cu anode tube was used as X-ray source, the scanning effect was achieved moving step by step the collimator with fixed object and detector in front configuration or moving the object with fixed collimator and detector in edge-on configuration.

Each image profile was acquired and the final image was obtained via software by juxtaposing all the different profiles.

The mammographic phantoms consisted on polymethyl-methacrylate matrixes with embedded little aluminum oxide cylinders (diameter 1 mm and different heights 0.3-1.8 mm) oriented parallel to the trajectory of the incident photons. These phantoms simulate the presence in the breast of a specific type of mammary pathology called microcalcification.

RESULTS AND DISCUSSION

The detector system was characterized and its main analogue parameters presented in table 2.

These characteristics satisfy the basic requirements of a digital image system for medical applications [7].

Table 1. Characteristics of employed X-rays sources

X-ray source	Energy (keV)	Characteristics
^{57}Cu	6.4, 14.1	Calibration source
Cu	8.04	X-ray generator, Microsource® BEDE
^{109}Cd	22.16, 24.9	Calibration source

Table 2. Main analogue parameters

Parameter	Main	Sigma
Gain	62.4 μV/el	0.1 μ V/el
Offset at the discriminator output	3.3 mV	0.6 mV
Equivalent noise charge	153.7 el rms	1.04 el rms

Figure 2 presents the X-ray spectrum obtained by the superposition of the independent spectra of several sources measured with the detector. These data allowed to carry out the energy calibration of the system.

The energy of the ^{109}Cd source is similar to the energy of photons typically employed in medical applications. Due this their use allows to evaluate the behavior of the microstrip detector at work energy level, besides the source manipulation facilities. The disadvantage of this calibration source is its very low photon flow; their activity in the moments of the experiment was 6.297 μCi. This makes to be required very long acquisition time (t_{acq}).

The first imaging tests have been performed using ^{109}Cd source. Two different semiconductor light emitted diodes (LED) were measured using the detector front configuration and the resulting images are presented in figures 3 and 4.

One LED (yellow) was imaged using an acquisition time, t_{acq} = 1080 s, and the second ones (red) with t_{acq} = 2400. The selection of t_{acq} depended only on the available time for the experiment. The collimation was fixed in 500 μm.

As shown in both figures, the obtained images give an idea about their metallic internal structure (electrode and contacts). Nevertheless, the low number of counts and the poor space resolution (500 mm along the strips) resulted in images without the enough definition and contrast.

A similar experiment was carried out with a surface mount transistor (SMT) using the same source but with a collimation of 250 μm and t_{acq} = 900 s, figure 5. The little dimensions of the device and the low source activity lead to the poor image quality.

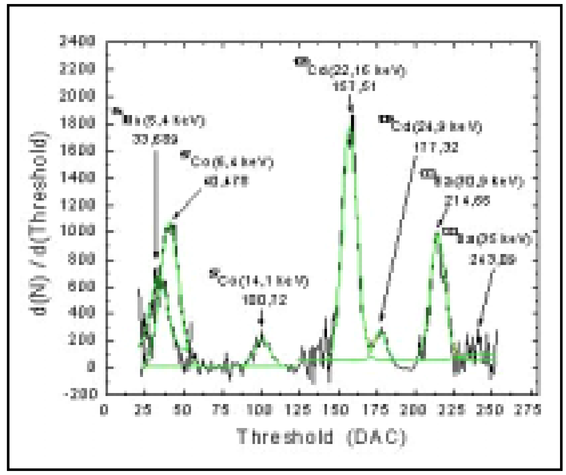


Figure 2. Energy X-ray spectra obtained with calibration sources, showing peaks ranging from 5 keV to 35 keV.

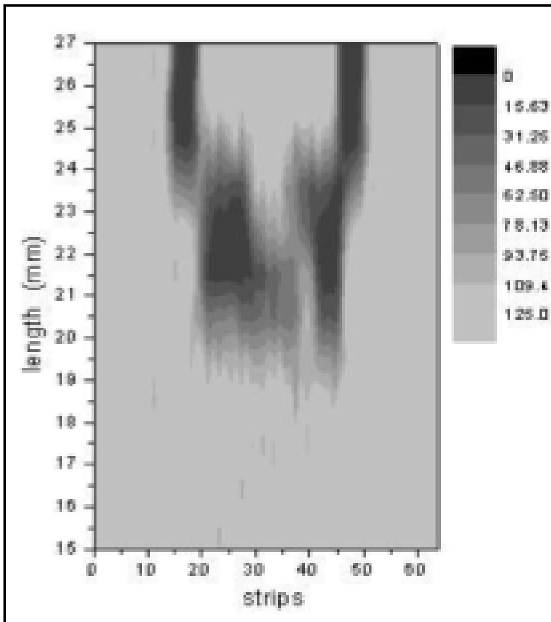


Figure 3. Image obtained by scanning the test yellow LED with collimated ^{109}Cd X-ray.

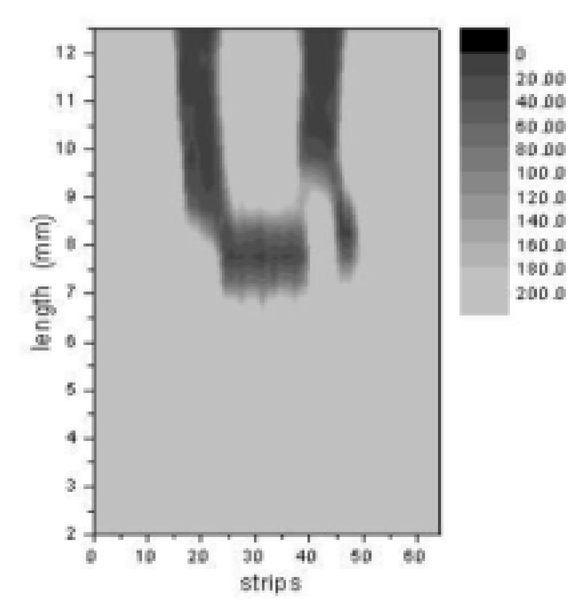


Figure 4. Image obtained by scanning the test red LED with collimated ^{109}Cd X-ray.

Repeating this experiment, but substituting ^{109}Cd by ^{57}Co source and increasing t_{acq} up to 1200 s, can see that the quality of the image deteriorates even more because the lower photon energy and therefore the absorption in the air and in the scanned object increases (figure 6).
Using ^{109}Cd source a black BC547 transistor was also imaged in front configuration and the obtained image is presented in figure 7 (a). For this analysis a collimation of 250 µm and t_{acq} = 900 s parameters were established. The image reproduces the main features of the test object and its internal details, although the resolution was not enough improved.

With Cu anode X-ray tube (V = 20 kW, I = 0.5 mA) as source, edge-on configuration (the strips were parallel to the incident beam) and collimation of 200 mm and t_{acq} = 5 s, the same transistor was scanned and its image was obtained just as it is shown in figure 7 (b).

This new image shows in details and with higher quality the internal structure of the transistor. Although the energy of the photons is much smaller, its high flow and the advantages of using edge-on configuration allow us to obtain better results.

Maintaining the same edge-on configuration and collimation the images presented in figures 8 and 9 were taken. In these images a little metal screw and a cricket are shown. In the case of the screw, it is appreciated, that the high material Z allows that the object almost absorbs all the incoming X-rays, improving the contrast. With the cricket this effect doesn't happen, because it is a biological body constituted fundamentally by soft tissues where the photons are lightly absorbed. Nevertheless it is perfectly appreciated the insect shape and even the internal structure of the insect appeared.

Finally, the results obtained for two house-made phantoms are presented. Images of phantoms with one and three simulated microcalcifications are shown in figures 10 (a) and 10 (b) respectively. They were taken using a front configuration, Cu tube X-ray generator, collimation in 100 mm and t_{acq} = 10 s.

The obtained images have a good quality. Each supposed microcalcification differs of the matrix and other details perfectly. Their different gray tones indicate different absorption due to its different thickness, which may be confirmed observing the profiles also presented in the figures.

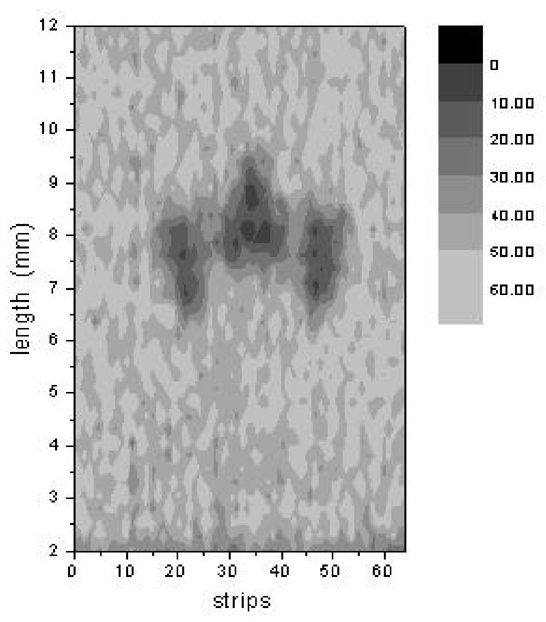


Figure 5. Image of a SMT at ^{109}Cd energy.

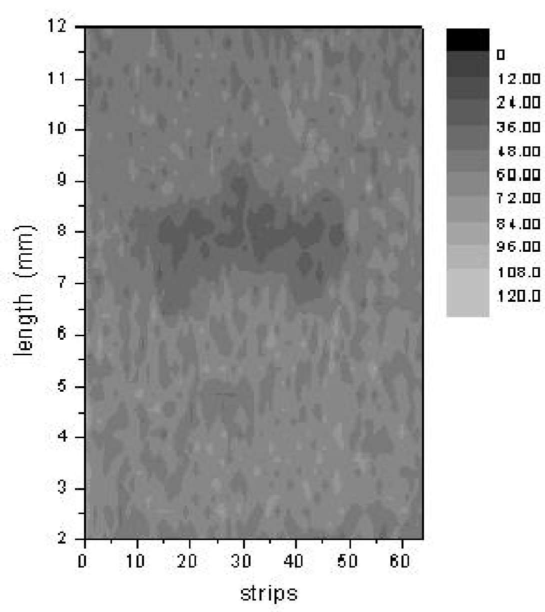
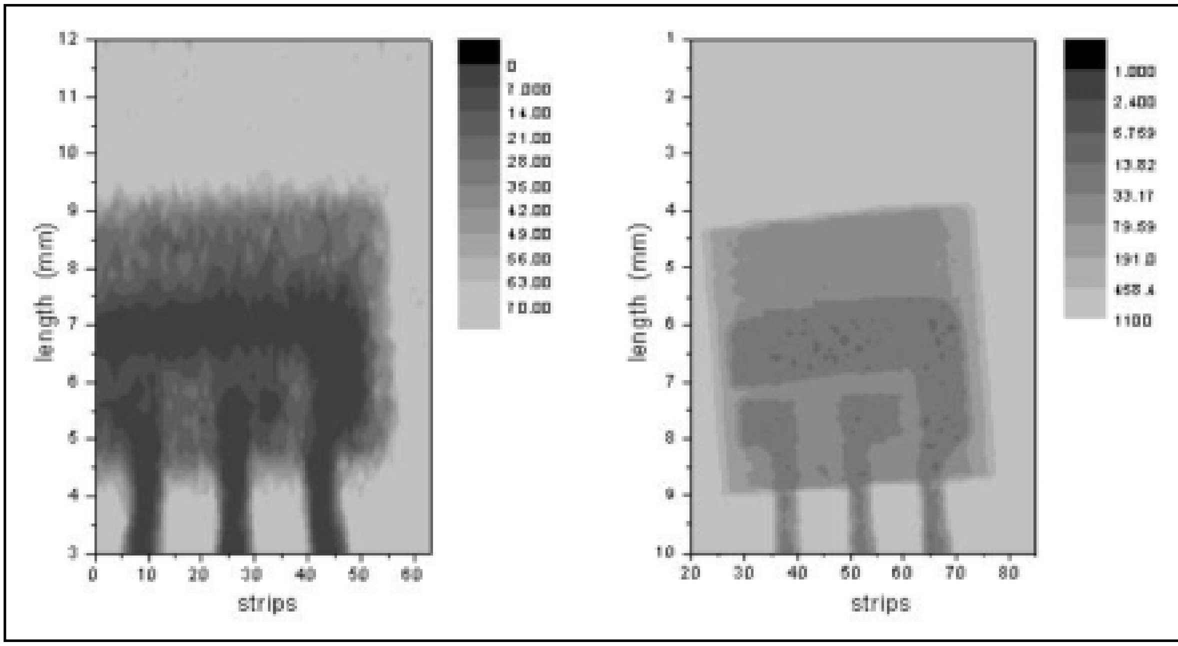


Figure 6. Image of a SMT at ^{57}Co energy.



(a) (b)

Figure 7. Images of the BC547 transistor at ^{109}Cd energy using detector front configuration (a), and at 8.04 keV using detector edge-on configuration (b).

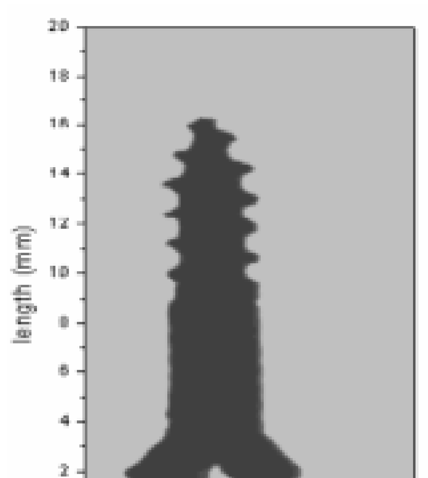


Figure 8. Image obtained by scanning a metal screw with the 8.04 keV X-ray beam in edge-on configuration.

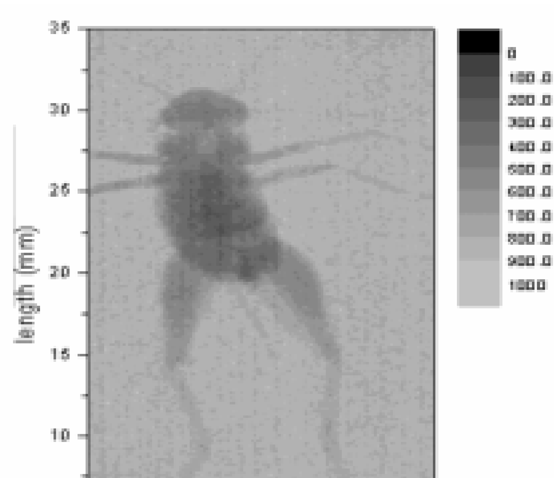
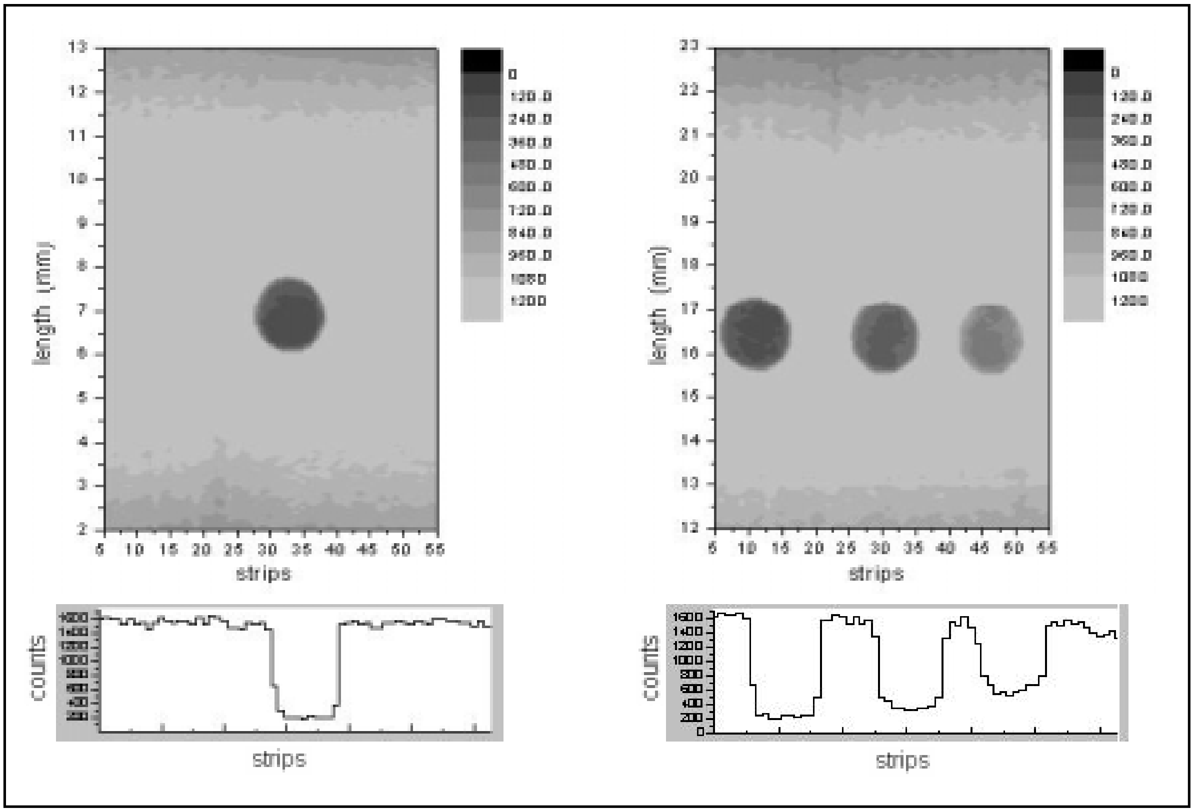


Figure 9. Image obtained by scanning a cricket with the 8.04 keV X-ray beam in edge-on configuration.



(a) (b)

Figure10. Images and profiles of mammographic phantoms with one microcalcification (a) and with three microcalcifications (b) at 8.04 keV and front configuration.

CONCLUSIONS

A microstrip crystalline silicon detector was characterized verifying that its mean measured parameters satisfy the basic requirements of digital medical radiography. Two-dimensional images of different test objects acquired in different geometrical configurations and using three X-ray sources have been shown in this paper. These results demonstrate the ability of the system to image small objects of different nature visualizing their internal structure. The results point to the real potentiality of this detecting system to be used in applications related with the digital radiography. The application field of this microstrip detector system and its future and more advanced versions could spread from medical radiography to non-destructive studies of materials and devices.

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