X-RAY IMAGING DETECTOR
USING SILICON FIELD EMISSION TIP ARRAY ENERGY CONVERSION

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Existing x-ray detecting technologies can be classified as either photon-counting (digital) or integrating (analog). Multi-wire proportional counters (MWPC) are digital detectors that have advantages such as high quantum sensitivity, high dynamic range, and high intrinsic energy resolution, and have a wide range of applications. However, most photon-counting detectors rely on gas conversion of the incident x-ray into primary electrons, and cannot attain both high count rate capability and high spatial resolution [1]. These have been replaced, in many cases, by analog integrating detectors, such as CCD-coupled cameras. Unfortunately, the latter are less sensitive, not real-time, have limited dynamic range and energy resolution [2]. There remains the need for faster photon-counting detectors. Although new "microgap" gas detectors and Si pixel array detectors have been developed for higher counting rates, the former has its maximum gain limited by discharges, while the latter requires a complex and expensive readout system [3]. We present here an x-ray detector based on Si field-emission tip technology. The x-ray is first converted to EHPs in the substrate Si The electrons are emitted into vacuum from spatially-distinct nanoscale field emission tips fabricated on the *back-side* of the conversion layer, and detected using an imaging multi-channel plate (MCP). The imager is conceptually depicted in Fig. 1..

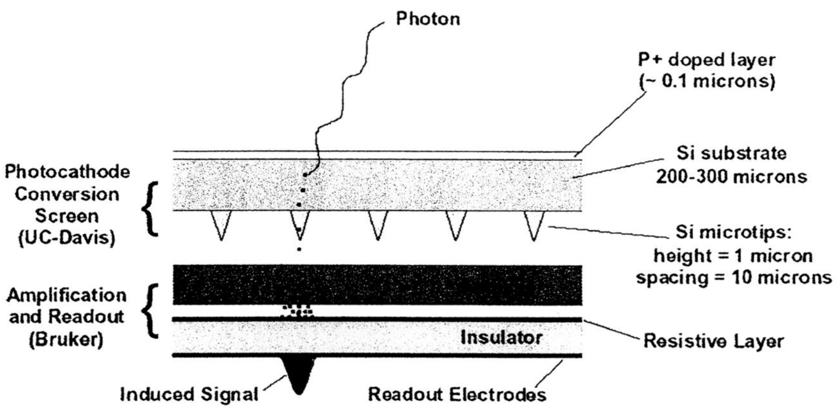

Figure 1 X-Ray Photon-Counting Imager

The detector was fabricated using IC technologies (Fig. 2). A double-side polished, float-zone p-- Si wafer (ρ>1500Ω-cm) with 100nm oxide on both sides, received a deposition of 100nm Cr on one side, and an implanted p+ layer on the other. ATHENA simulation (Fig. 3) shows the p^+ hole-evacuation layer to be 100nm and $R_s = 2$ Ω-sq. Tips with 6μm pitch over a 2cm×2cm active area were obtained using isotropic plasma etching with SF_6. The bed of nails was oxidation-sharpened and all oxide stripped before the arrays were cleaned and diced. The p^+ layer is accessed by point contact in the fixturing for measurement.

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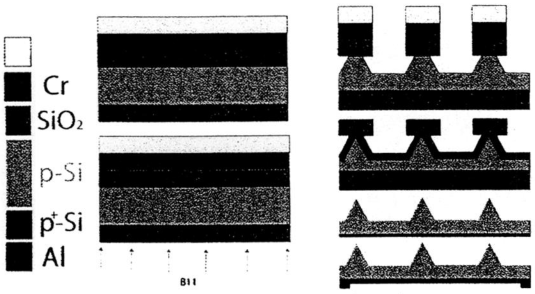

Figure 2 The microfabrication process

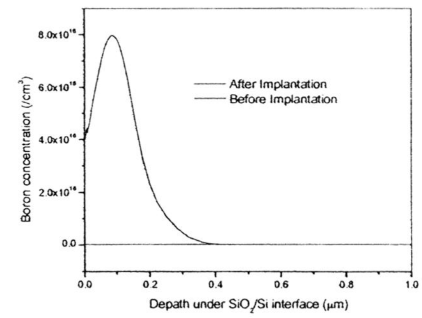

Figure 3 Simulated B concentration profiles

The measurement setup is depicted in Fig. 4. This allows us to expose the device to a stationary x-ray flux from a Fe^{55} crystal which should give an approximate count frequency of 3×10^3 counts/second and approximately 1616 EHPs per photon event.

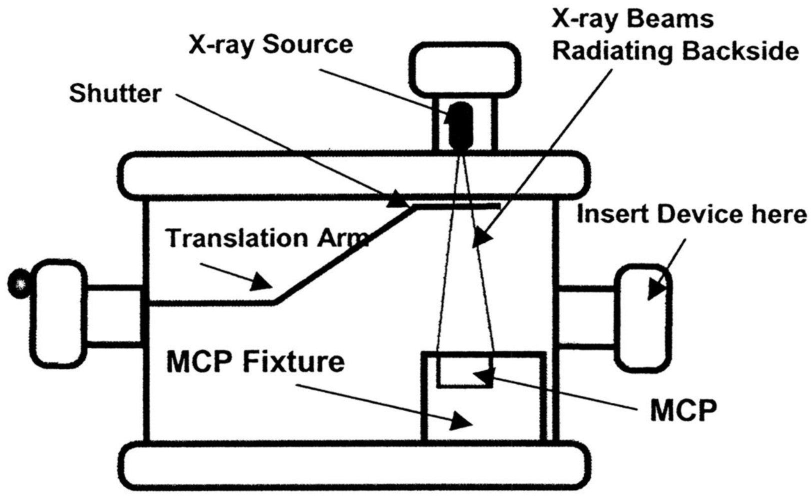

Figure 4 Schematic of the x-ray exposure system with surrounding vacuum chamber

The dark current (at V_a = 500V, A-C spacing = 40 μm) was measured ($P_o = 8 \times 10^{-7}$ Torr) and found to be 50fA. The FE-current SNR was measured in excess of 20dB. The uncoated Si tips produce non-negligible noise, as expected, and improvement of SNR will be obtained by coating these with ultra-nanocrystalline diamond (UNCD) [4].

In summary, we designed and implemented an x-ray imaging detector based on energy conversion by a Si substrate into electrons emitted by a field-emission tip array. The preliminary device suggests that significant improvements of resolution, count rate, dynamic range, and cost can be obtained through development of this technology.

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