The knowledge factory

**Polysilicon production:** The Siemens process has been the forerunning technology in the polysilicon production world for the last years. Even with the advent of fluid-bed reactors and vapor-to-liquid deposition, the Siemens process remains the unrivalled popular method. Thus, it was with great interest that *pv magazine* toured the Schmid Silicon Technology (SST) pilot plant in Schwarze Pumpe, in the east of Germany. SST has their own method; apparently ready to challenge the rest of the techniques.

The silver maze of pipes gleamed in the sunny end of April day in Schwarze Pumpe. Amongst old industrial reactor towers, rusting pipes from the GDR industrial heydays and Vattenfall’s massive power plant, the SST polysilicon production pilot plant was definitely distinct. *pv magazine* was greeted by complex arrays of pipe work and the rush of workers hurrying to get the finishing touches complete and the scaffolding removed.

“The plant will begin the startup phase this weekend,” says Jochem Hahn, Chief Operating Officer at SST. The pilot plant in the brown coal region is not just a polysilicon plant to produce raw material for the photovoltaic industry. It is a learning laboratory, a knowledge factory as Hahn proudly states. He has been looking forward to this day since the plant was planned on paper. It has not been smooth sailing, with delays of more than a year and hiccups along the way, but come Labor Day, the three years of hard work would have paid off. The pilot plant is like a massive laboratory in a sense.

From what Process Engineer Gerrit Fester says, the project was meant to be completed earlier. Nevertheless, the delay has not all been that bad. Fester explains that what the team has learned in the process can be applied to the solutions they provide clients to ensure that their plants run without a hitch. Hahn adds, “A lot of delays were driven by our own decisions because we wanted to change things, to do research and development as well as experiment to get the best model as a pilot plant.” Hahn elaborates that things were

The Schmid Silicon Technology pilot plant in Schwarze Pumpe is not just a facility to produce polysilicon, it is also a unique learning laboratory with the drive to improve the upstream production.
and are done very ‘different’ here. He says that with partner M+W Group, the development of the plant has given them the chance to assure themselves and customers that similar mistakes will not re-occur in new projects. SST is then able in turn to offer its customers full turn-key systems out of one hand, including building/structural steel, equipment, periphery, piping and instrumentation, electrical installation, basic and detail engineering, project management, permanent supervision of construction works, key operator training and after-sales-service.

During the tour, Fester points out that the SST plant has more pieces of process equipment than the norm. “Usually polysilicon production plants can do with fewer, but this extra equipment is present so that we can experiment and check the results,” he explains. The pilot plant in other words gives the staff at SST the luxury to improve process conditions and quality while at the same time maintaining regular production. Approximately 90 employees are part of this plant. Sitting right at the start of the solar module production life cycle, SST’s philosophy that was asserted time and time again is to ensure that costs are sustainable and quality, uncompromised.

As a sister company of Schimid Group that deals with turnkey fabs for the production of wafers, cells and modules, SST made the decision to develop this pilot
plant in the land pocket straddling Brandenburg and Sachsen thanks to generous state subsidies, the proximity to uninterrupted power as well as client and monosilane supplier Linde and an established transport network. SST calls this, another 'competitive edge of SST'. The competitive edge obviously stems from the value-added learning that is a constant in a pilot plant like SST’s. "We will always be faster to learn and we will transfer this knowledge to the next generation. Others may not be able to run reactors under production situation for other purposes. We can," declares Hahn.

SST does not only offer turnkey solutions for polysilicon manufacturers but also the possibility of upgrading former Siemens-based plants. "Most companies are now realizing that the installation plans made on paper looked good but in reality are hard to realize and operate. The goals of efficiency and results are not materializing. We had a company visit us here and they were looking for a part of our process (hydrochlorination) for a better method to make TCS or trichlorosilane," Hahn gives an example. SST has the background and experience necessary to convince customers to switch to the monosilane process.

Technology
What does SST offer that sets them apart from the rest of the turnkey solution providers for polysilicon production out there? SST is very proud of the fact that it is a technology provider that invests in its own technology. The giants of the silicon manufacturing industry like Hemlock, Wacker, OCI and GCL-Poly are all pretty much reliant on the Siemens process. One among the European polysilicon producers decided that the Fluidized Bed Reactor would be their method of choice. Others have been wrestling with vapor-to-liquid deposition (VLD) for years as a viable alternative to the Siemens process.

The pressure for cost-competitiveness is largely passed on to upstream manufacturers thanks to the biggest chunk of the production costs coming from this segment. However, it has been written time and time again that the Siemens process is rather complex and energy intensive. Despite this, the bigwigs of polysilicon are dependent on the Siemens process. The SST monosilane technology on offer claims to have a simpler process structure comparatively. Basically SST uses pure monosilane instead of TCS as an input material for the CVD reactors. The advantages that can be pointed out with two very different processes, deliberately by the crew at Schmid is the fact that with these advantages coupled with less distillation necessity, less waste production and the use of lesser equipment, piping and instrumentation, safer and easier operation is enabled. Ramp-ups are faster and the maintenance of the entire system is easier compared to fabs based on the Siemens process.

Energy balances and quality
In the Siemens process, hydrogen chloride is added to metallurgical silicon to produce TCS. After purification, hydrogen is added and the mixture is fed into CVD reactors where silicon decomposes into monosilane and ultrapure hydrogen. This is highlighted in the graph ‘Structure comparison: SST Monosilane and TCS Siemens’. "Polysilicon is achieved differently from the Siemens process. SST’s monosilane process is straightforward and more energy efficient," says Hahn. SST uses a single reactor for TCS production.

The advantages that can be pointed out via this single reactor is the fact that there is no free hydrogen chloride (HCl) and process handling becomes easier due to the running of endothermal and exothermal processes in one reactor.

The monosilane process also enables the SST plants to produce a second product as an output: monosilane, which is feed material for CVD (chemical vapor deposition) processes and is secondly also used in the thin film industry for production. SST’s monosilane process also has closed material loops. Hahn points out that silicon tetrachloride (STC) from monosilane production and hydrogen from CVD processes are used as feed material for TCS production. The fact that no chlorine (Cl) containing by-products emerge out of the CVD process eliminates the vent gas recovery that is required by the Siemens process on the other hand. Hahn adds that no thermal graphite converters are necessary either. What it highlighted by the crew at Schmid is the fact that these advantages coupled with less distillation necessity, less waste production and the use of lesser equipment, piping and instrumentation, safer and easier operation is enabled. Ramp-ups are faster and the maintenance of the entire system is easier compared to fabs based on the Siemens process. SST uses pure monosilane instead of TCS as an input material for the CVD reactors.

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<td>SST future with PTR</td>
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Source: Schmid Silicon Technology

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Nevertheless, one has to note that it is not entirely easy drawing comparisons with two very different processes, de-
spite the parallels here and there. Hahn agrees saying that one has to be careful and compare apples with apples. Without constants and parallel, it is rather tedious to break down the processes and compare efficiencies.

A European polysilicon producer claims that with its FBR technology, solar-grade silicon is produced at a lower cost, while using 80 to 90 percent less energy than the traditional Siemens method for converting silane gas to high purity silicon. The use of seed granules of purified silicon instead of seed rods claims to not generate ‘wasted energy’ via the need to cool the chamber walls to avoid silicon deposition as in the Siemens process. Ulterior VLD experimentation hopes to increase throughput to ten times the level of Siemens. The problem they keep stumbling on is controlling the process. Quintessentially what is clear with these alternatives is the argument that current polysilicon production needs to cut back on energy consumption and increase output. The battle ground is for quality, energy efficiency and throughput.

Hahn tells pv magazine that a rightful picture needs to be put forth when calculating energy use. Different companies do it differently, some taking into account just the energy used for heating and production and ignoring the cooling media and infrastructure. Hahn adds, “We do it differently here.” And this is what leads SST to the “sweet spot” as Hahn highlights.

SST closed a strategic partnership for a 3,000-ton polysilicon turnkey fab with Xinjiang Puxing. The “sweet spot” that needs to be highlighted is the fact Chinese Polysilicon Industry Access Standards document dictates that electricity consumption of the solar grade polysilicon ought to be less than 80 kilowatt hours per kilogram (kWh/kg) for starters and thereafter, further reduced to 60 kWh/kg by the end of this year (see pv magazine, 04/2011). SST feels that with regards to these standards, it sees no issues in delivering polysilicon efficiently.

SST has been getting calls from companies in China wanting an improved quality in their polysilicon. “Producers are starting to realize that quality matters. After all, quality is one driver of efficiency,” says Hahn. He candidly adds that once upon a time (not too long ago), if it was gray, smelled right and looked right, wafers were made. This was, of course, not too long ago when ‘dirty silicon’ snuck its way into wafer production. In terms of achieving the coveted quality required to pump costs down, SST believes that its monosilane process is the way to go. “The fact that monosilane is much easier to purify than TCS allows us to reach a higher quality product,” asserts Hahn.

Quality control is an important aspect to consider as well. At the SST pilot plant, pv magazine observed that the company has a laboratory present where impurity
measurements can be taken and quality control is assured. The fact that this is a pilot plant, where research and development takes place alongside with production, enables the company to directly implement changes if necessary as well and thereafter provide the same upgrades to customers.

**Costs and the innovation curve**

With all the technology and quality advantages discussed above, the SST process will produce polysilicon at a total cost of about 20 euros per kilogram (using raw material and energy prices typically available in China, and depending on plant size). This figure looks better than any other merchant technology provider and competitive with the best existing poly producers.

Innovative increments: the SST curve is one that is still on a steady rise. Hahn draws a curve that shows the increasing opportunities that the monosilane process can bring in the future. Experiments are undertaken, efficiency in production technology is assessed and changes are made accordingly. It is a constant cycle of improvements as seen bubbling in the atmosphere at the plant. SST is already working on its future technology excitedly. pv magazine was brought into the core of operations where the Phase Transfer Reactor (PTR) sat, ready to be called for duty any moment. “This will revolutionize polysilicon production, ingot manufacturing,” echo both Hahn and Fester. With the PTR, SST is set to challenge existing polysilicon production methodologies.

The Siemens process is established. The number of companies employing it is large and successful in their own right. Hahn questions, “How do you proceed on with innovations? More rods in the reactor?” The innovation leaps that he believes the SST’s monosilane process can potentially take are much higher.

“The PTR replaces a batch process by a continuous process. As polysilicon is no longer harvested as rods, numerous process steps like filament production, loading/unloading the reactor, mechanical and chemical treatment, transportation and melting are eliminated,” says Hahn. All in all, a generous amount of savings in terms of operation costs and area requirements.

SST predicts that with the advent of the PTR technology, polysilicon prices can fall to 16 euros per kilogram in the mid term, lower than the stipulated 20 euros per kilogram currently with the SST monosilane process. Looking further ahead, in the long term with PTR and direct casting, SST sees further cost reduction in ingot costs of 30 percent.

**The knowledge factory**

Hahn wants SST’s monosilane process to drive how modules get manufactured in five to ten years. Together with Schmid Group, SST covers the whole value chain from metallurgical silicon to finished modules that gives the company an advantage having the know-how throughout the silicon to modules life cycle. Growth is great, but growth cannot be too fast either.

This is a challenge for the future as Hahn asserts. “If you think on the ranges of 12,000 tons a year, imagine that this is where we would like to be,” he concludes. ◆

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