Liverpool design of an "n-in-p" silicon pixel sensor for use with the Atlas FE-I3 readout chip

Purpose: the first pixel detector prototype for the technology proof, irradiation samples and mechanical specimen for the bump bonding techniques.

Task description: modify the CMS pixel sensor prototype (RD50 Wafer) for the Atlas pixel readout chip FE-I3.

Semiconductor foundry: e2v

Process: p-type substrate, single poly, single metal, feature size (alignment precision ?)

Wafer layout: multi-project wafer (area available ?) engineering run (wafer size ?)

Submission deadline: this week (30.06.08-04.07.08)

Design proposal: the CMS sensor prototype consists of 22 columns and 40 rows of pixels. The size of each pixel is 150 um x 100 um (the boundary pixels are somewhat larger), thus the active detector area is 3.6 mm x 4.1 mm and the die size including the guard ring structure and the scribe line is 5.4 mm x 6.4 mm. The number of modified pixels (400 um x 50 um) fitting into this area will be 9 columns and 80 rows is rather small for the beam test, moreover mechanical handling of samples of that size could be difficult, therefore the pixel matrix could be extended to 18 columns (9 column pairs) and 160 rows to match the layout of one FE-I3 chip. This geometry would also ease matching the detector prototype to the Beetle chip for the analog readout of pixels (see the Project Extension section).

Layout description: a gap between adjacent pixel implants, equal to 20 um, is the most critical parameter for the radiation-hard detector design, fig. 1. Layout of the pixel punch-through biasing, based on the CMS (RD50) technology, follows closely the Atlas design, fig 2. Figure 3 shows a simplified design of the pixel bias contact whose yield should be better than in the original case, but this solution could worsen the pixel performance – to be checked experimentally.

The Atlas pixel sensor prototype has a direct metal-to-implant contact, fig.4, while the CMS pixel sensor prototype uses polysilicon as a contact interface between the implant and the metal layer [1]. The CMS technology could be adapted for the Atlas pixel size, fig. 5.A, but it may cause faults of the bump bonding process due to rugged metal layer relief. A simplified design with inter-layer contacts terminated before the pad region, fig. 5.B, could be evaluated.
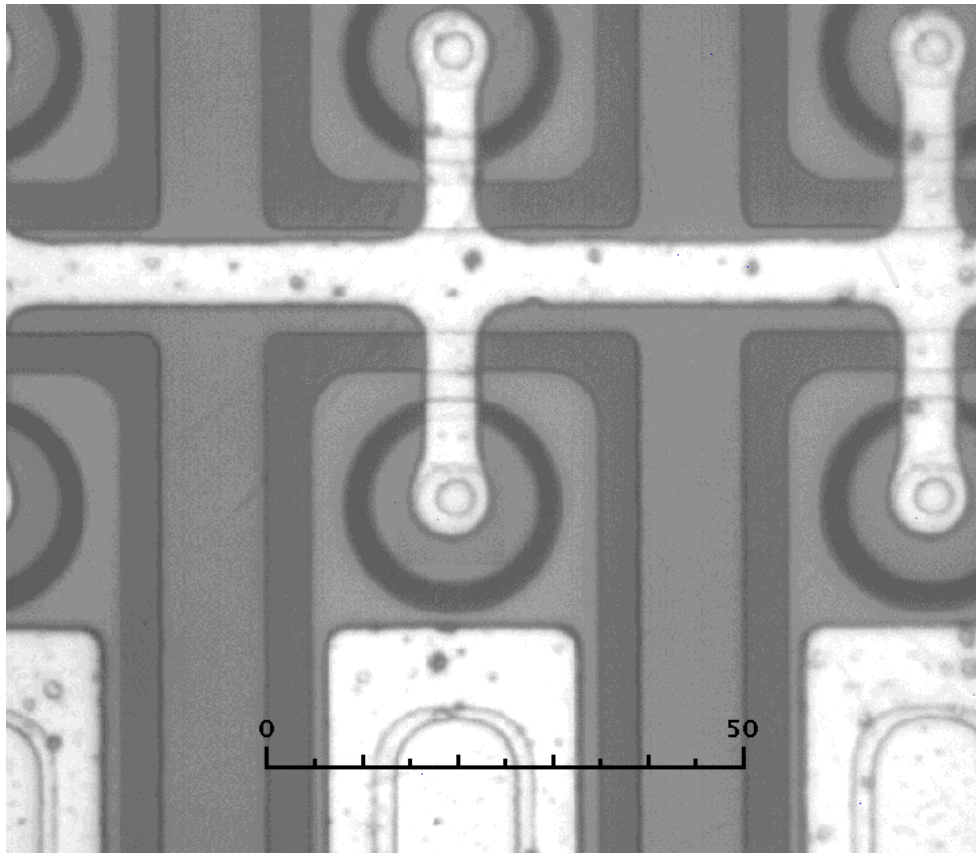

Fig. 1 Snapshot of the bias grid of the Atlas pixel detector showing dimensions
of the sensor structures: the gap between implants, the bias contact shape,
the metal coverage and the implant via.

The bias ring, the guard ring structure, and the scribe line from the CMS design have been converted into parameterized cells (Pcells) - the cadence layout components whose size could be adjusted for the pixel matrix through the library menu. It was not possible to compile all three components into single Pcell, therefore each of them has to be inserted into layout separately at the same origin point. The guard rings are floating and the bias ring contains the standard bump bond pads, fig. 6 for the pixel biasing through the FE-I3 chip. It has also wire bond pads, fig. 7 for the I(V) and C(V) measurements.
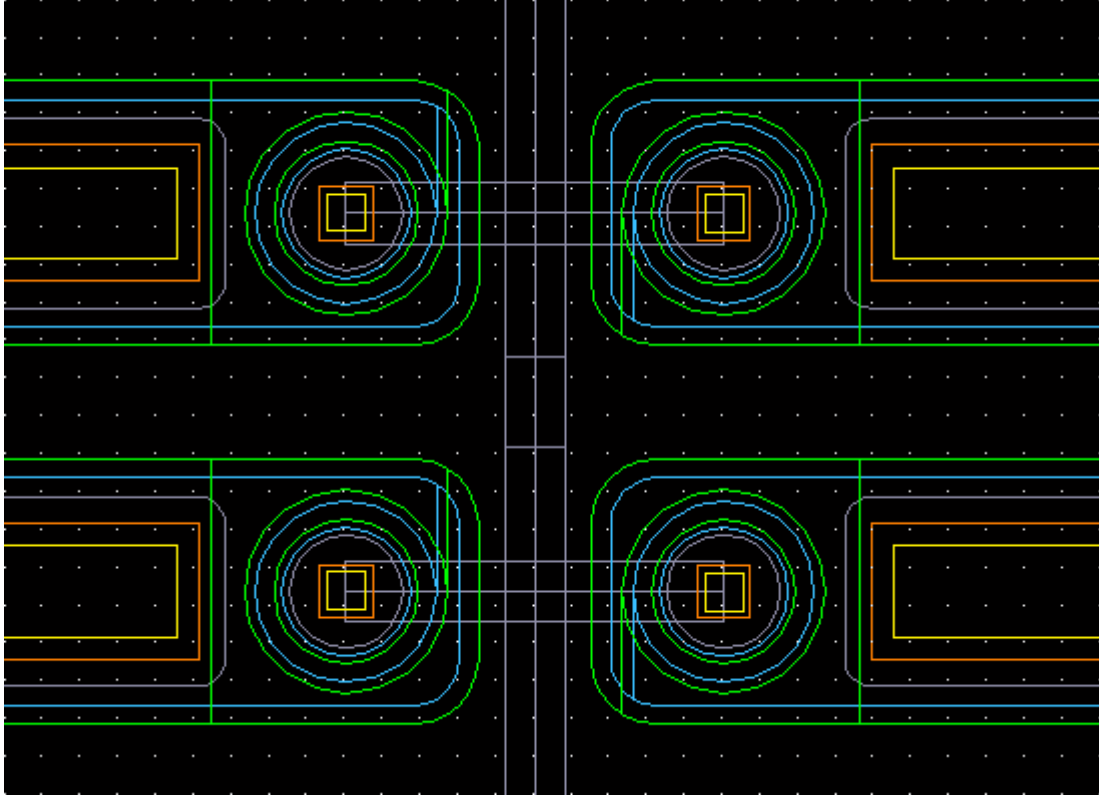
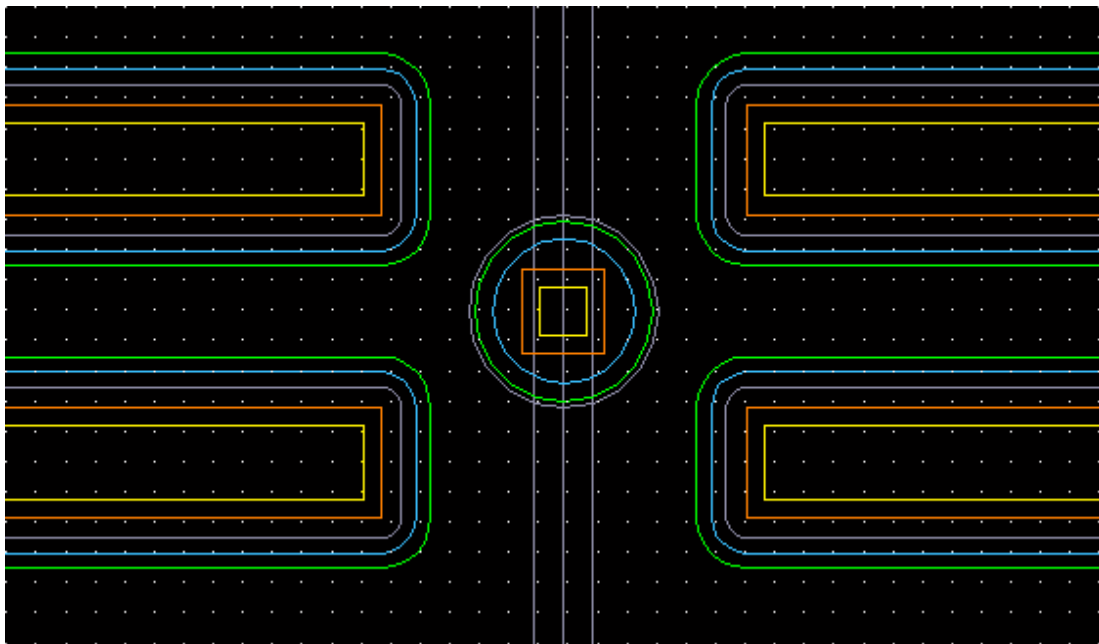Fig. 2. Pixel bias grid: each pixel has an individual bias contact

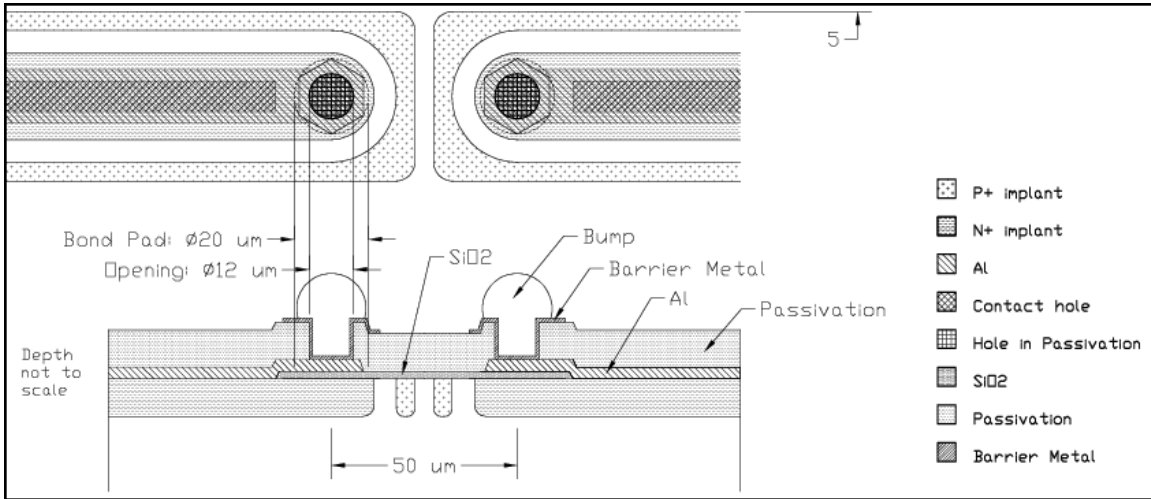Fig.3 Pixel bias grid: the group of four pixels share one bias contact

Fig. 4. Cross-section of the First Prototype Pixel Sensors for ATLAS as described
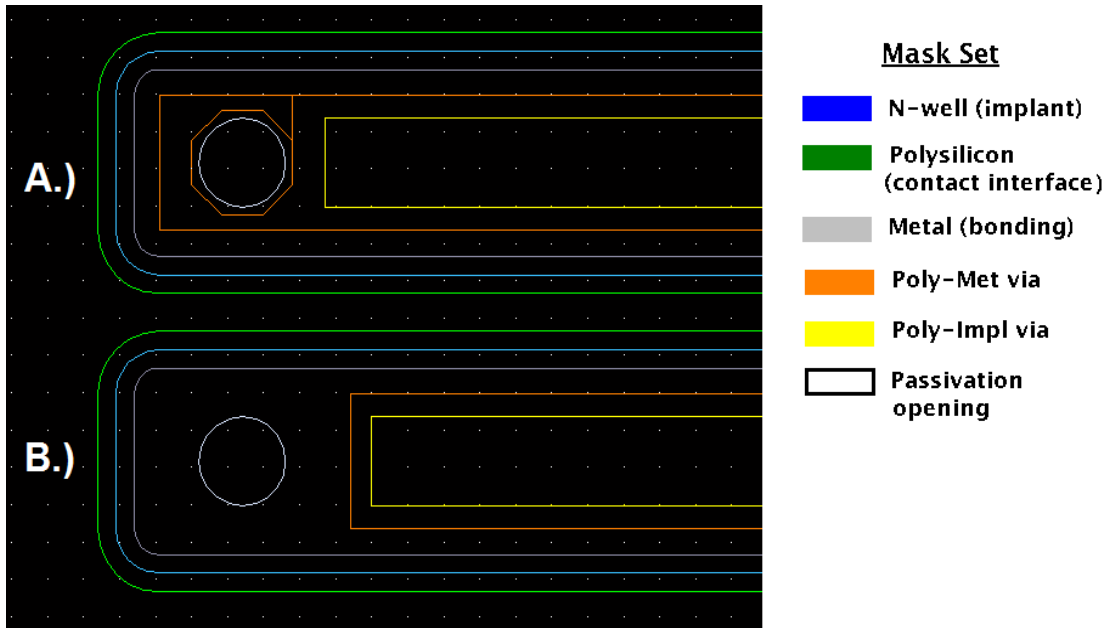in the Technical Specification (Atlas Inner Detector Note 180)

Fig. 5. Two options for the modified CMS pixels to match the Atlas pixel size:
a.) the Poly-Metal contact extends over the bump bond pad region and
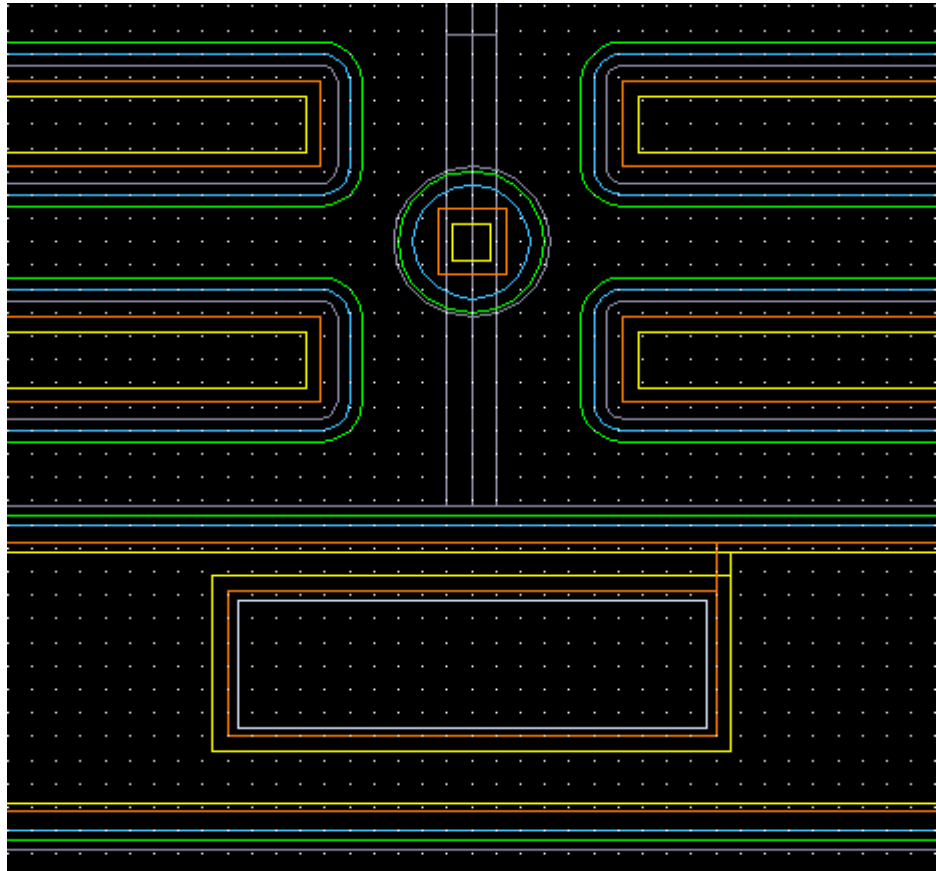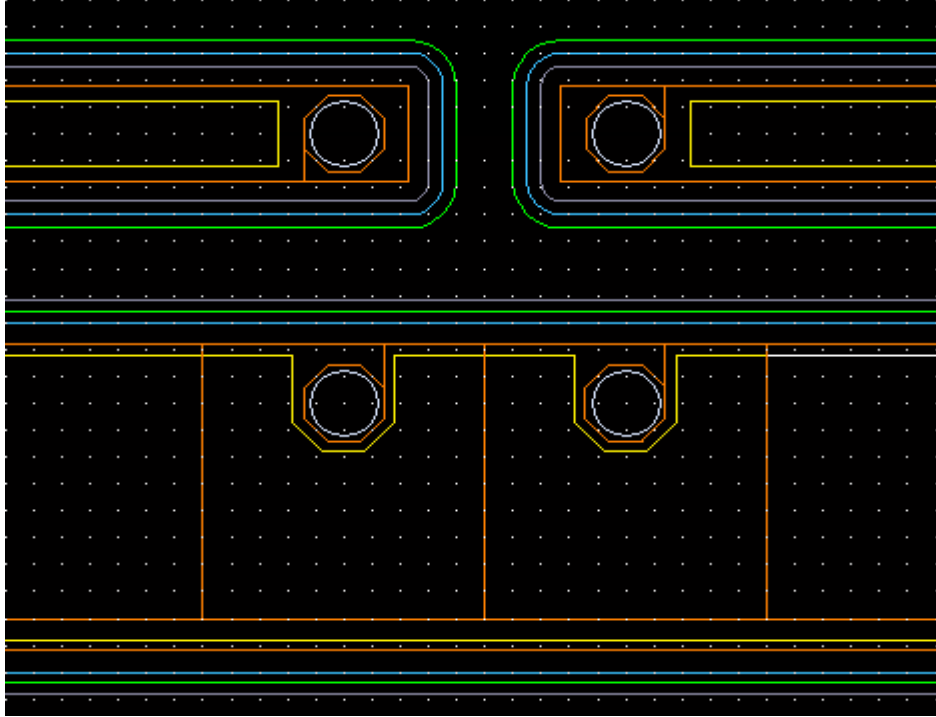b.) the simplified version with the terminated contact.

Fig.6 (top) and Fig.7 (bottom): the bump bond and wire bond pads on the bias ring.

Design summary

Detector Geometry: 9 column pairs, 80 rows of pixels, 50 x 400 um each.

There are 2 options for the bump bond pads and 2 options for the punch through biasing, the design logo indicates each of them.

Design template: the cadence library LAP08 (Liverpool Atlas Pixel 2008) could be found at http://hep.ph.liv.ac.uk/~tsurin/POOL/Atlas/lap08.zip This archive contains also the technology file – the description of physical and logical layers, to which the library could be attached to. The display resource file for the layer color palette is provided.

Layer description:

1. NWELL (n-type implant)
2. POLY (polysilicon contact interface to implant)
3. P-DIF (via between polysilicon and n-well)
4. METAL (bias grid and bond pads)
5. P-MET (via between polysilicon and metal)
6. guidelines (wafer outline, passivation opening)

References:

1. "Pixel Devices on the common RD50 Strip Detector Mask Set"
   T. Rohe, 5-th RD50 workshop, October 14-16, 2004, Firenze, Italy

Project extension

The best performing sensor (in terms of the biasing scheme) could be modified for the analogue readout of its pixels using the Beetle chip and the newly developed aLiBaVa board. The first option would be to replace the outermost pixels by the wire bond pads and connect those pads with the remaining inner pixels using the second metal layer. Another choice would be to leave the detector unchanged and to design the fanout and pitch adapter on a glass substrate that could be bump-bonded to the sensor before irradiation and wire-bonded to the Beetle chip after irradiation.