

Detecting Dislocations in Trenches by Chemical Etching

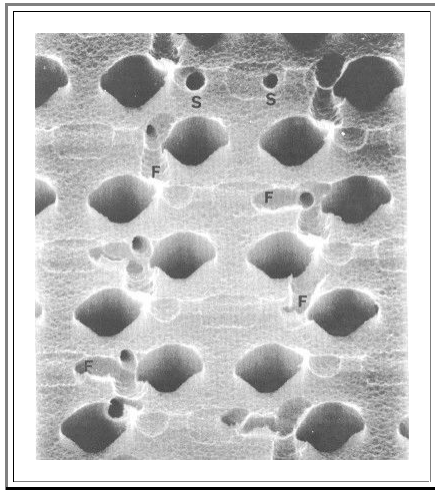
Advanced

With the development of the 4 Megabit Dynamic Random Access Memory (**DRAM**) and of the eighties, a new process was introduced into **Si** technology: [Trench etching](#) for trench capacitors.

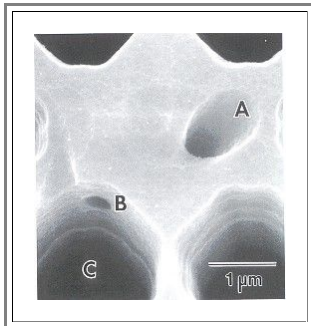
- A **trench**, contrary to the literal meaning of the word, is simply a small **hole** - typically **1 μm** in diameter and **(6 - 8) μm** deep. It is made to provide a large area for the capacitor while still using only about **1 μm^2** in "real estate" on the chip surface.
- All kinds of problems were encountered with the performance of the trench capacitors, some - maybe - caused by dislocations ending inside the trench.
- Since there are about **4 · 10⁶** trenches on one chip, and some **100** chips on a wafer, looking with an electron microscope at a few trenches will not do much good - you will turn to defect etching,

There is a clear question to the analytical people then: Are there dislocations inside the trench, and if yes, does his correlate with electrical performance? Well, **Wendt, Sauter and Kolbesen** of Siemens AG answered this question in an elegant, if tricky way with chemical etching. Here is what they did.

- If you etch your wafer with some defect etch, you may obtain pictures like the following one



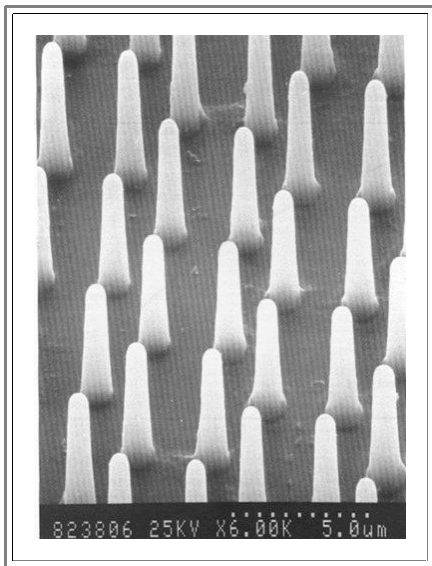
- This is a **SEM** picture, because you would not see very much with a light microscope - the big holes being the trenches are just about **1 μm** across. In fact, while you would detect the relatively shallow dislocation etch pits marked by "F", you would miss the sharp little holes marked with "S".
- Well, you see that there are dislocations ending at the surface. What you do not see is if there are dislocations ending on the surface of a trench; i.e. **inside** the hole. If you look real close, you might on occasion find something as shown below:



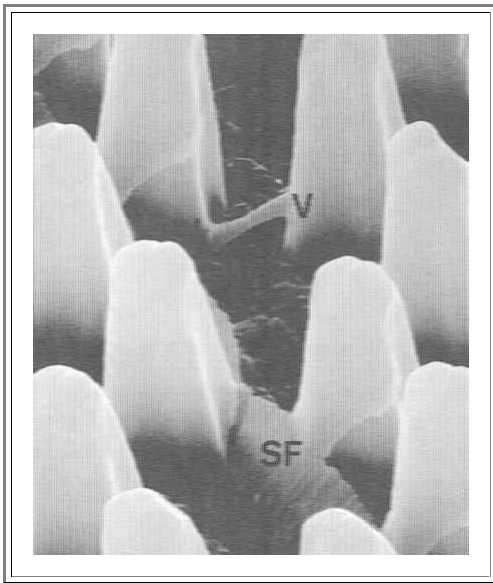
- OK, here you have the etch pits of a dislocation that starts at the surface at "A" and ends obviously inside the trench at "B" - but still rather close to the surface.
- How about deeper down in the trench? How do you look inside a **1 μm** trench (with any method)?

Here is the solution:

- 1. Etch the whole wafer, producing etch pits inside the trench if there is a dislocation.
 2. Coat everything with a thin layer of **Si₃N₄**.
 3. Etch off all of the **Si**, leaving only the **Si₃N₄** layer intact.
 4. Inspect the **Si₃N₄** layer. It is a kind of "negative" of the trench structure which now is easily inspected.
- Pretty tricky (and by far not as easy as it sounds). Here are some results (the "stripes" are artifacts from image processing)

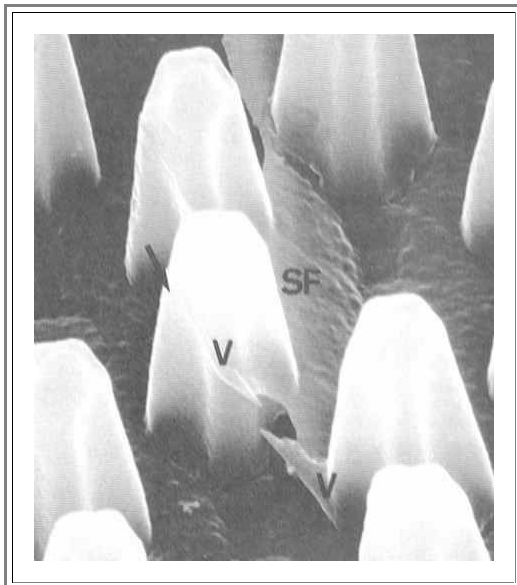


- The inverted trench structure - pretty perfect in this case.



- The structure marked "V" clearly results from a dislocation running from a trench to its neighbor.

- The structure marked "SF" actually shows a stacking fault.



- Same thing here - a prominent stacking fault (and a dislocation).

- So we have stacking faults, not just dislocations at work here! This is a major finding, that would have been practically unavailable with other methods.

- It is a major finding, because now we have a pretty good idea where the defects are coming from: We most likely deal with a new kind of [oxidation induced stacking fault](#), and that give us a clear idea of what needs to be done to get rid of those defects.