

New monosilane-based technologies

Fluidized bed reactor technology

Most of the non-Siemens polysilicon capacity to be added over the next few years is based on FBR technology. Currently there are three large FBR plants with capacities of several thousand tons/year in the pipeline; GCL-Poly (China), REC Silicon and Youser Group joint venture (China), and SunEdison Semiconductor (South Korea). Even though the principles of FBR polysilicon production was developed in the 1960's, there is substantial room for variation in the practical implementation [12]. Most of the recent development has taken place in-house in the various companies. There is therefore little information available on the projects that are currently under construction, but there is reason to believe that all the three main current projects are substantially different [6].

Recently the German-American company SiTec claims to have developed a concept based on decomposition of monosilane in a vibrating FBR, which they intend to offer as a third-party equipment provider [13]. Vibration contributes to the fluidization of the bed and makes the reactor able to run with low gas flow velocities and no dilution gas.

Centrifugal chemical vapor deposition

Dynatec Engineering has since 2011 tested two pilot-scale reactors based on a completely new principle within silicon production, in what they call a centrifuge chemical vapor deposition (C-CVD) reactor [14], [15]. The principle is to inject monosilane gas in a rotating reactor volume. The centrifuge effectively separates heavier gas molecules and fines from the light hydrogen gas. The pilot reactors have proven very promising; yields reach well above 95%, growth rates are 40 times higher compared to the Siemens reactor, and the reactor operates in semi-continuous mode [15]. The material from the C-CVD reactor is granular and can therefore be handled similar to FBR granules. More information about Dynatec's progress is available in the current conference proceedings [16]. Some results from the C-CVD reactor are also presented in this article as a demonstration of how the silicon production lab platform at Institute for Energy Technology (IFE) can be used for testing pilot technologies.

Free space reactors

The simplest of all monosilane decomposition technologies might be the hot wall, or so-called free-space reactor (FSR), where flowing silane gas is subjected to heating and converted to hydrogen and solid silicon. Several players, including Union Carbide and Joint Solar Silicon, have attempted to develop FSR technology for polysilicon production [17]. To the best of our knowledge, none of these technologies are currently being pursued.

However, free space silicon products may find other applications. Beyond the electronics and solar cells, there is a promising future application for silicon as a battery material. Silicon in the anode of Li-ion batteries is capable of storing up to ten times more Li ions than the current carbon anode [18]. For this purpose, silicon particles with size distributions in the sub-micron range are desired, and production methods are therefore different from those for polysilicon grains and chunks. Mangolini et al. have provided a thorough review of research-scale production methods for silicon powders and their applications [19]. Technology based on the use of lasers, or low-pressure plasmas give high level of control with the reaction zone and high quality products, but yield low production throughput. We believe that thermal decomposition in atmospheric or higher pressure CVD chambers is the most industrially relevant method. At IFE, we have developed a pilot FSR capable of producing silicon powder at a rate