A Monolithic Multi-Channel Secondary Electron Detector for Distributed Axis Electron Beam Lithography and Inspection

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The throughput of electron beam systems is severely limited by Coulomb scattering within the beam which blurs the beam when writing with large currents. One way to overcome this limit is to employ multiple electron optical systems (Chang, T.H.P., EIPBN, 1992). However, this has not proved practical because of the difficulty of making a sufficient number of matched columns. Another approach, described previously by us, employs a uniform axial magnetic field to focus thousands of electron beams simultaneously (Groves, T., EIPBN 1998, Pickard, D.S. EIPBN 2003). With this approach, one challenge is to maintain a tight beamlet packing density (250 μm pitch) while preventing crosstalk between adjacent secondary electron signals, either by trajectory or within the detector.

In our system, the secondary electrons spiral around the magnetic field lines forming tight bundles which can be focused, accelerated, and deflected much like the primary beam, but with larger chromatic aberrations. This action confines the secondary electrons (SE) generated by each beamlet from those of adjacent ones so that detection of a signal from each is practical, even within a closely packed array. This attribute is advantageous because it provides a means of interrogating the surface for defects or reference markers with thousands of tightly packed beamlets simultaneously.

A PIN-diode-based detector was investigated as a potential multi-element detection scheme for our system. The detector features a two-dimensional array of elements on high resistivity float-zone silicon. This type of detector was developed for fast detection of ionizing radiation during the past decade for the high-energy physics community (Kenney, C., IEEE Trans. Nucl. Sci., NS-46(4) 1999). The detector attributes that were attractive to our application include modest internal amplification, fast response time (<10 ns), ability to be made compact and with dense packed electrodes, low electrode capacitance (<1pF) and ability for CMOS circuitry to be integrated directly onto the detector array so that low noise amplification of each signal can be performed. This detector requires a retarding field for the primary beam, which accelerates the secondary electrons to energies sufficient to excite a large number of internal secondaries.

Two examples of fabricated devices are shown, Figures 1a-d. A structure designed to allow one dimensional scanning of the primary beam through the detector array is shown in Figure 1a and 1c. It features a single slot for primary beam transmittance, allowing primary beam deflection in one axis through the detector assembly. A second detector, designed with individual circular through holes for each beamlet, is shown in Figures 1b and 1d. A planar variation (no slot or holes) of this device was tested by irradiating 8 elements of the front detection surface with 15kV electrons (Figure 2b). The measured signal (Figure 2a) indicates that this type of detector exhibits minimal crosstalk (<50 μm) within the detector. Experiments are currently underway to evaluate the detectors with holes and slots. Details of the secondary electron detection schemes are presented along with results from our PIN detectors.

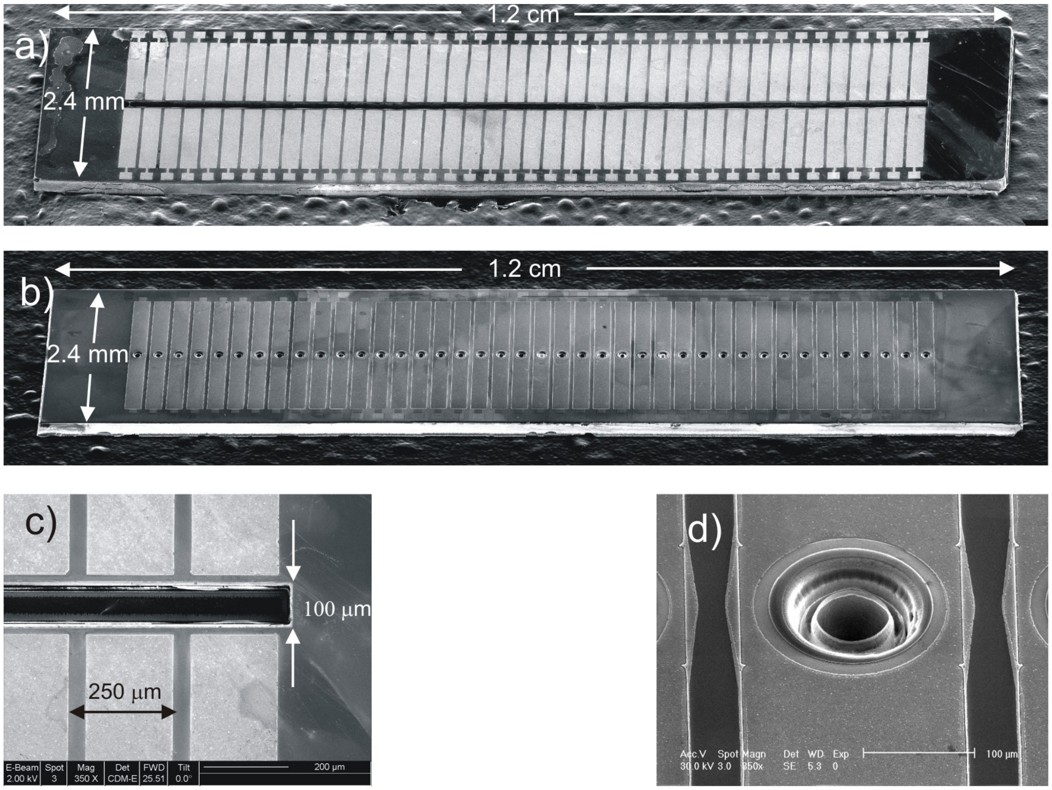

Figure 1 The PIN secondary electron detector array featuring a single slot (Figure 1a) and grounded through-holes (Figure 1b) for primary beam transmittance. The detection occurs on the opposite side (not shown) and the electrons are swept through the wafer thickness. There are a total of 40 electrodes. The slot geometry allows primary beam deflection in one axis above the detector assembly (enlarged view in Figure 1c), whereas the circular aperture (enlargement in Figure 1d) minimizes sources of astigmatism on the primary beam if an electric field terminates on the detector.

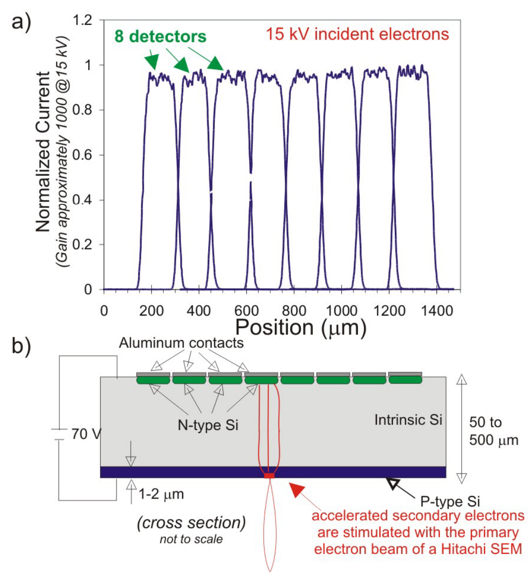

Figure 2 The measured signal from a planar detector with an electrode spacing of 150 microns shows minimal cross talk between adjacent electrodes (Fig. 3 a). The 150 micron electrode spacing on this device represents a much more aggressive spacing than our system requirements of 250 microns and was chosen to illustrate the confinement of the drift field within the intrinsic silicon. The experimental arrangement used for this measurement (Fig. 2b) consisted of variable energy electron beam (2 kV to 15 kV) from a Hitachi S-2500 SEM which was swept across 8 elements of the front active region with a line scan.