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Novel Imaging Techniques for the Nuclear Microprobe

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Many of the developments of the scanning electron microscope (SEM) have been parrelleled during the development of the scanning nuclear microprobe. Secondary electrons were used in the early development of both devices to provide specimen imaging [1,2] due to the large numbers of secondaries produced per incident charged particle. Other imaging contrast techniques have also been developed on both machines. These include X-ray analysis, scattering contrast, transmission microscopy, channeling, induced charge and others [3]. Techniques on the nuclear microprobe still need to be developed for live-time imaging of specimens. This aids greatly in specimen positioning and generally makes the device more user-friendly.

The "cross-section dependant" imaging techniques such as PIXE, RBS, NRA, etc., rely on the beam current on target for a given resolution. This has prompted research and development of brighter ion sources to maintain probe resolution at high beam current. Higher beam current bring problems with beam damage to the specimen.

Low beam current techniques [4] however rely on high countrate data collection systems, but this is only for spectroscopy. To produce an image we can increase beam currents to produce live-time images for specimen manipulation and observation.

The work presented here will focus on some developments in live-time imaging with a nuclear microprobe that have taken place recently at the School of Physics, MARC, University of Melbourne.

1 The Techniques

In STIM imaging the high countrates(100's of kHz) can be used to produce pseudo-live-time images but the response of the detection system is limited by the charge collection time for a single ion and the system quickly saturates. This paper will investigate other detection systems for the production of true-live-time images.

Over the last few years PIN photodiodes have been developed that can be used for charged particle spectroscopy and have sufficient resolution to compete with traditional surface barrier detectors. The big advantage of PIN diodes is there price, about 10^3 times less than a surface barrier. This makes the PIN diode very attractive as a radiation detector. To produce a D.C. signal from a PIN diode for true live-time imaging we have used the detection system shown in figure 1. This system shows a standard PIN diode (normally used for STIM) that has been covered with a thin (0.5mm) layer of NE109 plastic scintillator. The scintillator has in turn been covered with a thin (1000 angstrom) layer of Al to prevent charging. A beam of 1 - 10 pA is then used in STIM mode to obtain live-time images. This beam current is about 3 orders of magnitude greater than standard STIM beams. The scintillator acts as a charged particle-to-light converter and allows these much greater beam currents to be used. This means that spectroscopic information is lost, but if only an image is required to position or view the specimen then the loss of spectroscopic data is irrelevant.

The low current techniques of Ion Beam Induced Charge (IBIC) can be made pseudo-live-time by the use of a variable persistence ocsilloscope (VPO). The VPO is an ocsilloscope with X-Y display capability and Z contrast input and a persistence control. This control varies the time that the Z bright-up signal stays bright. Low contrast images can therefore be improved and provide a pseudo-live-time image. This will be discussed in more detail later.

2 Images and Results

Figure 2 shows a STIM image of a 2000 mesh grid taken with the above detection system using a 2 MeV proton beam. This provides true live-time imaging that can be viewed using any ocsilloscope with X-Y capability and Z contrast control.

Figure 3 shows a series of images taken with the above detection system of a piece of 8μm thick Si crystal with the <100> channeling axis at right-angles to the crystals surface. The beam was ~2 pA of 2 MeV protons and the scan size is about 200 X 200 μm. The first image (a.) shows the specimen in a random direction (shown in black) close to the <100> axial channel. The specimen issurounded by vacuum where the beam passes directly into the detector to give a white background. In the second image (b.) the specimen has been tilted closer to the <100> axis and now more of the beam is passing through the sample without being scattered and the specimen is seen to become more white. In the final image (c.) the specimen is in a axial channeled orientation and most of the protons pass through the specimen without being scattered to produce an all white image (i.e. there is no contrast between the crystal and the vacuum). This type of imaging could be very useful for radiation damage studies of thin materials.

The IBIC images shown in figure 4. are of true live-time (a.) and pseudo-live-time (b.) images of a TA 670 CMOS SRAM. This type of imaging can be used to easily position the device for further spectroscopic analysis. THe image was taken by connecting a charge sensitive pre-amplifier to V_{DD}, biasing the device (5V) thru V_{SS} and connecting the output of the charge sensitive pre-amplifier to the Z contrast of the VPO. The persistence is off in figure 4a. and has been turned up to an arbitrary value in figure 4b.

3 References

[1] M. Knoll, Z. Tech. Phys. 16 (1935) 467.

[2] P.A. Younger and J.A. Cookson Nucl. Instr. Meth. 158 (1979) 193-198.

[3] F. Watt and G.W. Grime (eds) "Principles and Applications of High-energy Ion Microbeams", Adam Hilger (1987), chapter 2.

[4] A. Saint, J.S. Laird, R.A. Bardos, G.J.F. Legge, T. Nishijima and H. Sekiguchi, Proceeding of the 8th Australian Conference on Nuclear Techniques of Analysis (1993) 21-23.

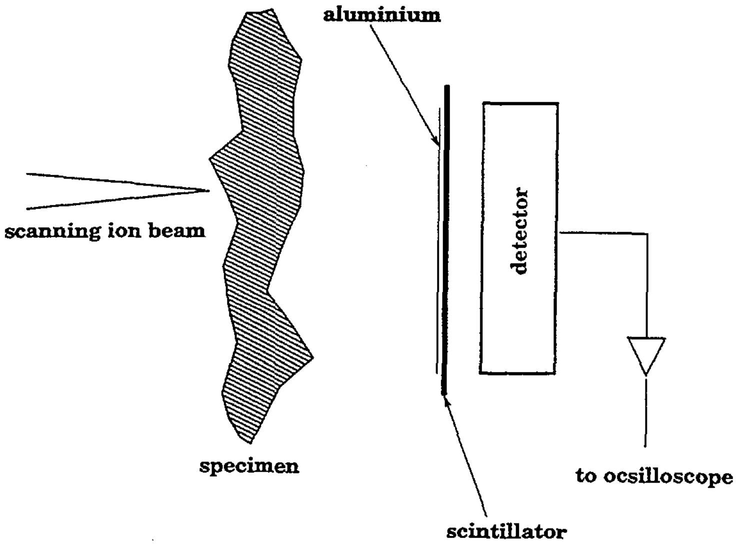

Figure 1 - Detection system

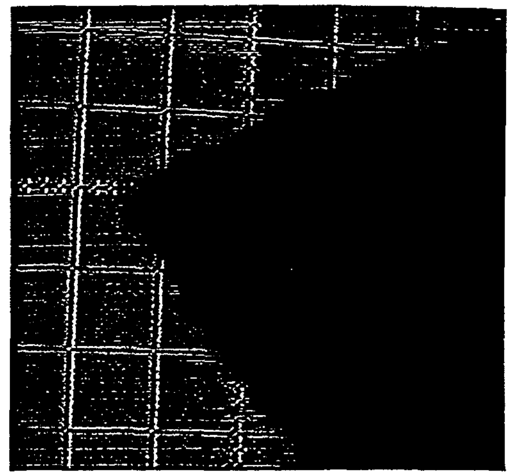

Figure 3a. - CSTIM image - random

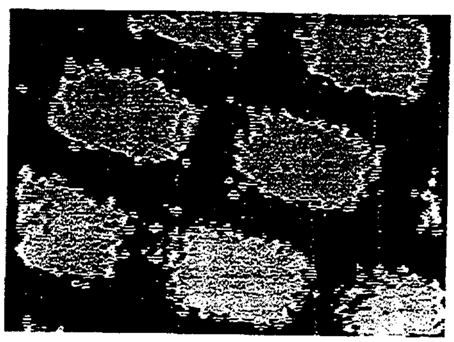

Figure 2 - STIM image of grid

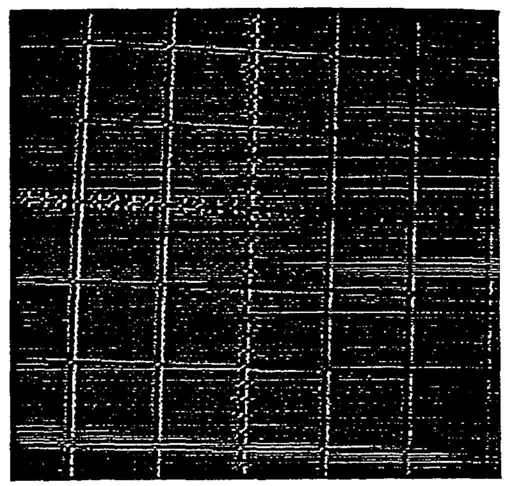

Figure 3b. - CSTIM image - partial channel

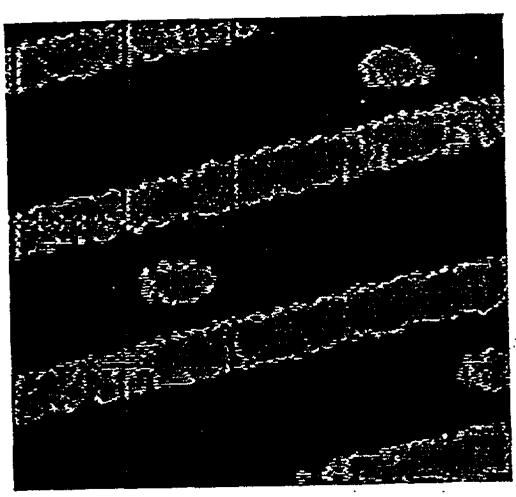

Figure 4 - live-time IBIC image

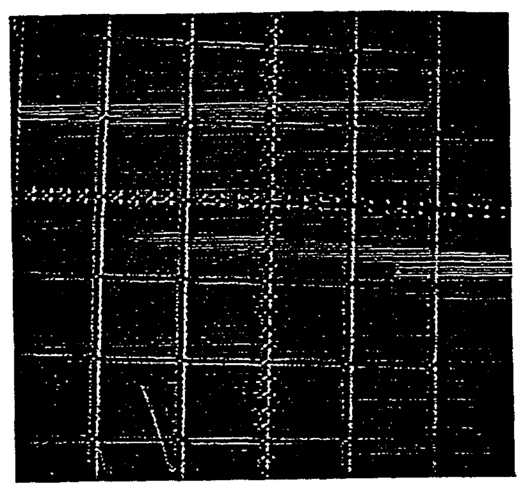

Figure 3c. - CSTIM image - channeled