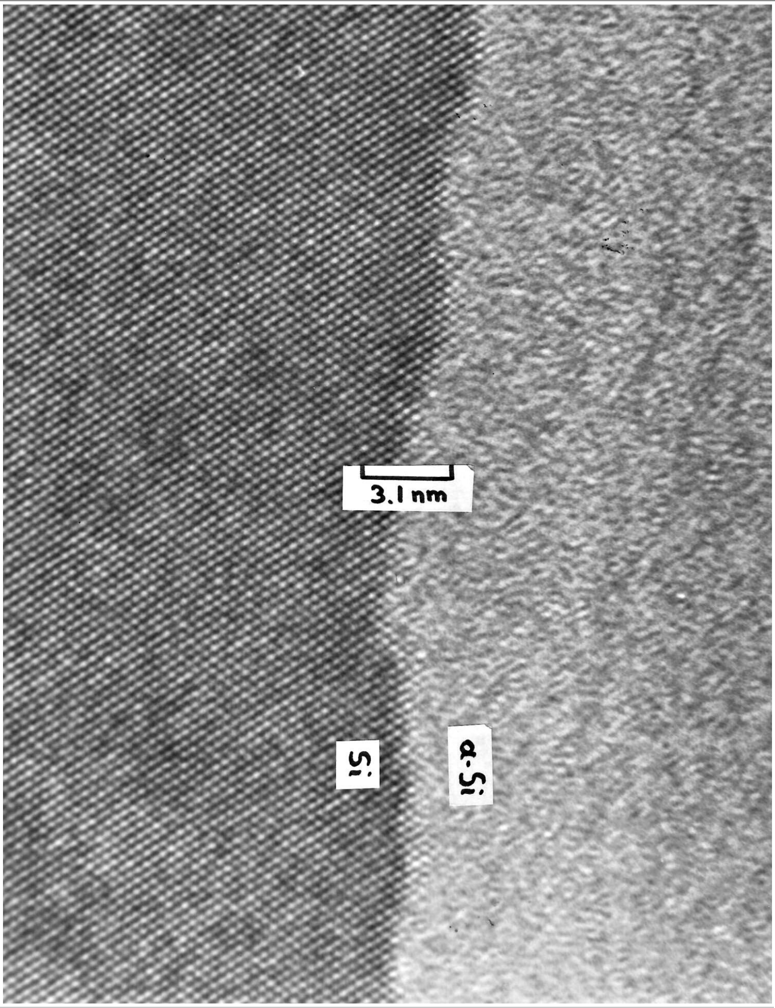
Pictures to: 4. IBM T.J. Watson Research Center

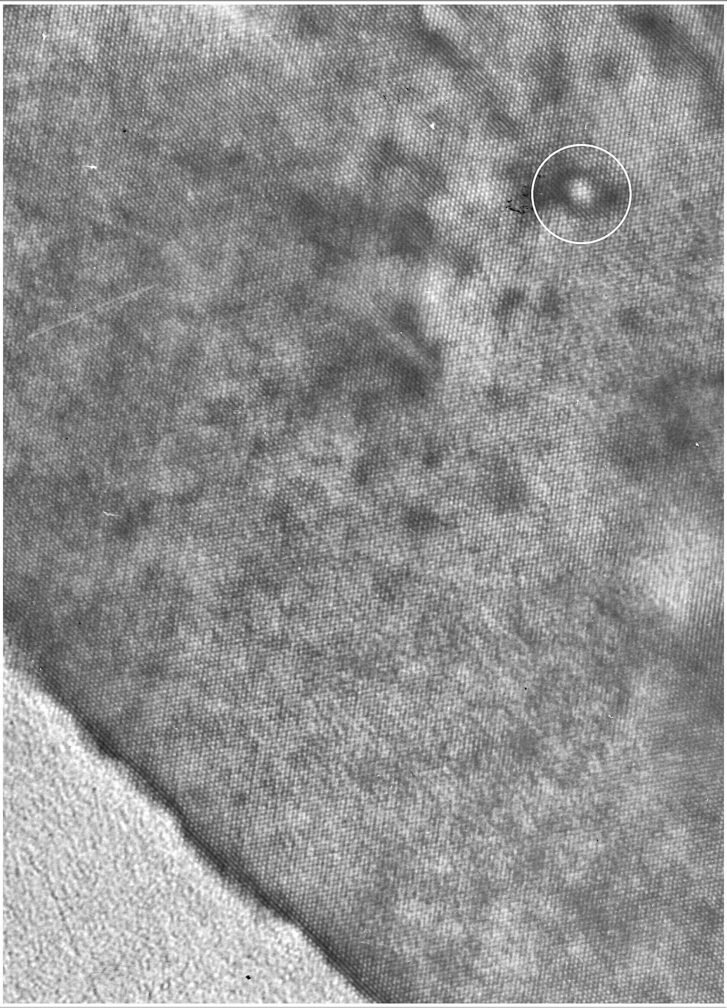
4.2 TEM of Defects Produced by Ion Implantation

Teh Crystalline - Amorphous Interface

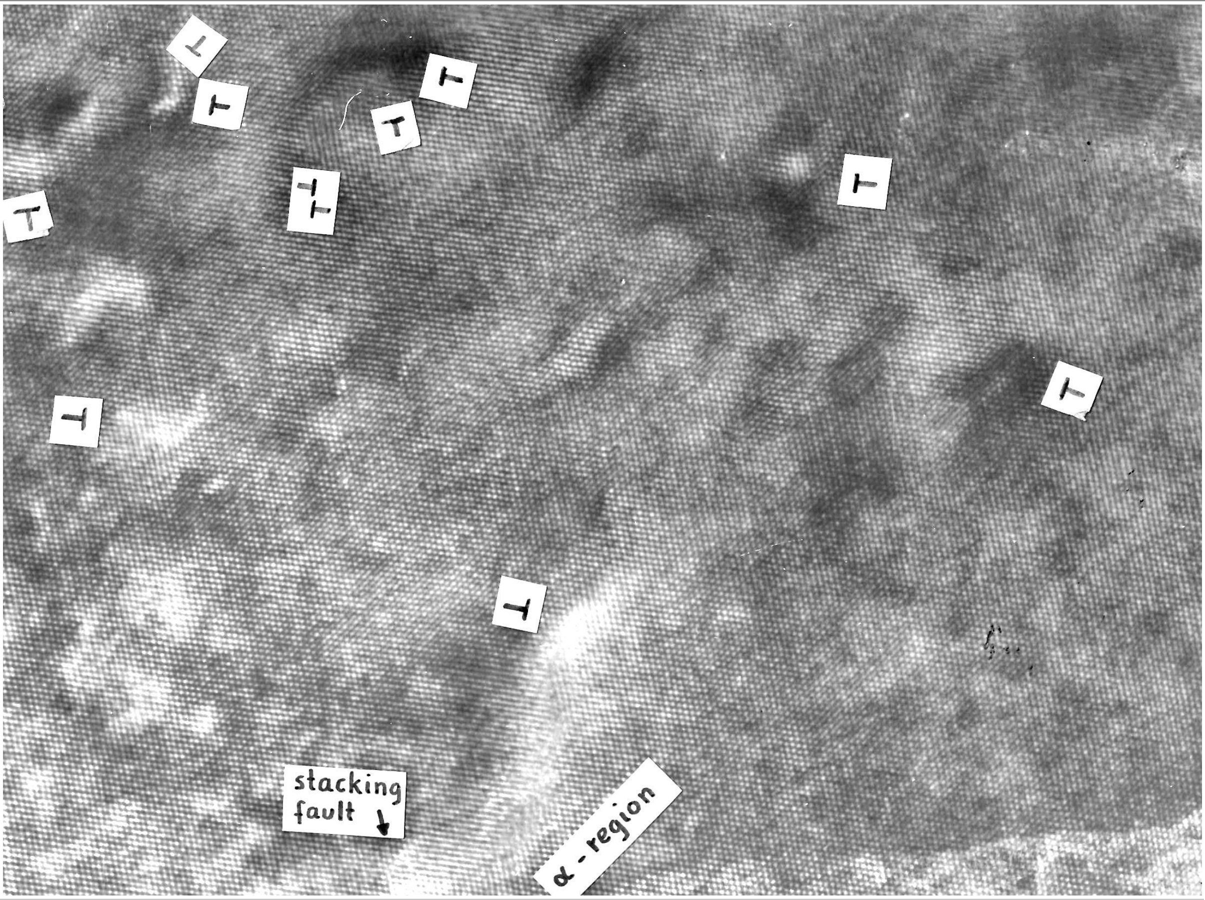
- What follows are some HRTEM pictures of the crystalline - amorphous interface obtained after implanting p-type {100} oriented 12 Ωcm Si with 7880 keV As^+ ions to a dose of 8 x 1012 cm^{-2} at (nominal) room temperature.
  - For around 1979/80 and a Siemens Elmiskop 102, this is an amazingly clear pictures - and it is the first one of its kind. These pictures, however, were never published.



Amorphous - crystalline interfac in Si after ion implantation
The transition is rather sharp. There are no easily recognizable deficits in the crystalline area.
They will be farther back



The "Hinterland" of ion implantation damage.
Some distance behind the amorphous – crystalline interface a lot of damage become visible – if you look closely! Something is definitely no right in the encircled area, and wherever you have strong background contrast you for almost sure will find something. Look at some of the publications listed above to get an idea. Or look at the next picture.

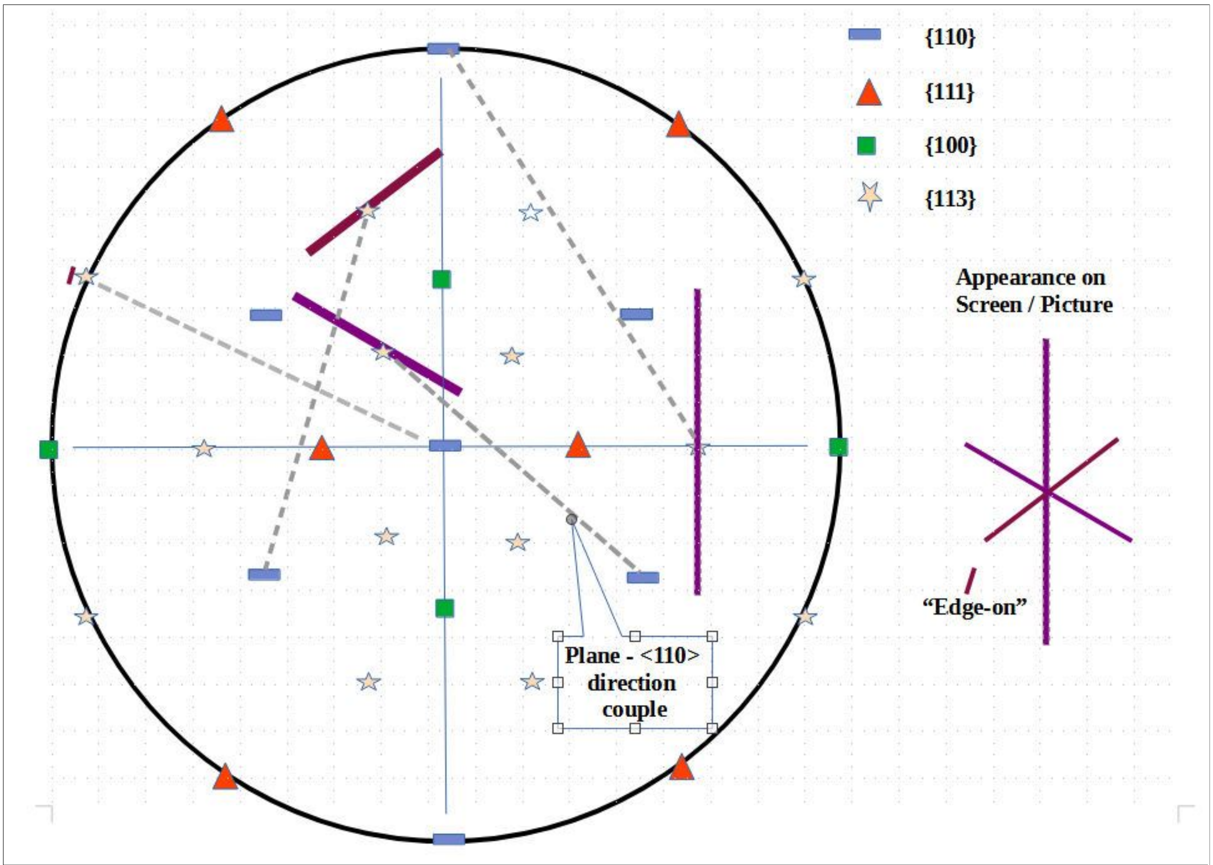


Same as above but with some ending lattice fringes marked.

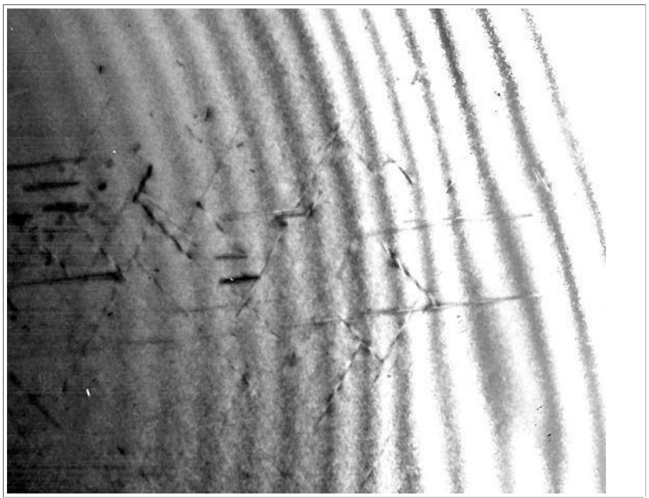
The {113} Stacking Fault

Next, let's look at the "rod-like" stacking faults on a {113} plane. The defect is oriented into the only 100 direction contained in a {113} plane, it can be several 100 nm long. It is a planar defect but only a few nm wide, i.e. it appears to be “rod-like”.

- Given this information, you can figure out how it would appear on the screen / pictures for, e.g. a {100} specimen orientation The figure below helps. It shows the (100) pole figure with the major orientations plus the {113} poles. The combination of the <100> direction contained in a specific {113} plane is shown by dotted lines. That allows to draw the projection of the rod onto the screen (violet lines). The rod on the {113} plane perpendicular to the electron beam would be seen “edge on” The next pictures show exactly what is derived here.

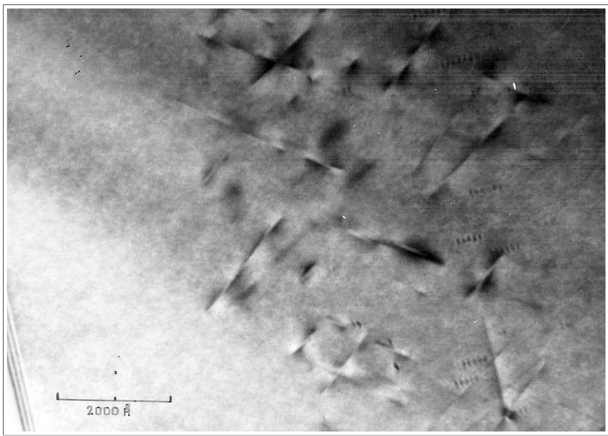


The geometry of rod-like defects and what you would see on the screen.

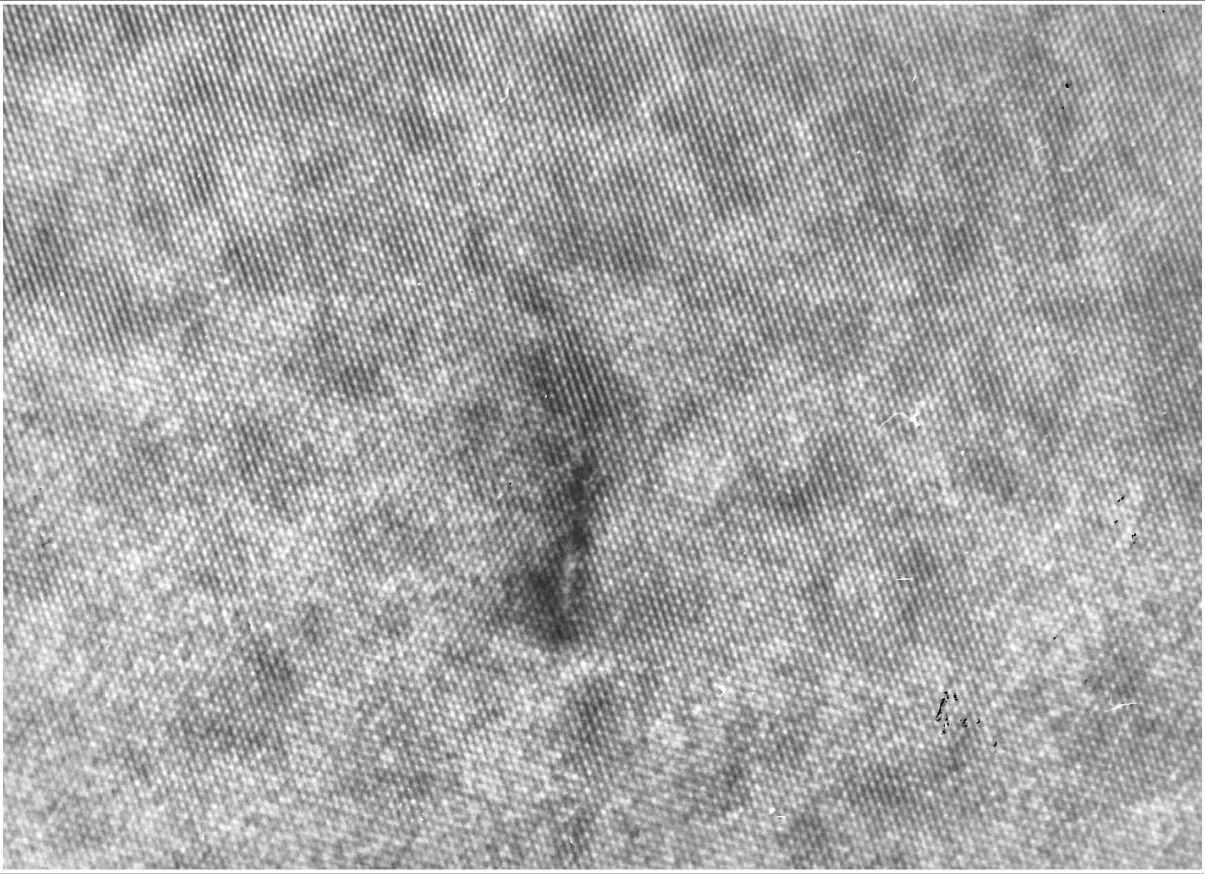


Rod-like {113} stacking faults.
Not a good picture but the geometry is clear. With the eye of faith,
you can even see some edge-on rods. The scale can be inferred from
the next picture This picture was never published.

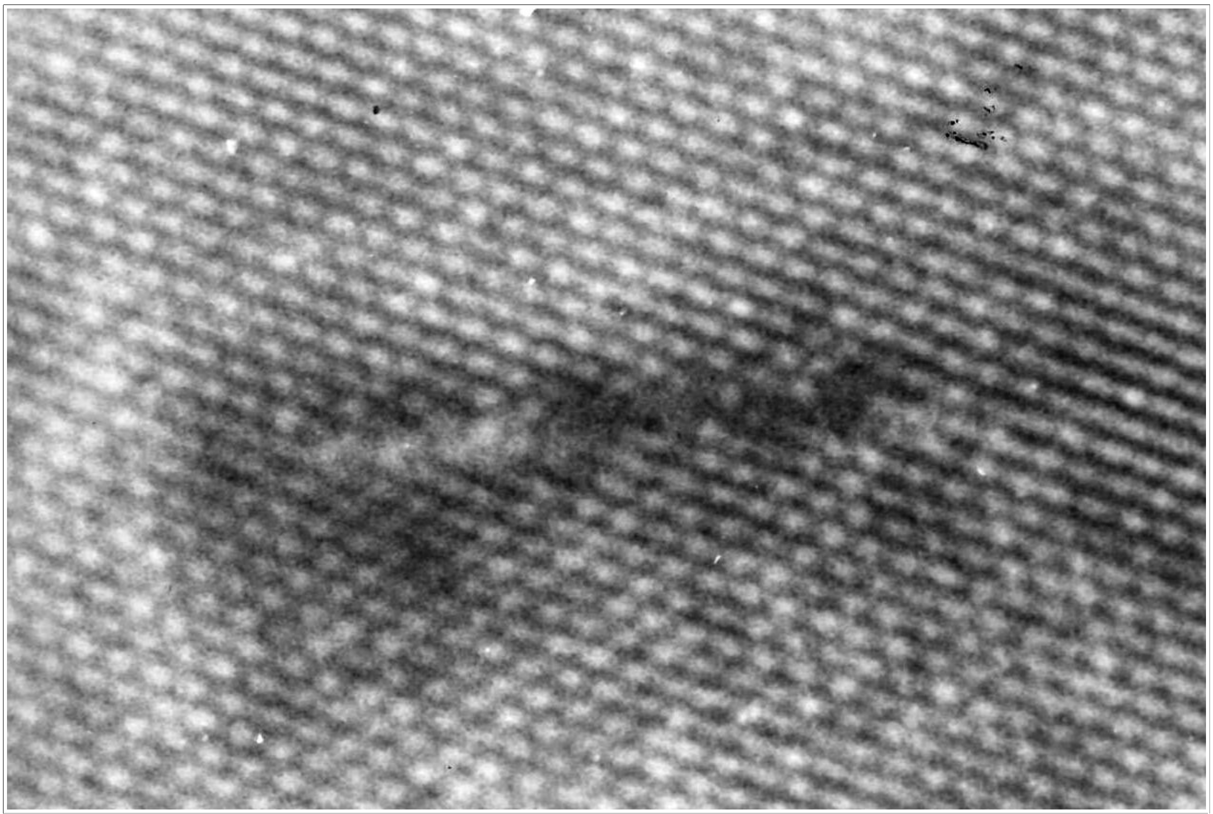
Same as above
Here the specimen is slightly tilted off a <110> direction. The edge-on defects therefore appear as short “zebras”, showing the typical stacking fault fringes. This picture was never published.



Same as above.
Here we have a scale and the “zebras” are clearly seen This picture was never published.

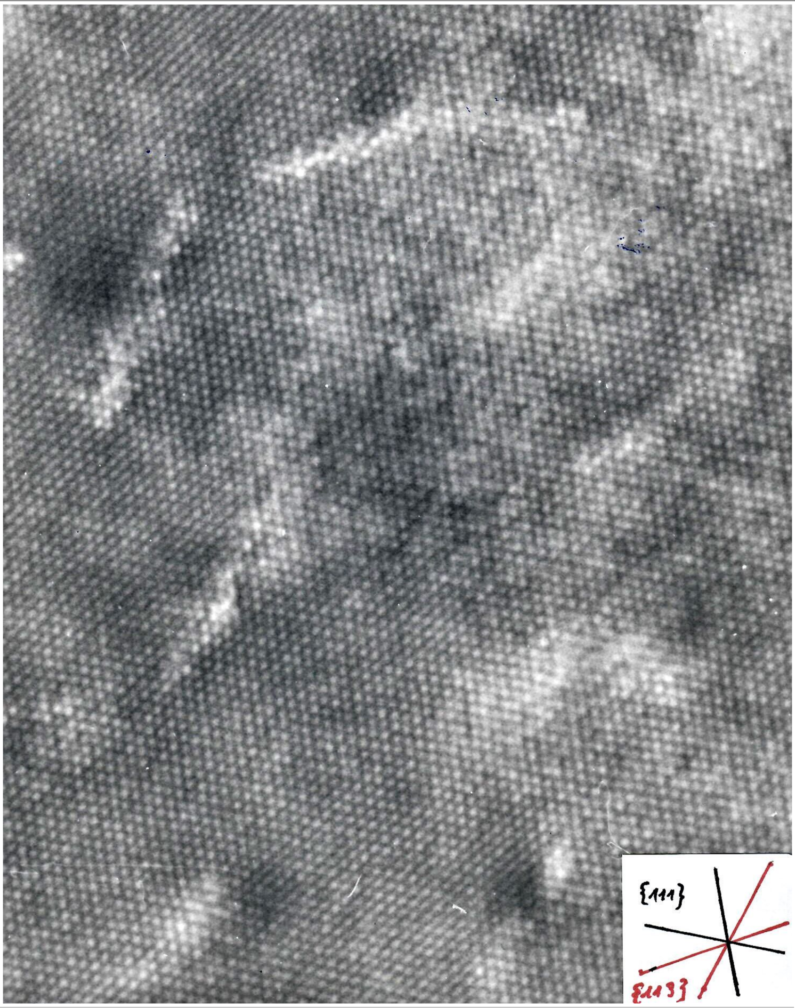


Relating to Fig. 3 and 4 in In Publication 28
The first HRTEM of a {113} stacking fault seen "edge-on"
It would extend several 100 nm perpendicular to the image plane



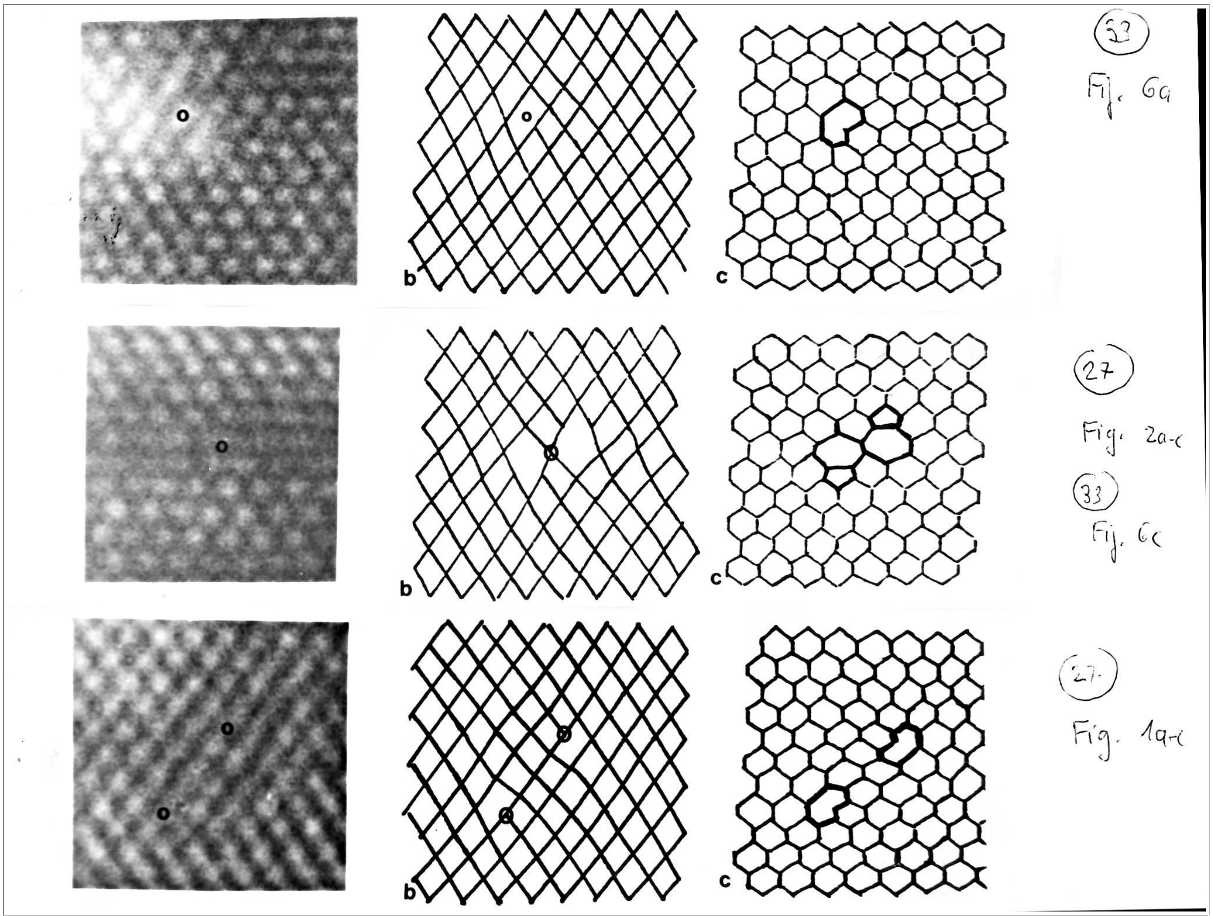
As above; enlargement..

Next an auxiliary picture and a personal remark. When I took these and related HRTEM pictures around 1978 / 79 I was a member of a very small and privileged group: researches with access to one of the very few transmission electron microscopes that could – if everything was optimizes - produce images with “atomic” resolution. Two emotions came with this. A real “high” when you saw for the first time something that nobody else had seen – like the HRTEM image of a {113} stacking fault or the Si – Pd_2Si interface. This was often followed by deep frustration when you realized that yes, you saw it almost down to the atoms but you still couldn’t quite figure out what you saw. The picture below provides an example. There are many defects present for or sure – but what exactly?

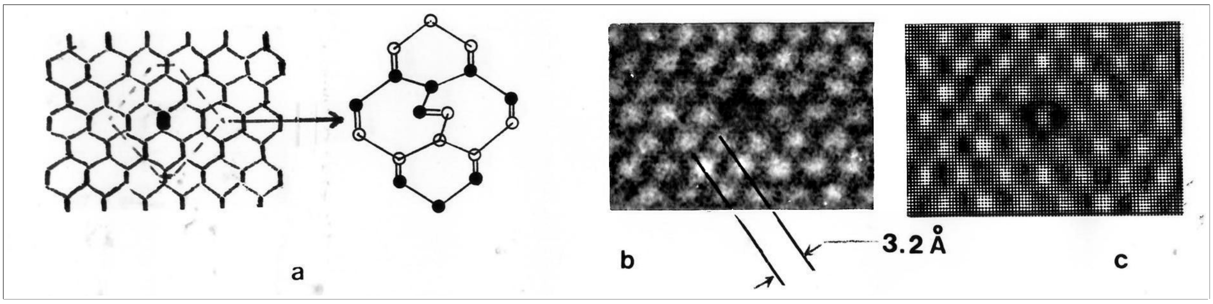


Several {113} "edge-on" stacking faults in Si
The traces of the {113} and {111} planes are outlined
This picture was never published; I didn't realize its significance then.
Compared to the picture above, the defects are less prominent. This might be due to the specimen being thinner and some possible rearrangement of the atoms close to the surface.

Finally, just two pictures relevant for papers 27, 30 and 33 above



"Intermediate" defects in Si (??).



Picture to Ref. 30: Extended interstitial chains in Si (??).