Active Edge Silicon Sensors & JRA19

J Morse, Instrument Support Group, Exp. Div., ESRF

3D sensor technology

Original motivation was/is radiation hardness for HEP applications (full-3D columnar structures).

Use of processing technology to create 'active edges' now of interest for synchrotron- and medical imaging (⇨ large detector arrays with ' <1 pixel wide ' dead stripes)

Recall: groups actively developing '3D' *silicon* sensors

1. SNF-Stanford
2. Sintef-Oslo
3. VTT-Espoo
4. Glasgow-IceMOS
5. CNM-Barcelona
6. ITC IRST-Trento

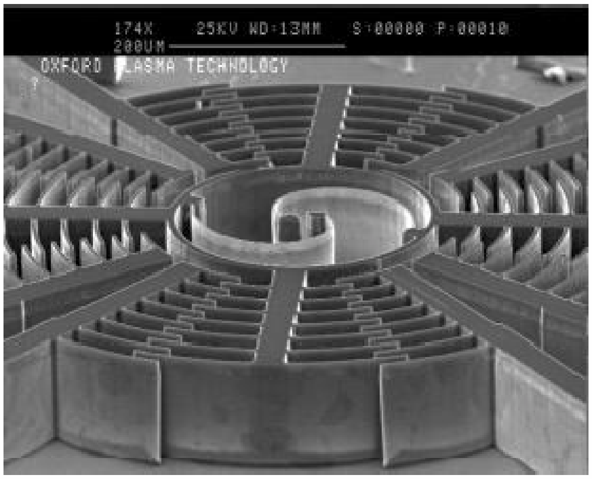
(7. Canberra-Olen)

Only SNF group has a track record of beam tested *active edge devices* , both columnar 3D and planar-3D architectures.

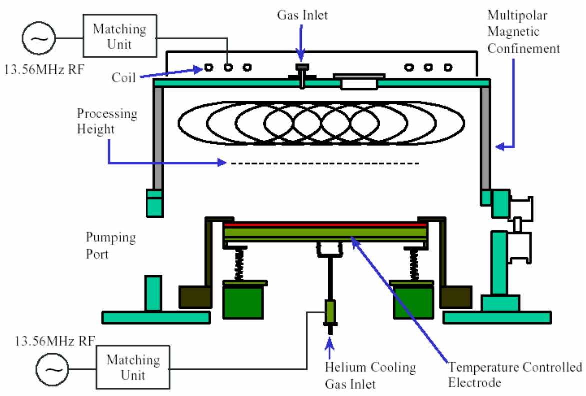
Consortia already formed: *Sintef, Univs. Oslo, Manchester, Hawaii, + Kenney (Stanford)*
VTT in 'Adpix';
Canberra in 'Relaxd'

3D device fabrication

Combination of MEMS plasma etching process and established planar detector processing technologies

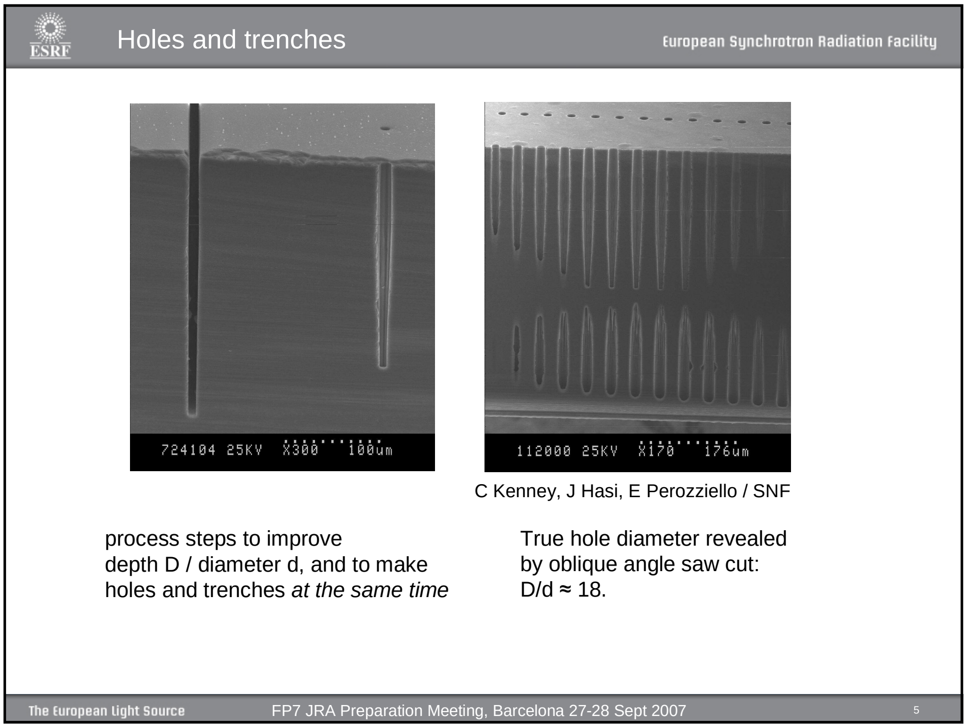


Inductively Coupled Plasma Etch



Bosch process: SF_6 inductive plasma (etching), rapid cycling (1-10sec) with octofluorocyclobutane c-C4F8) passivation.

Etch rates ~1…10 μm/min. Resist selectivity ($Si0_2$-Si) ~ 300



ESRF

Holes and trenches

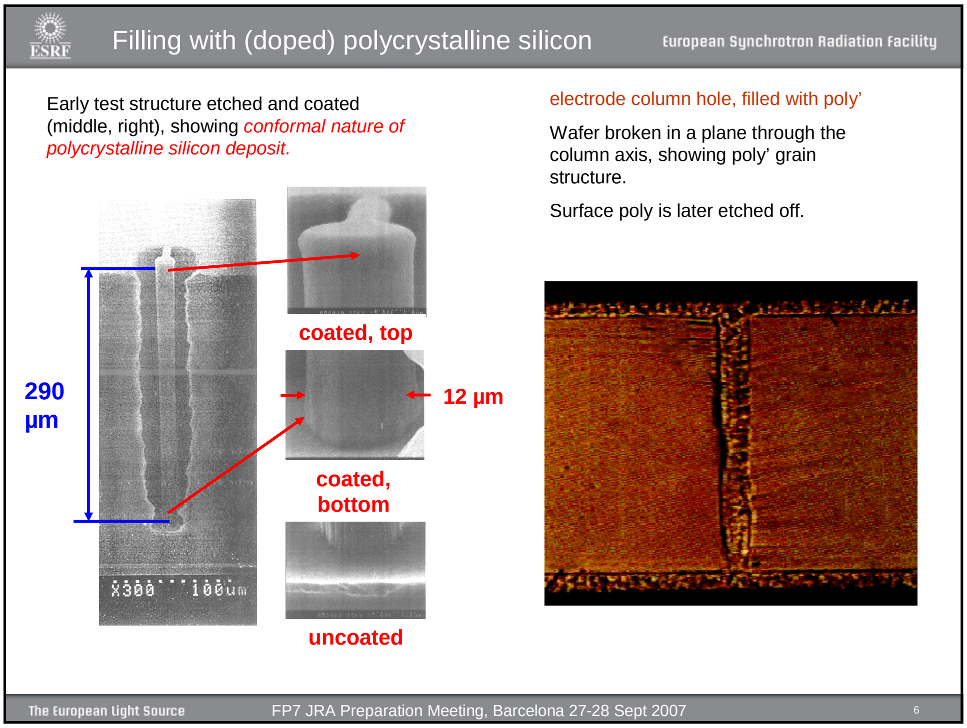
European Synchrotron Radiation Facility

C Kenney, J Hasi, E Perozziello / SNF

process steps to improve depth D / diameter d, and to make holes and trenches *at the same time*

True hole diameter revealed by oblique angle saw cut: D/d ≈ 18.

The European Light Source FP7 JRA Preparation Meeting, Barcelona 27-28 Sept 2007 5



ESRF

Filling with (doped) polycrystalline silicon

European Synchrotron Radiation Facility

Early test structure etched and coated (middle, right), showing *conformal nature of polycrystalline silicon deposit.*

electrode column hole, filled with poly'

Wafer broken in a plane through the column axis, showing poly' grain structure.

Surface poly is later etched off.

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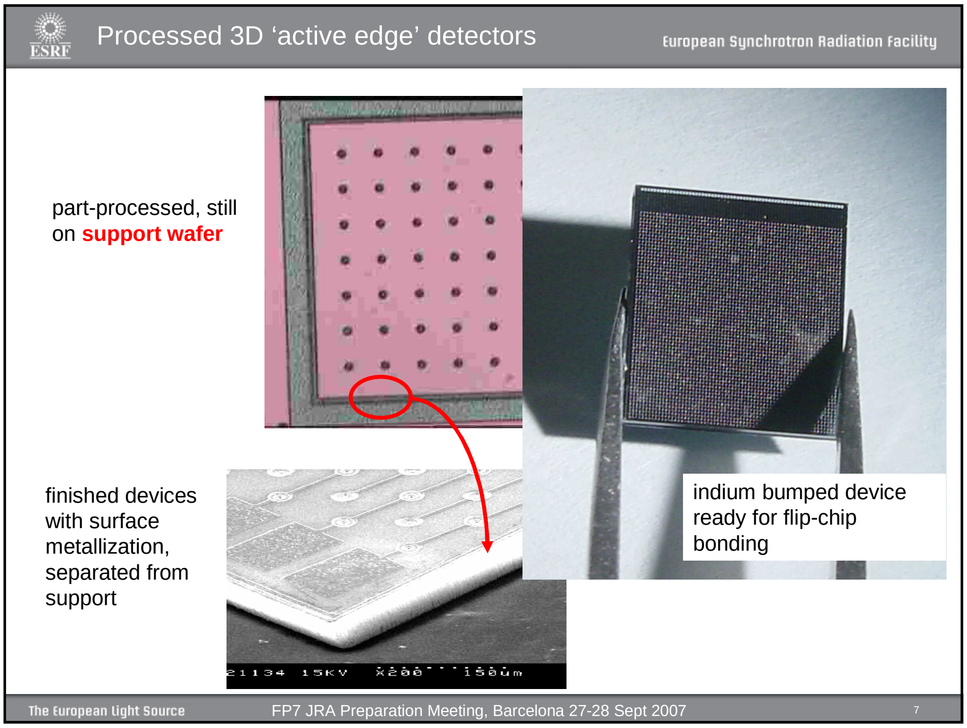
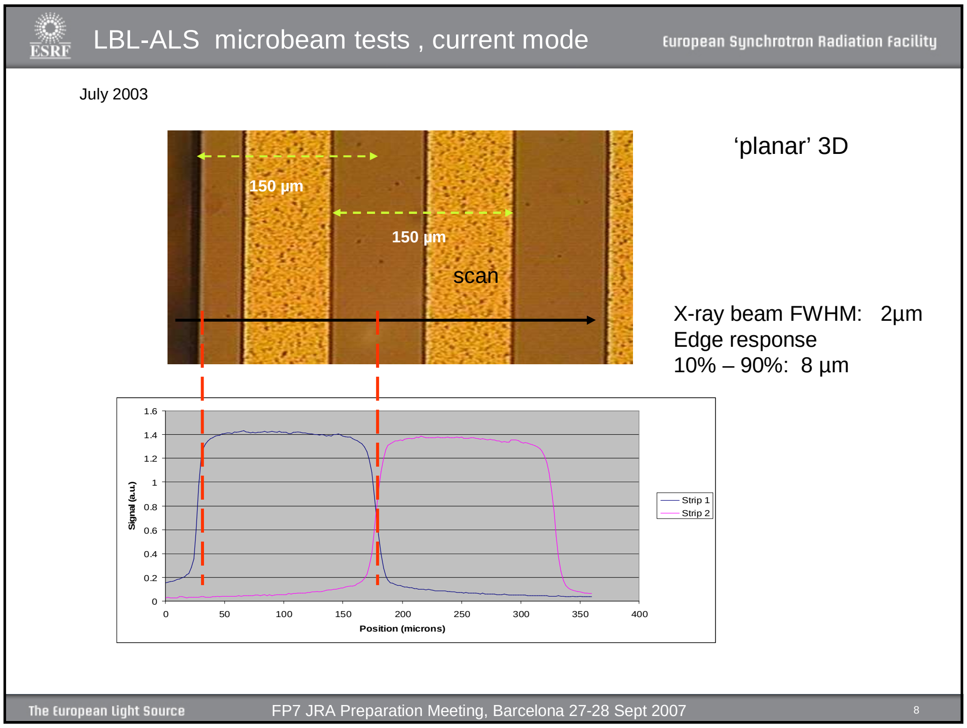


Processed 3D ‘active edge’ detectors

part-processed, still on **support wafer**

finished devices with surface metallization, separated from support

indium bumped device ready for flip-chip bonding

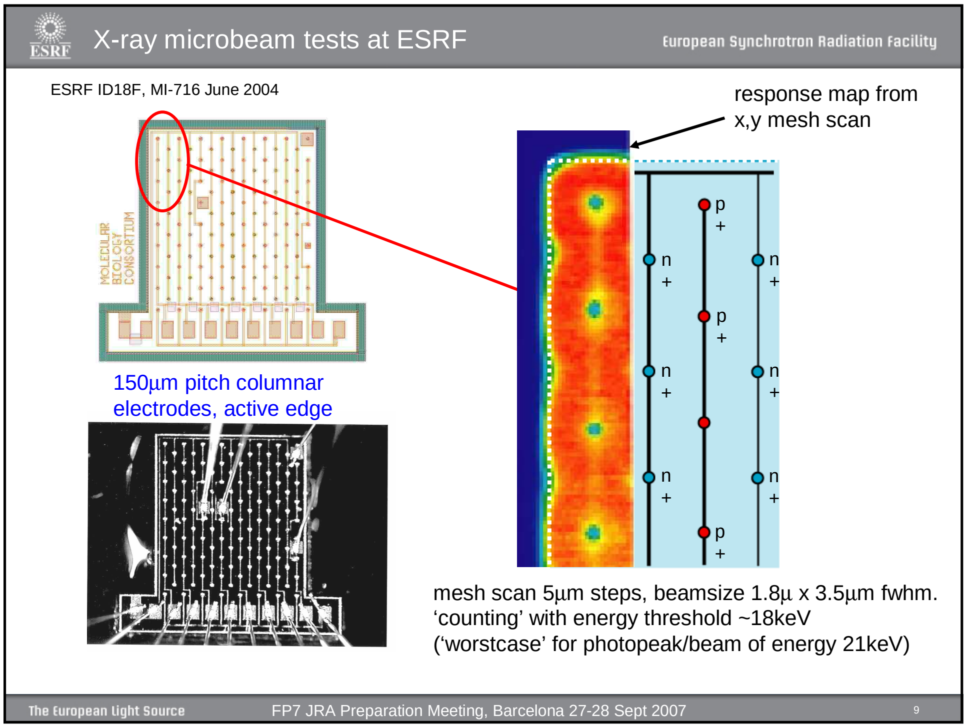


LBL-ALS microbeam tests , current mode

July 2003

‘planar’ 3D

X-ray beam FWHM: 2µm
Edge response
10% – 90%: 8 µm



X-ray microbeam tests at ESRF

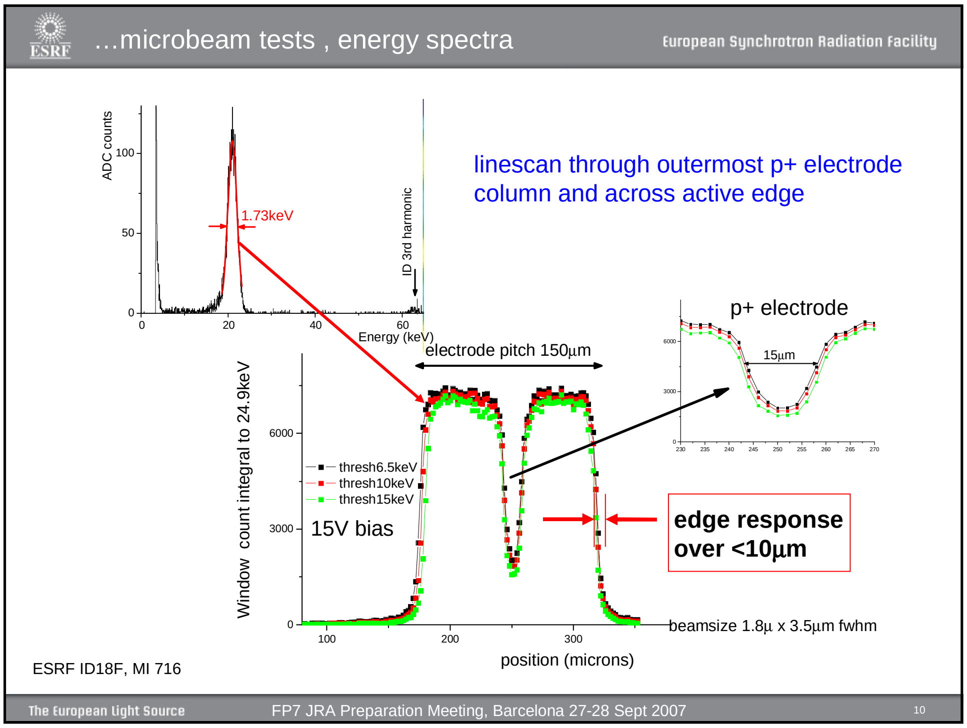
European Synchrotron Radiation Facility

ESRF ID18F, MI-716 June 2004

response map from x,y mesh scan

150µm pitch columnar electrodes, active edge

mesh scan 5µm steps, beamsize 1.8µ x 3.5µm fwhm.
'counting' with energy threshold ~18keV
('worstcase' for photopeak/beam of energy 21keV)



…microbeam tests , energy spectra

European Synchrotron Radiation Facility

linescan through outermost p+ electrode column and across active edge

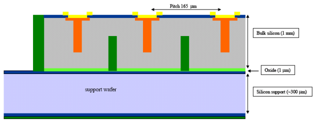
edge response over <10µm

beamsize 1.8µ x 3.5µm fwhm

ESRF ID18F, MI 716

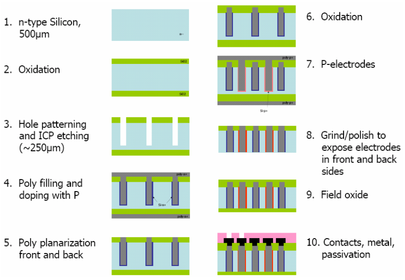
On-going European 3D projects

VTT Nasa Imager, 1mm Si

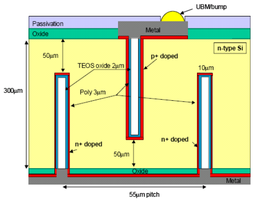


Planar + active edges??

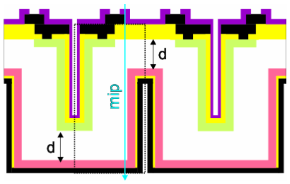
Glasgow - IceMOS



CNM Barcelona



ITC-IRST



Proposed JRA workpackages

1. Design and simulation, manufacturing of active edge sensors. Particular issues: radiation hardness (oxide interface quality, lower leakage currents…)
2. Bump (and wire) bonding of ASICS and sensors. Assumes access to various proven ASIC designs (Medipix, ESTEC-Laben…)
3. Characterization, X-ray tests of single chip modules. Laboratory and field tests at SR beamlines.
4. Assembly of demonstrator detector assemblies: at least 1 x 2 and 2 x 2. Stable thermal/mechanical design to permit close butt-jointing. Laboratory and field tests at SR beamlines, complement with real applications.

Synergy: 2, 3, and 4 overlap with workpackages for high-Z pixel detectors

Select two potential sources of active edge devices: one “industrial” [SINTEF, VTT ?] and another more academic (a few groups to choose from, some of these are already working together…).

Cost of a planar-active edge process run ~30…40kEuro (VTT)

VTT

Estimation of the cost 30k-40k euros for the process runs on 15 wafers to fabricate active edge planar pixel sensors.

National project ADPIX (Advanced PIXel detectors). WPs of ADPIX:

- WP1: Pixel roadmap to 2015
- WP2: physical device and process simulations (2D/3D, silicon and compound semiconductor)
- WP3: Dicing of the planar structures
- WP4: Compound semiconductors
- WP5: 3D and active edge detectors

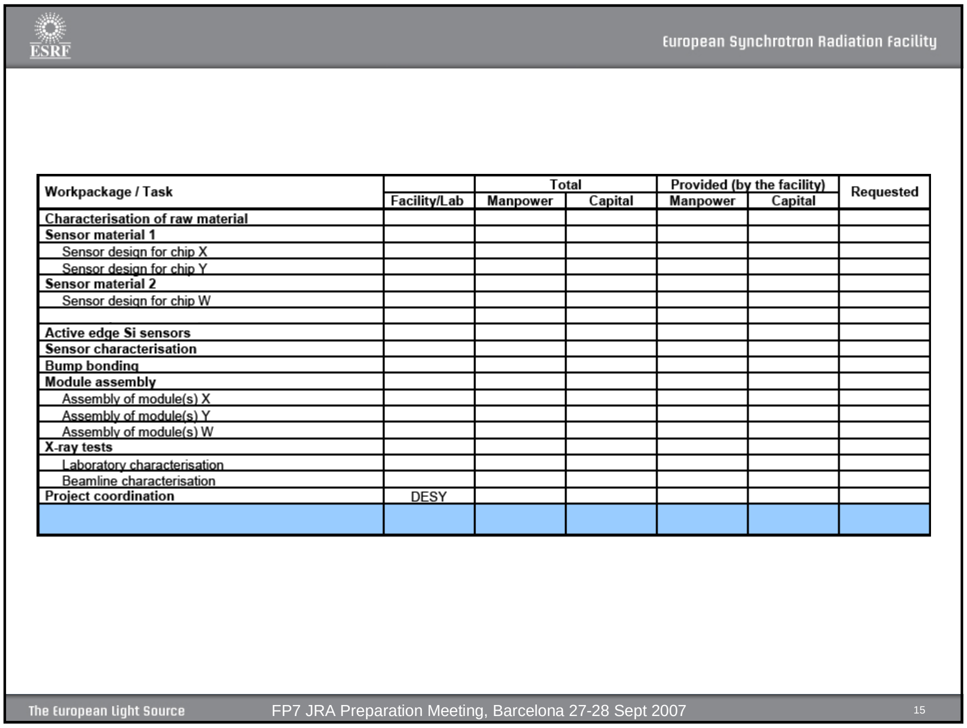
Currently fabricating planar active edge sensors where the dicing of the chips is done using the ICP-etching.

On the masks we have drawn 10 pieces of medipix2 (55 um pitch) compatible active edge pixel sensors (1.4 x 1.4 cm2); large DC and FOXFET coupled strip sensors (5 x 5 cm2); and small DC, punch-through and FOXFET coupled active edge test structures (1 x 1 cm2). We have the SOI-wafers and the fabrication has been started, should be finished by October.

Spring 2008 planning to move towards the NASA EXIST 1 mm silicon active edge 3D detectors.

VTT is a member in Medipix3 collaboration and has good yield expertise in bump bonding.

Info from Juha Kalliopuska , Simo Eranen VTT



Workpackage / Task		Total		Provided (by the facility)		Requested
	Facility/Lab	Manpower	Capital	Manpower	Capital	
Characterisation of raw material						
Sensor material 1						
Sensor design for chip X						
Sensor design for chip Y						
Sensor material 2						
Sensor design for chip W						
Active edge Si sensors						
Sensor characterisation						
Bump bonding						
Module assembly						
Assembly of module(s) X						
Assembly of module(s) Y						
Assembly of module(s) W						
X-ray tests						
Laboratory characterisation						
Beamline characterisation						
Project coordination	DESY					