2.4 Process Induced Defects in Si Chips (Investigated in a HVTEM)

Background

- I forgot when I first met Bernd Kolbesen from Siemens Research - must have been some time in 1975. We first worked together on the swirl defect problem but soon enough Bernd brought along specimen containing (usually faulty) integrated circuits. We looked inside these circuits and found lots of fascinating defects.
  Bernd, Kolbesen, together with **Kurt Mayer**, headed a relatively small group at Siemens that endeavoured to find out why integrated circuits were not always doing what they should. They were ably assisted by Gottfried Schuh and some other highly competent technical staff at Siemens in Munich and then by me and my colleague (and friend) **Horst Strunk**, providing the High-Voltage Transmission Electron Microscopy (HVTEM) work at the "***Max-Planck Institut*** für Metallforschg" in Stuttgart. We were looking at very early integration technology like a 4 kbit memory (equal to 500 kB, providing storage space for half a page of written text). The idea that defects in the Si crystal were somehow involved was not totally new but most workers in the field didn't know much about that. It was clear to some extent that defects like grain boundaries and dislocations already present in the starting material were bad, but it was not so clear that processing the wafers could generate all kinds of defects by a number of mechanisms.
  It was certainly not clear at all that impurity concentrations far below levels considered "high purity" and often below detection limits of the analytical technologies available then, could cause huge and deadly defects by a complex chain of reactions.
  - As far as TEM investigations were concerned, Siemens was in a unique position relative to its competitors (entities like Bell Labs or IBM):

    - Siemens could thin a whole wafer to a thickness of around 5 µm. These wafers were still too thick for a normal TEM, and making them thinner would have removed part of the device. However:
    - Siemens could investigate any part of that wafer (e.g. containing devices with some unusual electrical characteristics) in the Stuttagart High-Voltage Transmission Electron Microscope (HVTEM), the only one in Germany. This microscope could penetrate the specimen and produce clear pictures of what was inside.
- I do belie that nobody else in the world could do such an intricate analysis. A lot of work went into this and so we must have produced a lot of first-rate publications.

Publications

- Well, the total count is one (1). And that one publication is just a conference proceedings paper, not much read or referre to-.
  Here it is:.

  1. FÖLL, H., KOLBESEN, B.O.: Advantages in the study of crystal defects in Si starting materials and devices by use of a HVEM. Semiconductor Silicon (1977), p.740
  - Why just one? Partially because the topic was not so interesting to the electrical engineering community, and the physics community. The latter didn't consider this to be real physics and the former had no interest in "material" issues. Somehow, the journal of choice for many years was the Journal of the Electrochemical Society, and the conference proceedings that I mentioned above was actually known as the "Blue bible" among the few cognoscenti and was issued from a kind of satellite conference included biannually in the big meetings of the Electrochemical Society. Considering that chip making then (and now) has nothing whatsoever to do with electrochemistry, this is a bit odd
  - The main reason for the lack of publications, however, was that the Siemens guys were not much interested. Firstly, a lot of the stuff was confidential, secondly, as an employee of Siemens, you were beyond the (in)famous "publish or perish" paradigm.
    As far as us ***MPI*** guys were concerned, we had our "real" work to do (the Siemnes stuff, while highly interesting, was "on the side") and in those happy days we weren't overly worried about the publish or perish stuff either.
- However! The Siemens work was (partially) run on a grant from the Federal Research Ministry and eventually you must write a report. That happened in March 1979 (2 years and 3 month after I left Stuttgart) and in April 1981 (6 months after I joined Siemens in Munich) and these two reports give a detailed insights into the many battles we fought (and mostly won) against all those devious things out there that were bend on killing integrated circuits.
  - I truly believe that these report (possibly moldering in some archives but probably longs since gone for good) mark a significant milestone on the way to making integrated circuits. Understanding process-induced defects made it possible top avoid them (often by rather simple tricks) and nothing whatsoever has changed since then. Produce a dislocations or a stacking fault in a modern IC and it will be just as deadly as in the primitive 4 kb memory in 1975. Here are the reports:

Kristallfehler in hochintegrierten Schaltkreisen aus Silizium
B.O. Kolbesen
K.R. Mayer

Kristallfehler in integrierten Schaltkreisen aus Silizium, insbesondere in Hinblick auf Größtintegration (VLSI)
G. Franz,
B.O. Kolbesen

- I (and H. Strunk) couldn't have been authors for formal reason, but many TEM pictures shown were in the first report were taken by me, the rest (all in the second report) are due to Horst Strunk.

Pictures

I scanned my high-quality pictures of the first report and improved some of the photos by digital means to some extent. Here they are

Report pictures

Abb. 1 - 22 Abb. 23 - 45 Abb. 46 - 71

- The next set of pictures come from my paper archive. Many are the originals of the pictures shown in the publication and the first report, some are additional material.

Additional pictures

How did it go on?

- I go out of this kind of research when I left for Cornell University at the end of 1976. It is of interest or even amusing to look at what happened to chip making at Siemens after that.
  - It is rather pleasing to note in Oct. 2022 that Siemens is still making chips. Well – not exactly Siemens but Infineon, the company outsourced from Siemens in 1999. Siemens Semiconductor and later Infineon survived (sometimes only barely) many life-threatening crises. Infineon is now (2022) among the 10 leading chip producers world-wide. The same cannot be said about our then biggest competitors like IBM or Bell Labs who outshone us by far when we started work on this. As far as Bernd Kolbesen and I are concerned, Bernd stayed with Siemens until about 1990, when he became a Professor at Frankfurt University. Most of the time he did what he did when I worked with him: Heading a group looking into integrated circuits.
    My career track was a bit more meandering. After two years at Cornell University, I joined IBM Research, doing this and that but mostly looking at Si – silicide interfaces in the context of using silicides for IC's. Back to Germany I joined Siemens in Munich, heading a small group that was supposed to analyze various kinds of "solar" silicon made by various so-far unexplored techniques. That lead to various interactions with Bernd Kolbesen and his group. For a short time I even had to rake over some of his group while Bernd was doing something else. When interest in solar cell activities declined (the oil crisis was over for good), I switched to chip technology development, ending up (in July 1989) as the project leader for the development of the 16 Mb DRAM) I got out of the (doomed) project by not only becoming a full Professor at the Christian-Albrechts- Universität (CAU) Kiel but the founding Dean of the "Technische Fakultät" (Faculty of Engineering) where I continued solar energy research (among other stuff).