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SOME DISCONNECTED SPECULATIONS ON SLICING SILICON

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This talk has two purposes:

1) To remind workshop participants of the basic principles needed to qualify wafering methods.

2) To briefly describe some offbeat approaches we have considered, mainly to encourage others to volunteer unconventional ideas.

The main purpose of the workshop is to open up new areas of applicable technology. To overuse a current phrase, we are to explore and extend the "cutting edge" of cutting edge technology.

First the basic principles:

We must slice silicon from large grown or cast ingots (tens of kg mass, dimensions hundreds of centimeters). Although some pre-slabbing is OK, the slices must be 75-100cm deep.

The method must have:

- High slicing yield (m^2/kg).
- High throughput (m^2/hour).
- Minimal damage.
- Reliable equipment, applicable to single or poly crystals.
- Low cost.

High yield results from reduced sum of the (slice + kerf) (S+K) thicknesses (Figure 1). We see that high yields result from reduced kerf and also from reduced slice thickness.

Although reduced kerf is less important when the silicon cost is lower, the cost of generating this scrap must be included. Generally, reduced K and S are obtained by reduced slicing speed; to maintain reasonable throughput, this leads to the need to form many slices simultaneously. This reduced slicing rate will, however, reduce work damage. The formation of many slices must not lead to increased complexity, monitoring or maintenance; if possible, the scrap silicon should be available for reprocessing. Remember, that all necessary conditions must be met by a successful slicing method.

I will now turn to the offbeat approaches:

Like many others, we were frustrated at having to waste so much high quality silicon in our daily slicing procedures. We had also envied the kerfless operations of baloney slicers, or of foam plastic cutters in a neighboring factory. For this reason, we speculated on possible uses of cleaving to form slices. In cleaving, the kerf loss is zero, although some crystallographic orientation is required, and we knew from experience that cleaving thin slices was difficult, because the cleavage forces turned towards the free surface, even when we tried damping this surface.

At the time we considered this, a popular TV ad showed the vibration-free Ford Granada automobiles, by demonstrating a skilled diamond cutter cleaving a valuable diamond while in the back seat of a moving Granada - very dramatic, and we all sighed with relief when he achieved a perfect "cut" of this valuable item near the end of the ad. On short analysis, we ruled this method out, because of the high labor cost of the cutter and of the always present, non-productive companion who was describing the process, the slow throughput, (one per ad) and also because we could not afford to buy the Granada.

We next turned to geology for a possible method. The phenomenon we considered can break large granite boulders, by using the expansion of water trapped in small crevices when it freezes. We combined this method with our ODE slicing method, wherein many close spaced, narrow slots are formed parallel to the (111) planes which are natural cleavage faces for silicon. We formed fairly deep slots, filled them with water and froze the water by immersion in liquid nitrogen. We were not successful in cleaving the silicon, although there is a chance that with modifications this method could work. Since this method used slow application of force to cleave the silicon, we next turned, in a whimsical mood, to consider fast impulse applications. Also around this time, an article in Scientific American analyzed the forces involved in Karate blows used to break concrete or wooden blocks (see Figure 2). Short calculations show that with suitable concentration of this force in narrow slots (perhaps aided by a small wedge), we could exceed the rupture strength of silicon, and that slices of silicon several centimeters thick should be achievable.

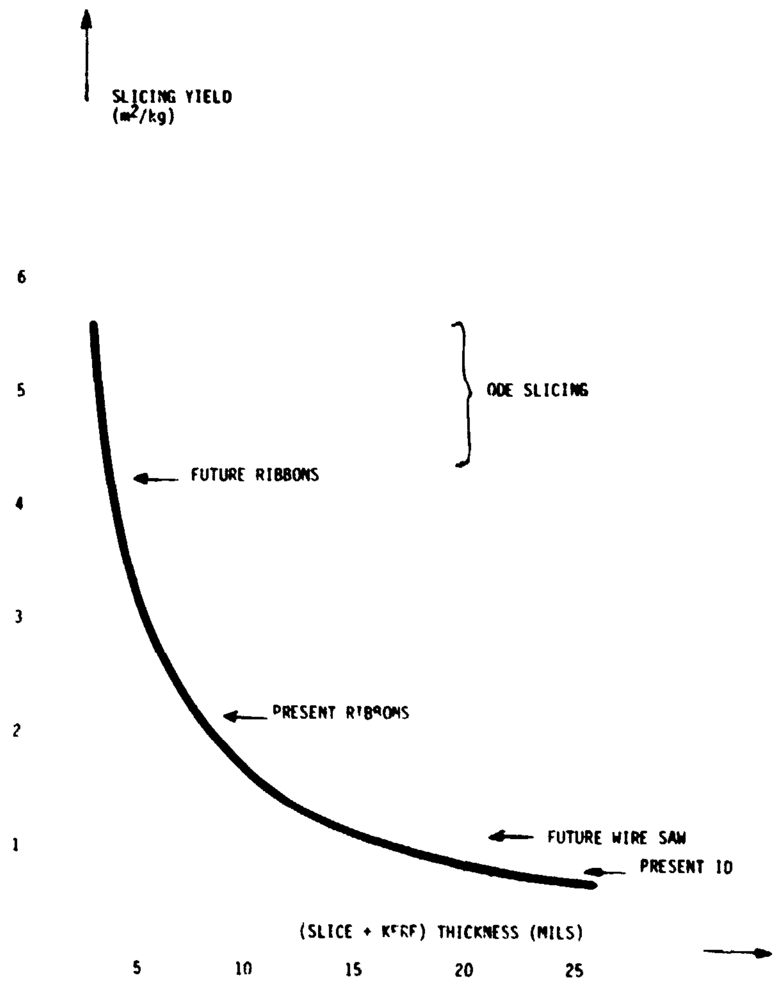
However, before making an actual test, we considered several disadvantages to this method which made it less attractive. We realized the labor costs would be high, because highly skilled (brown or black belt) Karate practitioners would be required, and their throughput would be low because of the need for extended concentration periods between blows. Also the maintenance and repair costs on their hands would be high, and there was generation of noise pollution (shouts) for each slice. We did not consider that ganging of the Karate operators would lead to a compact operation, or allow easy simultaneous slicing.

We were particularly sorry to drop this method because we had already coined an apt acronym. In line with the Crystal Systems method called Fixed Abrasive Slicing Technique (FAST), we could have described our process as the Fast Impulse Slicing Technique, or FIST for short.

Well that concludes the talk. It will have achieved its purpose if it encourages other people to speculate freely, to try and uncover new wafering methods which can be applied, to prevent ingot methods from being dominated by the ribbon growth methods in the near future.

FIGURE 1

SLICING YIELD VS. (SLICE+KERF) THICKNESS



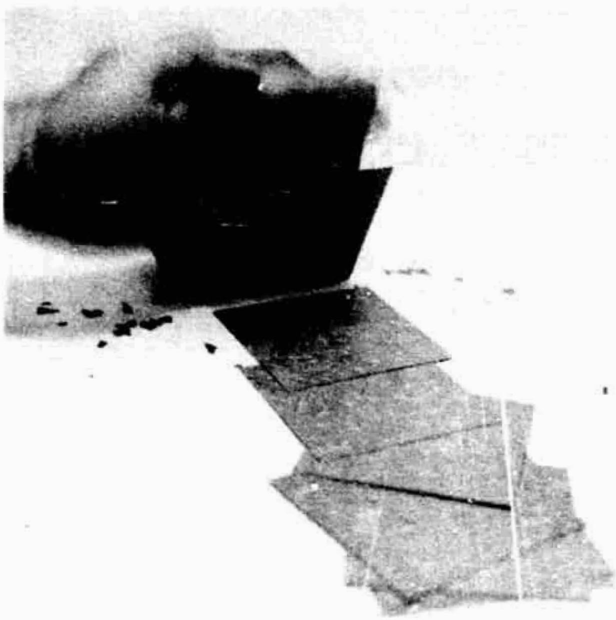


Figure 2. Fast Impulse Slicing Technique (FIST)