Report on Experiment MI-716 at ID18F, 28 June - 02 July 2004
"Study of Charge Collection Processes in Active Edge, 3-D Silicon Sensors"
J Morse, ESRF 09 Aug 2005

Several '3D' silicon sensors with active edge technology were supplied by Dr. C Kenney (Molecular Biology Consortium, Chicago USA) for these tests. The sensors (figure 1) were from a recent production batch made at the Stanford University Nanofabrication facility by Dr. Kenney. Laboratory tests (at ESRF) of these sensors showed room temperature leakage currents of ~3nA per channel, which was disappointingly high and limiting for the experiment envisaged at the ID18F beamline. It was thus decided to operate ID18F at the relatively high energy of 21keV, to minimize the effects of the electronic noise associated with the leakage current. 'Last minute' attempts were made at ID18F to cool the sensors with dry N2 cooled gas, and while this did reduce leakage currents, this method of cooling could not be used during data taking as it was insufficiently stable. Because of the leakage current problem, only one sensor (amongst the many different geometries that we intended to test) was studied in detail.

Figure 2 is a composite image showing

1. the actual X-ray response of the left side of a sensor micro scanned in the microbeam of ID18F. Red areas are high count intensity. This data was derived from the multichannel analyzer spectroscopy data which has been energy 'thresholded' to consider only events >6.5keV ;
2. the schematic of the sensor (n+ and p+ refer to the electrode column structures of the sensor);
3. relation of the area scanned to the metal surface contact layer of the sensor.

Figure 3 shows the energy response of the sensor. The 1.7keV energy resolution shown is dominated by the readout electronics noise. Thresholded data was used to construct the spatial response of the horizontal linescan through a p+ electrode, and also confirm the 'active edge' response characteristic of the sensor, which is shown to be sensitive to within a few microns of its physical edge, as predicted.

Data was also accumulated using a multiparametric MCA system set-up to record X-ray events measured at neighboring sensor electrodes in time-coincidence. This was to gain better insight into the extent of charge diffusion and splitting following absorption of individual X-rays. Unfortunately this data has been of little use as the detector bias regime was restricted to prevent leakage current saturation of the preamplifiers of one or both neighbour channels.

The data collected at ID18F was presented by Dr Cinzia daVia at a Cern seminar presentation October 2004 for the LHC 'Totem Detector' Collaboration which will use such 3D active edge sensor technology. It was also presented (by myself) in an invited talk to the European Materials Research Society, in their Fall 2004 Meeting. The data taken at ID18F is not considered by us to be of sufficient quality to stand alone as a publication, but the results will be integrated in a paper that combines this data with that obtained in experiments made at the LBL-ALS source in July 2003.

Figure 1: (top) Micrograph of the active edge, 3D sensor tested at ID18F. The bright vertical lines are surface aluminium traces that connect the individual column electrode structures buried in the silicon bulk. The horizontal separation of the vertical rows of electrodes is 150µm.
(bottom) The sensor was mounted on top of a silicon layer in a DIL ceramic ship carrier that permitted easy exchange in the preamp housing assembly (itself mounted on the ID18F beamline precision scan stage).

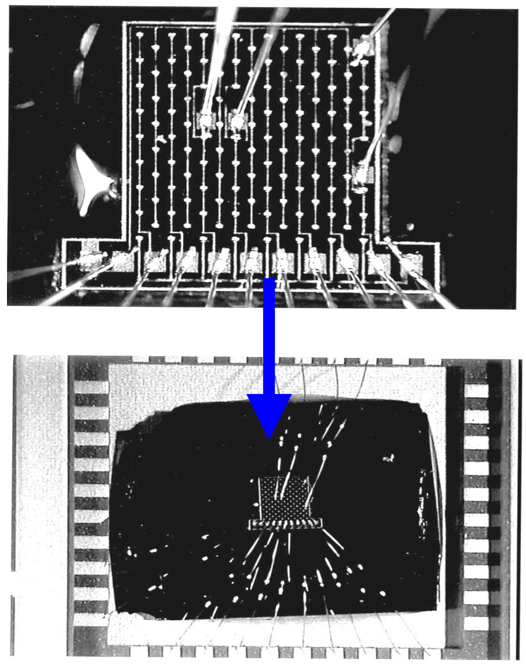

Figure 2: Area response of detector, including the 'active edge' region (refer to text above).

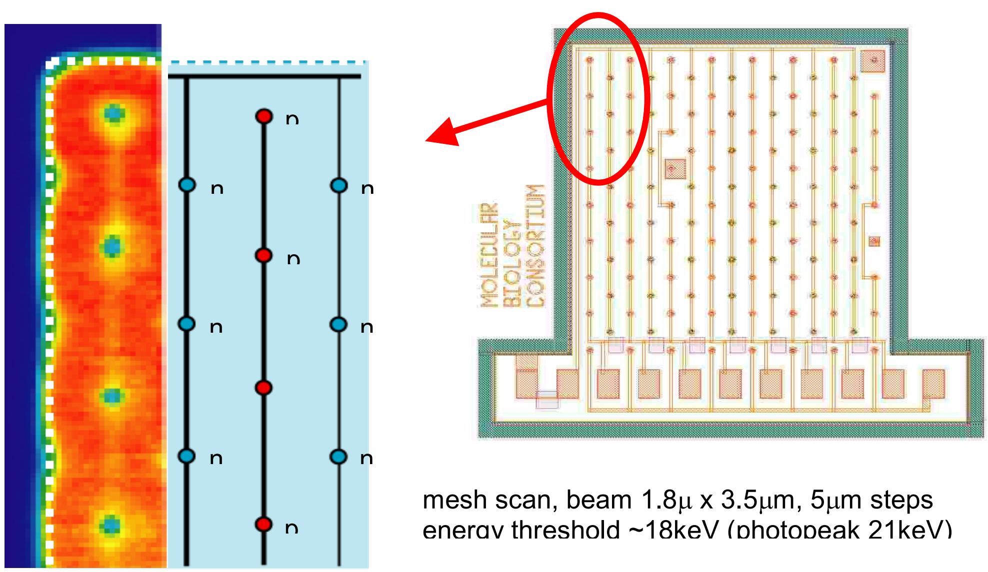

Figure 3: Line scan though a p+ electrode and over the active edge of the sensor (position indicated in composite colur map on right). Energy spectrum showing clean photopeak at beam energy, with resolution dominated by sensor leakage current noise. Note the ‘dead’ sensor areas corresponding to short charge carrier lifetime and field-free region within the p+ electrodes.