

## 3.3 Defects in EFG Si Ribbons

### 3.3.1 Background

Nov. 25th 1973 is a day to remember. It was a Sunday and you were forbidden to drive your car on a German "Autobahn"! We experienced the high point of the first (world-wide) oil crisis! The crisis started the very first wave of research in what today we like to call "green" energies, in particular solar energy and solar cells. My post-doc contract with Cornell university included TEM studies in Si ribbons made by the "**Edge-defined Film fed Growth**" (**EFG**) method. I actually did a lot of work on this topic – but never published anything!

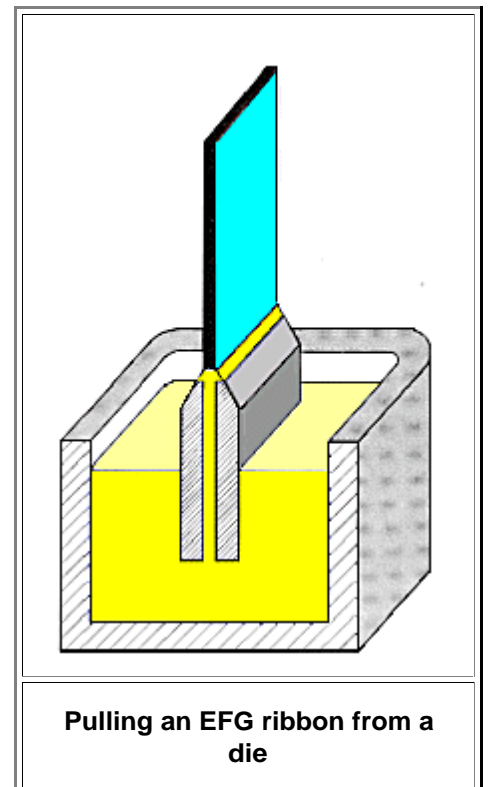
Nevertheless; I include some pictures and explanations here for a very good reason:

**This work started me on solar cell research**

Since 1977 until 2014 when I retired, I have worked almost without interruptions on solar cell research.

What is "Edge-defined Film fed Growth"? Well, it was one of the many (mostly apparently crazy) methods to come up with thin sheets or ribbons of solar-grade silicon that could be used directly to make good solar cells. The picture on the right gives an idea of how to pull a Si ribbon with the help of a die. Use [this link](#) if you want to know more. Two points should be made today (Nov. 2022)

1 None of these (and lots of other methods / materials) made it. Solar cells today are the cheapest way to produce electrical energy (something none of us would have believed in 1977), and they are made by cutting Si "wafers" (typically square) from blocks of cast silicon. All these many methods that wanted to avoid the expensive and wasteful cutting process added costs and waste of their own and did not anticipate that cutting would become very cheap (by using wire saws that cut 100 wafers in parallel) and produce almost no waste anymore (by using ultra-thin wires). You also can't beat silicon pricewise. There is plenty around and the methods to extract it from  $\text{SiO}_2$  have also improved and became cheaper since then



2 In 1977 not much was known about defects in Si crystals. Si then came as (almost) defect-free single crystal (see 2.3 and 2.4), and its brittleness at room temperature made plastic deformations and thus dislocations generation impossible.

Samples came from (I believe) Mobil Tyco Solar Energy Corp., and IBM. Hard to believe now but IBM in 1977 still did a bit of Si crystal growing and also looked into "solar silicon". In essence, I studied the structure by defect etching, "electron-beam induced current" (**EBIC**) microscopy done in a modified scanning electron microscope (**SEM**) and by good old TEM. The defect etching and EBIC results are lost for good, but I still have a few TEM pictures, including rather interesting ones.

In essence, the ribbons contained a lot of (micro)twins that also acted as dislocations sources. Twins and other defects were not always electronically active (in the sense of degrading solar cell performance). It appeared that detrimental effects came from secondary defects (like precipitations of impurities at the primary defects), something I already knew from the work on [process induced defects in Si chips](#)

Why do I devote that much space and effort to this old stuff? Because I do believe that our successors (if there are any) who will see solar cells as the most important technology that supplies all their energy needs of humankind, will also want to know how it all got started. Maybe this survives. Chances are slim but much higher than the survival probability of some yellowing paper in some attic.

When I looked at the beginning of our most important technology for the last 2.800 years - iron and steel - I found very little. That didn't keep me from writing a largish [Hyperscript](#) about it, though. Some guy some day, I hope, will do the same for solar cells.

### 3.3.2 Publications

There are no publications! I never got around to it and the results just did not quite warrant publications in my opinion (I must have been an arrogant prick then).

I did, however, write internal reports (since my advisor forced me to do so) and I give you one [here](#).

### 3.3.3 Pictures

The pictures relate to the report; I also give you a few auxiliary ones. Since there is not much text in the report I will supply some explanations on occasion

[EFG Ribbon Pictures](#)