in a wave like manner at the speed of 344 thousand kilometres per second. Consider a still pond into which a stone is cast; the wave patterns that result are a good analogy except that light waves are much finer and radiate in three planes instead of two. Photons are infinitesimally small yet their velocity is so high that when they strike a photo-voltaic cell they dislodge electrons from the silicon atoms in the cell structure. The cell is polarised so that the top contact becomes positively charged and the bottom contact becomes negatively charged. If the circuit is completed a stream of electrons (an electric current) will flow whose strength is directly proportional to the cells surface area and the light intensity.

Fig 2.5 Mono-crystal solar cell
The original silicon solar cell, made from ultra refined semi-conductor grade silicon.

Silicon solar cells fall into three main categories; mono-crystal, poly-crystal and amorphous. The original cells back in the early 1950's were made from mono-crystal silicon. This was and still is a tedious, high energy process. Quartzite rock (silicon dioxide) is reduced in large arc furnaces to form metallurgical grade silicon (MG-Si). It is then further refined by the Siemens process into semi-conductor grade polysilicon (SeG-Si) which is primarily used in the electronics industry The polysilicon must then be refined still further into monosilicon by the *Czochralski process* , during which, boron, a "P" type dopant is added to the molten brew. A seed crystal is then inserted into the melt and slowly withdrawn. Cylindrical ingots of up to two metres in length and thirteen centimetres

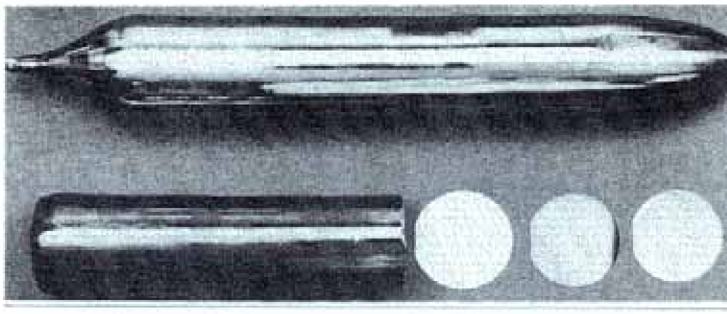

Fig 2.6 Mono crystal silicon ingot
Formed by inserting a seed crystal and rotating as it is slowly withdrawn from the melt.

in diameter can be routinely produced in this way. The ingot is then sliced into thin wafers where over half the precious material is wasted as swarf. The "P" type wafers then undergo heat treatment in another furnace where an "N" type dopant, phosphorus , is diffused into the top surface to form a *P-N* semi-conductor junction, which is the key to solar cell operation. Finally, a thin metallic grid is vacuum deposited on the top of the cell and the output terminals are attached.

The time and energy taken to produce cells in this manner are not consistent with the ethos of environmental sustainability that the manufacturers of such products claim to be a main benefit of using them. At least a third of their twenty year average lifespan is spent recovering the original energy investment embodied in their construction, severely compromising the environmental benefits of using them.

The second type of silicon solar cell is made from poly-crystal material. The same basic

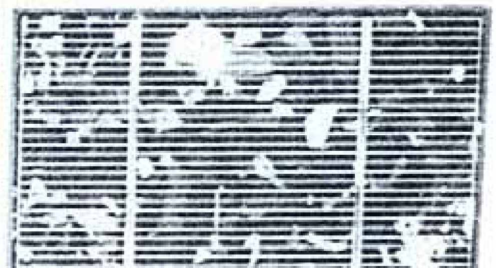

Fig 2.7 Poly-crystal solar cell
Dating from the early 1980's, these cells use less refined silicon but manufacturing inputs are still too high.