Silicon technology in India: a tribute to A. R. Vasudeva Murthy

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A. R. Vasudeva Murthy (ARV) who recently passed away was not only an eminent scientist, but a visionary and made significant contributions to the development of Indian science and technology. He was interested in silicon from a young age and was instrumental in developing the only facility for production of silicon in the country. Here the saga of his struggle in achieving this is described from an historical perspective. This tribute narrates his deep conviction and dedication in achieving this goal. It also narrates the unique collaborative efforts by the Indian Institute of Science, Bangalore and the Mettur Chemical and Industrial Corporation, Mettur in establishing a wholly indigenous silicon plant.

Background and early work

A. R. Vasudeva Murthy as a second-year Honour's student at Central College, Bangalore visited a ferro-silicon plant at Mysore in 1943. He was fascinated by the shining grey material. He thought it could be a valuable material and that he should make use of it. After completing his M Sc at Central College in 1946, ARV joined the Indian Institute of Science (IISc), Bangalore as an analytical research assistant under Sanjeeva Rao, who was the Head of the Department (HOD) of Inorganic and Physical Chemistry (IPC) at that time. Rao's group was engaged in chlorination of materials like chromite, ilmenite and rubber. ARV completed his D Sc in 1953 and was promoted as a lecturer. K. R. Krishnaswamy was the HOD then. He encouraged ARV to study silicon chemistry. ARV bought some ferro-silicon from Bhadravati, where the ferro-silicon factory is located. Chlorine cylinder was obtained from the Mettur Chemicals and Industrial Corporation (MCIC), Mettur Dam. He made a fused quartz reactor, added some broken lumps of ferro-silicon and after heating the bed with a Bunsen burner, fed some chlorine from the cylinder. The lumps started glowing because literally ferro-silicon burnt in chlorine. ARV could collect more than a litre of silicon tetrachloride. He reacted this with ethyl alcohol and made ethyl silicate which he gave to M. R. Sheshadri of the Foundry Section at Mechanical Engineering Department for making investment casting. The material worked!

Importance of silicon

Silicon is a strategic material used in several sectors: About 95% of present-day microelectronics and photovoltaics are dependent on silicon. For electrical power transmission and control, silicon diodes, rectifiers, silicon controlled rectifiers (SCRs) and thyristors are used. Silicon is also used in making detectors which are important for the defence, nuclear and space technologies. Realizing the importance of silicon, the Government of India in 1958–60 requested IISc to work on it. S. Bhagavantam, the then Director of IISc asked ARV to take up this work. He gave ARV full freedom to set goals and work. Realizing that silicon production needs interdisciplinary approach, ARV with his chemistry background teamed up with G. Suryan (GS) of the Physics Department for this purpose. They conducted laboratory-scale trials on depositing silicon in a small reactor by reacting silicon tetrachloride and hydrogen gas. They got encouraging results and were thrilled with this work. Silicon was a rage at that time and considerable work was being done all over the world. Silicon transistors and IC chips made using the recently developed planar technology were coming to the market. Hence, both ARV and GS decided to continue the work on silicon.

Industrial collaboration

For further work, they needed large quantities of chlorine and hydrogen gas. Hence, they decided to approach an industry which was making them. The nearest one was MCIC, a pioneer in chemical industry being the first in South India and only the second in the country to produce caustic soda, chlorine and hydrogen. ARV wrote to MCIC officials and got an appointment to meet them. The IISc Director released Rs 60 from a fund he had earmarked for industrial development for this visit. Both ARV and GS met the General Superintendent of MCIC and started explaining the purpose of their visit. As luck would have it, the Managing Director of MCIC, R. V. Ramani (RVR; a physicist by training but an industrialist by profession) was in Mettur that day and chanced to meet the two professors. After the initial introductions, ARV explained the purpose of their visit. RVR who had been himself contemplating some diversification into silicon materials, was more than glad to hear the two professors talk on the same subject! Soon MCIC and IISc entered to an agreement for working on silicon-based materials. In 1971, MCIC gave IISc a project for this work[1]. As IISc had worked on silicon tetrachloride, ethyl silicate, silicon, fumed silica and methyl chlorosilanes, the agreement envisaged taking up work on these materials in the same order. RVR at the helm of MCIC played an important role in developing a strong tie-up between IISc and MCIC. Between 1971 and 1976, the technology for making silicon tetrachloride and ethyl silicate was implemented on a larger scale at Mettur. MCIC started supplying ethyl silicate to local investment casting foundries, who were glad to procure it from a local source thus avoiding the hassles of imports.

During ARV's visit to the UK in 1977, a leading user and distributor of ethyl silicate approached ARV for this material which was not readily available at that time. ARV suggested to this user to procure the material from Mettur. After his return to India, ARV informed MCIC about this requirement. MCIC had discussions with the party and after negotiations a trial order was placed by the party; the material was supplied by MCIC and was successfully tested by the user. A huge order followed immediately. By the end of 1977, a big plant for producing silicon tetrachloride and 1000 tonnes per annum (TPA) of ethyl silicate was started (Figure 1). The export business was good. It generated valuable foreign exchange to the country and good profits to the company. Soon exports were made to other countries, including USA and Australia. MCIC realized the importance of silicon-based materials and decided to do further work. Since silicon tetrachloride was readily available and hydrogen was available in plenty in the plant, combining the two to produce silicon was the logical next step.

Silicon R&D

In February 1978, a small set-up was established for the purpose of making silicon. It comprised of a purifier for silicon tetrachloride by distillation, a dryer for hydrogen gas using sulphuric acid, a reactor for depositing silicon and an electric power supply unit for heating the reactor. The small reactor for depositing silicon was fabricated by GS at IISc with an aluminium base plate and quartz bell jar, tantalum 'hairpin' for deposition and an optical pyrometer for measuring temperature. The entire set-up was located in the maintenance shed of the boiler room. The process for deposition of silicon is called chemical vapour deposition, as the chemical reaction takes place in the vapour phase and the product is deposited on the heated hairpin. This unique design is needed because silicon has to be of very high purity with impurities at less than one part per billion and therefore should be made without being in physical contact with any other material. More on the technology is available in the published literature[2]. The reactor was started on 19 February 1978 and was run for about 24 h. The hairpin was removed and weighed. Nearly 100 g of silicon had been deposited (Figure 2). Pertinent to note at this stage is that silicon so deposited is in the form of a solid rod formed by aggregation of a large number of small crystals. Hence it is called polycrystalline silicon or polysilicon in brief in contrast to single crystalline material made from it, which is essential for fabricating electronic devices. It is the highest purity material that man has ever made in large scale. Encouraged by the success of the first trials, scaling up of the reactor was taken up during the next few years. The next size reactor produced about 1 kg of polysilicon. The next scale up was for 10 kg (Figure 3). By 1982, a 100 kg size commercial-scale reactor was being operated. The situation was thus ripe for a commercial venture in polysilicon manufacture.

Hurdles for the MCIC silicon

Realizing the importance of silicon for the Indian industry, MCIC worked on a project for establishing a 25 TPA polysilicon facility based on the pilot plant data. On 29 October 1982, R. Venkataraman, the then Defence Minister laid the foundation stone for the silicon project. He visited the R&D set-up to see the commercial size reactor operating and discussed further plans with the plant officials (Figures 4 and 5). He stressed upon the special significance of silicon to the defence industry. He also stressed on the need for industry and research institutions to move closely together. However, during 1983–84 MCIC was taken over by Chemicals and Plastics India (Chemplast). Finances for the project had to be negotiated with the new management. Further, the new management wanted this technology to be implemented by a separate subsidiary company. Hence, a new company by name Metkem Silicon Limited (MSL) was incorporated for implementing the project. In addition, some technical problems in the design of the poly reactor surfaced. Considerable efforts had to be made to overcome them. Ultimately a state-of-the-art design was developed and tested successfully on a commercial scale. All these delayed the implementation of the project.

Should silicon technology be imported?

At this juncture, the Department of Electronics (DOE), Government of India wanted to establish a National Silicon Facility (NSF) by importing technology for producing high-purity polysilicon at the insistence of the then Prime Minister (PM) Indira Gandhi, who wanted India to be self-sufficient in this strategic material. A high-power committee headed by G. Ashok Parthasarathi was constituted

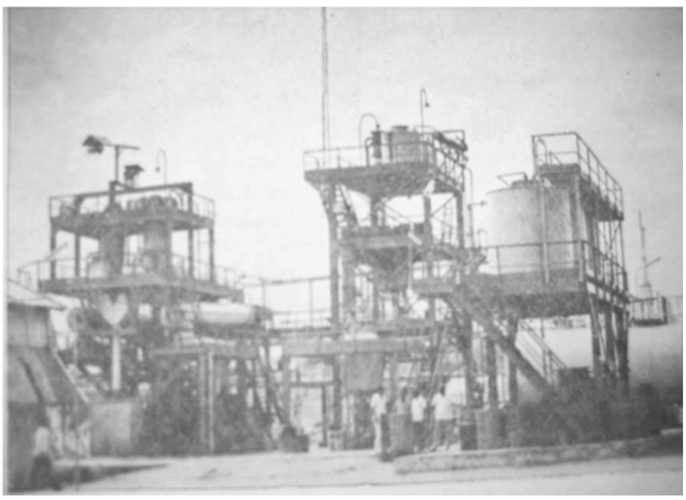

Figure 1. Silicon tetrachloride and ethyl silicate plant at Mettur dam.

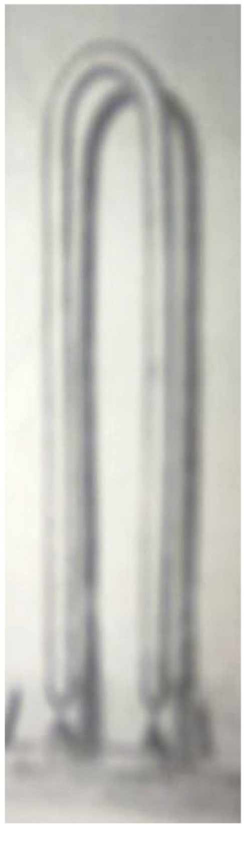

Figure 2. First polysilicon hairpin of 100 g produced at Mettur on 19 February 1978.

for this purpose. Also, the following institutions were asked to carry out work on silicon manufacture: National Chemical Laboratory, National Physical Laboratory, Bhabha Atomic Research Centre, Solid State Physics Laboratory and National Metallurgical Laboratory/IIT Kharagpur.

A narration of the events that took place during this time, including the NSF and the Semiconductor Complex is available in a book authored by Parthasarathi[3]. After reviewing the work done by these institutions, the high-power committee concluded that progress was not satisfactory and the technology had to be imported. A committee for establishing a NSF was formed under the chairmanship of Parthasarathi. The committee went round the world, visiting various polysilicon manufacturers to explore possible technological partners and short-listed a few.

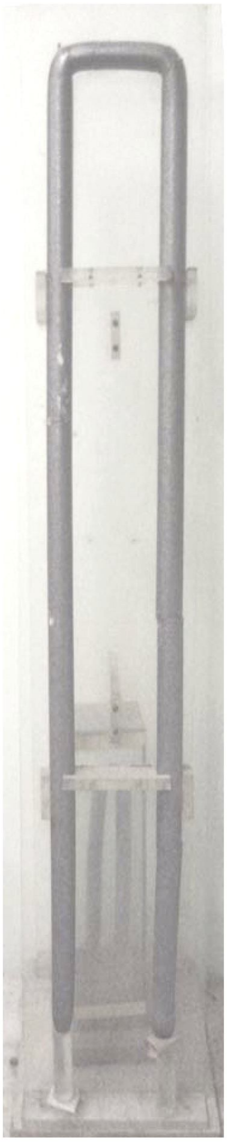

Figure 3. Further scaling up of silicon production.

At this juncture two industrial establishments, Grindwell Norton/Siltronics and Metkem Silicon in collaboration with IISc were also carrying out developmental activities in silicon manufacture.

Siltronics was trying the technology based on silane gas, which was made by decomposition of magnesium silicide and deposition of polysilicon from the purified silane gas. It had also established facility for the manufacture of silicon single crystals, both by the float-zone and Czochralski methods and cutting the ingots into wafers of maximum 3″ diameter. Metkem was of course running a commercial pilot-scale reactor for producing silicon (Figure 5) and had ordered downstream equipment for crystal growth and wafer slicing up to 6″ diameter. Both represented to DOE that they had developed capability for making silicon and hence should be encouraged.

The NSF committee visited both the facilities and expressed doubts about the success of these attempts. It suggested to DOE that these could be given help in continuing their R&D work in silicon, but the Department should go ahead with importing the technology. It recommended sourcing the technology from Hemlock Semiconductors, USA. A proposal was submitted to the Government of India for implementing this project at IPCL Baroda at an outlay of Rs 200 crores.

Figure 4. R. V. Ramani (MD, MCIC) speaking to R. Venkataraman (RV; the Defence Minister). A. R. Vasudevamurthy (ARV) is to the right of RV and G. Suryan on his left. S. Ramaseshan (Director, IISc) is seen between RV and ARV. The present author is at the extreme left.

Conflict between government departments

At this juncture, the new Department of New Energy Sources (DNES), later made into the full-fledged Ministry of New and Renewable Energy Sources (MNRES) was working on establishing photovoltaics (PV) electricity as an alternative for conventional grid electricity. It made a claim that silicon production should be in its jurisdiction as the requirement of silicon for PV was much more than the requirement for electronics. It was looking at ways and means of making PV viable in the country. It hotly contested the recommendations of NSF for establishing the proposed silicon facility at Baroda on the following grounds: an outlay of Rs 200 crores was too high. The capacity of 200 TPA was also too high for the expected demand. No down-stream facilities to use polysilicon produced existed and no recommendations had been made for establishing such a facility by NSF. Cost of production at NSF was too high – more than 3 to 4 times the market price. Technology to be provided was old and incomplete. Hemlock had not offered technology for production of trichlorosilane (TCS), which was the starting material and disposal of silicon tetrachloride (STC) produced as a waste. Also, no effluent-handling procedures were available. Purity of material would be lower as STC (used by Metkem) gives better purity. Metkem, ARV and GS joined DNES in refuting the assessment made by DOE on Metkem technology and said that they had confidence of commercializing the technology and meeting the needs of the country at international prices. DNES therefore wanted NSF to

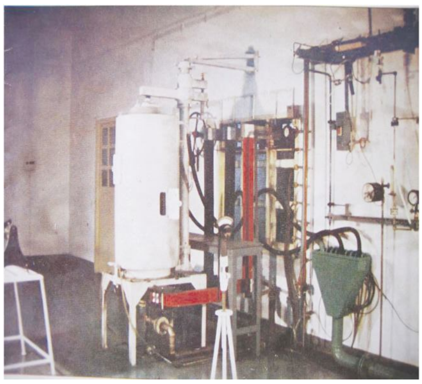

Figure 5. Commercial-scale pilot polysilicon reactor with quartz bell jar and shield.

be scrapped and Metkem to be encouraged for establishing the silicon facility.

Two belligerent groups thus evolved. The first group spearheaded by DOE vehemently supported the import of technology and establishing NSF. The second was led by DNES, which supported IISc–Metkem technology. Thus a controversy about the technology to be adopted by the country ensued and there were heated debates in the leading newspapers and many from the Government agencies, educational institutions and industry participated in the debate siding with one or the other group.

DOE justified that the outlay of Rs 200 crores was just not for the polysilicon plant alone, but for an R&D centre as well. It went ahead with its discussions with Hemlock as members of NSF were close to the PM and signed an MOU with Hemlock for the project by late 1983. Stiff penalties were stipulated in case DOE rescinded the contract. DOE started preliminary work at IPCL Baroda. However, it faced an unexpected difficulty. In early 1984, the US Government refused permission for transfer of technology, because silicon is a material of strategic importance. During this time as a part of its project work, Metkem made enquiries with several equipment suppliers for crystal growth and wafer slicing. One such supplier was Siltec Corporation, a leading silicon equipment supplier in California, USA. Siltec wanted to test the Metkem material before providing guarantee of performance for its crystal-growing equipment. Metkem sent a small sample of its material to Siltec which got it tested by MIDAC Corporation, USA. The test report stated that this material was as good as made anywhere else in the world. Siltec communicated this to Metkem on 17 January 1984 and agreed to sell their equipment to Metkem. Coincidentally, within a week of this announcement, the US Government released silicon from the list of restricted technologies to India. Immediately DOE signed a contract with Hemlock for supply of technology and equipment for a 200 TPA polysilicon plant at a cost of US$ 14.2 million. It paid US$ 6.7 million for the technology. The plant was to be established at IPCL Baroda in about 4 years time.

Important developments took place during October–November 1984. Indira Gandhi was assassinated on 27 October and Rajiv Gandhi became the PM. In his inaugural speech, Rajiv Gandhi promised to foster indigenous technologies. Taking a cue, ARV wrote a letter to him (much against the advice of his colleagues) complaining that much against Rajiv Gandhi's assertion of fostering indigenous technology, DOE was thwarting the technology for silicon developed by IISc in collaboration with Metkem. Rajiv Gandhi, as a pilot, knew the significance of electronics and silicon. He therefore took personal interest in this subject and called ARV and RVR (MD, Metkem Silicon Limited) for discussions. Both ARV and RVR explained the issues involved. As NSF would take at least 4 years to come up, ARV pleaded that they be given a year to demonstrate the indigenous technology. Rajiv Gandhi agreed that this was reasonable. He told DOE to hold NSF for a year, till Metkem technology was evaluated.

Metkem had one year time to put up a 25 TPA polysilicon plant and produce the material. Though this time was too short for such a task (which involved basic engineering, detailed engineering, civil work, equipment ordering/fabriccation, erection, piping and instrumentation, utilities, testing of the plant and commissioning), the offer was taken as a challenge by Metkem. Work on setting up a polysilicon plant was started in April 1985 and completed by February 1986. The PM's Office was reviewing the progress on a monthly basis. Argon gas required for fabrication of equipment was not available. The PM's Office intervened to ensure the supplies. Again, when the plant was about to be commissioned, Tamil Nadu Electricity Board (TNEB) refused to supply power because of power shortage in the state. The PM's Office again intervened to arrange for power supply. The plant was successfully commissioned in March 1986. First production was reported in early April 1986. The polysilicon produced at Metkem had to be tested and certified to be suitable for the end-user. Metkem had still not installed its crystal growth and wafering facilities. DNES got a crystal grown in Super Semiconductors, Calcutta with Metkem polysilicon. The ingot was machined further and wafers were produced by BHEL, Electronics Division, Bangalore, which also made solar cells out of the wafers. The efficiency of the solar cells made was reported to be satisfactory. Further, 30 kg of Metkem material was sent to Japan for evaluation by DNES. Excellent results were reported by the Japanese. This was too good to be true for some who floated a rumour that Metkem had not made polysilicon at all, but had given clandestinely imported polysilicon for evaluation. Representatives of DOE and DNES visited Metkem, stayed for a few days, observed the plant in operation and saw for themselves the actual production taking place. They were fully satisfied with the working of the plant, the quality of the material and the cost of manufacture. They reported to the PM's Office that the plant at Mettur was fully in operation and successfully producing polysilicon at competitive price. Metkem thus demonstrated that the indigenous technology was good and hence, there was no need for import of technology.

DOE was asked to abrogate the contract with Hemlock but the amount of US$ 6.7 million already paid was lost as a penalty. DOE was severely criticized by CAG in 1987 for this and investigations were made by CBI on this fiasco. DOE funded IISc to establish a facility for characterization of Metkem silicon at the Physics Department. Later, Metkem learnt that Hemlock had planned to sell poly reactors of an old design with quartz bell jars working at atmospheric pressure, which they had scrapped at that time. In contrast, Metkem established state-of-the-art high-pressure metal reactors which ensured that the productivity, cost and quality were acceptable (Figure 6). As almost 99% of the plant and machinery required were local, the capital cost was also low.

Govt of India decided to encourage Mettur as a centre for silicon development. Grant-in-aid and loans were provided by the Government to improve the process and reduce the cost of production (probably for the first time to a private company). Two projects were taken up and successfully completed between 1987 and 1990. Metkem got the admiration of DNES, as this was one rare example where a project was successfully completed and targets were fully met.

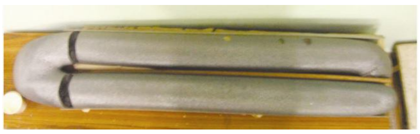

Figure 6. Fully grown polysilicon hairpin.

Figure 7. R. V. Ramani explaining to Rajiv Gandhi at the polysilicon site. Sonia Gandhi is also seen. Suryan is partially visible between the two.

On 20 June 1988, Rajiv Gandhi visited Metkem (Figure 7). Though the visit was to be for only 20 min, he spent more than 100 min in the factory. He saw the poly reactors and asked penetrating technical questions to the plant operators. He appreciated the plant layout and saw the operations of the crystal growth, wafering and polishing departments also. He and Sonia Gandhi planted saplings of 'Pride of India' in memory of their visit. At a hurriedly called press conference at the plant, Rajiv Gandhi declared 'Here is an indigenous technology defeating foreign technology'. He promised full support to Metkem. He also had lunch with all the plant personnel and showered praise and encouragement to all people involved in the project.

Within a few months of its commencement, the Metkem plant had produced more than 10 tonnes of polysilicon. Metkem had just commissioned its crystal-growing furnace and wafering machines. In-house requirement for one crystal-growing furnace was about 5 tonnes only. Inventory of polysilicon build-up was because there was no other taker for the product in the country.

Polysilicon is itself not useful. It has to be converted into single-crystal ingots, which have to be cut into wafers. The wafers are used for making devices and solar cells. Thus making polysilicon is only the starting point. Down-stream facilities of crystal growth and wafering are essential for using polysilicon. While there were considerable imports of wafers by companies like BHEL, CEL and BEL for making solar cells, there were no worthwhile facilities for crystal growth and wafering.

Metkem had to invest further on these activities to consume its own polysilicon. Stabilization of all these took time. At that time (and even today), wafers could be imported freely, without paying any import duty to encourage PV. Hence, Metkem had to sell wafers at international prices with no protection from foreign competitors. Crystal growth and wafering are highly specialized processes and were till then not familiar to Indian industry. Metkem with its chemical background had to go through the learning curve of these operations. It faced innumerable problems of sourcing spares and consumables like silica crucibles, graphite heaters, ID blades (for which it had to pay import duties) and even supply of pure argon gas which was highly priced in the local market and was in short supply.

Commercialization of polysilicon technology

As already stated, Siltronics which was established at Hosur during 1980 by Grindwell Norton, was closed down in 1986 as it could not produce 4″ wafers. Super Semiconductors, Calcutta, which had a small facility was also closed down as unviable. BEL had already closed its crystal growing and wafering facilities. BHEL which had established crystal growth and wafering facilities, also could not operate them. Could Metkem survive under these circumstances? Added to this, TNEB which had assured concessional power withdrew this offer in 1990. The power tariff was heavy and unbearable. Metkem could not meet customer requirements on time. The only silver lining was the quality of the wafers, which was excellent for solar cells. Indeed, CEL gave incentives to Metkem for crossing their relative figure of merit (RFOM) compared to Wacker wafers for three successive years. Then, Metkem wafers became their reference.

Facilities for making electronic wafers were established at a high cost, including facilities for lapping, polishing, cleaning, inspection and packing of polished wafers in 100 class clean rooms. Polished wafers were given to BEL for evaluation. The quality of the wafers was found to be satisfactory with several batches of wafers. However, when it came to buying regularly, BEL back-tracked with some lame excuses. It accepted to buy only test wafers from Metkem. Thus, Metkem was forced to idle a huge capital and supply silicon wafers to the PV sector only. Also, a wire saw technology had just been developed and Metkem imported one of the first few wire saws made in the world for reducing the cost of silicon wafers along with two crystal-growing furnaces to consume the polysilicon produced. Unfortunately, this wire saw had innumerable problems and could not be used for production. In its place two ID saws had to be procured. All these also added to the financial burden of Metkem. By 1992, the plant was streamlined and could stand on its own legs – at least there was no operating loss though the accumulated loss was a burden. By late 1992 and 1993, Russians started dumping their old stock of wafers at throw-away prices. All customers started grabbing this material. Metkem was forced to match the ridiculously low prices offered by the Russians, even though the Russian wafers were not of good quality.

Metkem took steps to reduce energy consumption considerably in making polysilicon, so much so that the cost of virgin polysilicon produced in Mettur was comparable to world prices even though electricity tariff was high and the plant was small (25 TPA). Still, for making PV wafers which were sold at low prices, the cost of polysilicon was high.

Metkem's polysilicon operations stopped

At this stage, a big manufacturer of polysilicon in Germany offered to supply Metkem its requirements at very low prices – almost at 30% of Metkem polysilicon cost by supplying semiconductor rejects like tops and tails and structure-loss material, which however was good enough for solar wafers.

In 1993, Metkem was the seventh plant in the whole world producing polysilicon. The six producers had formed a undeclared trade block like OPEC. They never allowed others to come up till 2007. In the guise of helping Metkem, they succeeded in stopping its poly operations. Metkem polysilicon plant was closed by the end of 1993. Short-term gain overshadowed long-term repercussions. By importing polysilicon from Germany, the cost of manufacture of wafers was however reduced.

Metkem's consolidation

In 1994, a new wire saw was procured. This single machine could produce 30%

more wafers per kg of ingot than were produced by the ID saws which were in use at that time. Within a year, the wire saw was made to produce three times its rated capacity and hence, all the 6 ID saws were retired. Even then, ingot production did not match the requirements of the wire saw and hence, ingots were imported from Germany. In 1995, three more crystal-growing furnaces were ordered to meet the ingot requirements of the wire saw. Many cost-cutting techniques were developed to survive in the market. Some of these were: Argon gas recovery and reuse; manufacture of local graphite parts; using thinner wires; recycling of wire saw abrasive and vehicle; recycling of water used for washing and improving production and increasing yields to 98–99% by motivating the workforce by providing yield-based incentives. All these techniques were novel and had not been implemented anywhere else in the world till then.

Lack of interest of the management

The cost-cutting measures yielded excellent results. Though the plant was small, it could produce wafers at low costs. In fact, the cost of manufacture was one of the lowest in the world. From 1995 to 2002, the unit was making good profits. However, Chemplast management did not show much interest in Metkem Silicon Limited, as silicon did not fit into its ‘corporate core competence’. It merged Metkem Silicon Ltd with Chemplast and made it a division of Chemplast because, by this merger, it could save considerable tax by writing off about Rs 9 crores accumulated loss of Metkem. The management did not make any further investment in Metkem because it was not familiar with the market and lacked capabilities of international marketing, which is important for silicon. Though many, including foreign corporates showed interest in participating in Metkem, the management did not entertain such offers and allowed Metkem to drift even though it was making good profit. Because of this attitude, operating personnel found difficulties in proper running of the plant, including repairs and maintenance of equipment. Many trained staff left for greener pastures, sensing the management’s lack of interest in Metkem.

Closure of Metkem Silicon operations

From 2003, PV started growing at a rapid pace worldwide. Demand for polysilicon and wafers increased manifold. Prices of polysilicon and wafers increased steeply. Chemplast made good money by selling wafers at high prices. However, import of polysilicon became difficult and expensive. As a result in 2005, Chemplast wanted to restart the polysilicon plant. It sought to import the technology, but no one was ready to give it. Chemplast got the technology from an ex-employee and constructed a new plant, as the old plant had been sold off as scrap (much against the wishes of the plant personnel). However, because of improper project management, the commissioning of the plant planned for March 2007, was considerably delayed. Therefore, the company could not take advantage of the steeply high price that polysilicon was fetching in the international market at that time. By the time it could commission the plant in February 2008 and make regular production from July 2008 (Figure 8), the price of polysilicon had fallen drastically and therefore the new plant was stopped by May 2009. The management felt that because of the crash in price of polysilicon due to huge capacity established by China, the Mettur unit could not make the profits that were envisaged. (For latest information on polysilicon technology and business, reports like the one by Bernreuter Research[4] could be studied.) The crystal growing and wafering were also stopped as the equipment failed to perform at the optimum scale because of ageing and poor maintenance. Added to this, belligerent trade unions aggravated the already difficult situation. Seeing such developments, trained technical manpower left the company leading to final closure of the Metkem Silicon activities in May 2009.

Figure 8. Polysilicon reactor being opened after completion of a deposition run.

Significance of Metkem Silicon

Today, there is no production unit in the country for polysilicon and silicon wafers. In a way, the great efforts put by ARV and others appear to have been futile. However, Metkem’s efforts in developing technology for making polysilicon, single crystals and wafers have clearly demonstrated Indian capabilities in all aspects of manufacture, including basic technology, capital equipment manufacture, skills of operating and managing sophisticated equipment and production plants. Many who had first-hand experience in silicon technology at Metkem, joined newer organizations world over. Therefore, if the country decides to establish a facility for producing silicon wafers (as being proposed by BHEL[5,6]), a firm foundation for this already exists. It has to be exploited so that capital and manufacturing costs could be well controlled, to make the project viable in the face of severe competition from China. The saga of Metkem also gives a good leverage to India in negotiating the technical and commercial aspects in procuring equipment and technologies for PV solar wafer manufacturing. (This is significant considering the fact that the negotiating committee of DOE with its theoretical knowledge of polysilicon technology had entered into agreement for purchasing actually retired equipment and old technology at considerably high cost. If they had established a facility with such poor technology, the plant would never have seen the light of the day, but the country would have incurred heavy and wasteful expenditure.) The sad state of Siltronics in Hosur, Birla Solar in Pune and Lanco Solar in New Delhi represents stark examples of wastage of money in procuring inappropriate technologies and equipment.

Looking back

Many institutions started work on silicon in the 1970s in the country. However, only the IISc–Metkem team succeeded. The reason for this is that at the very early stage, ARV realized that this work should be jointly carried out with an industry. Research institutions have vast capabilities, but inherent limitations. Similarly, industry has vast resources, but needs guidance at appropriate times in aspects like identifying or developing technology, sourcing of materials, analytical facilities, personnel training and coordination with authorities on technical aspects of the project. ARV was fully aware of these aspects and hence, established a joint development effort with an industry. He was able to provide the necessary initial fillip for the industry to establish pilot facilities, which could be scaled up by the industry using its in-house expertise. He realized that the industry needs fundamentals of science and technology. Thus supported, the industry is capable of progressing further, as it has vast experience and operational capabilities. Within a short time of his association with the industry, ARV showed his mastery in the chemistry of the processes that the industry was using and could explain to the operators, the many small, but important principles on which the plant was operating. The bigwigs of the industry soon realized that they could not belittle this man's knowledge and started to respect his words and heed to his advice. He could carry on with the industry and would never allow any ego-clash to come in the way of progress. He would visit the industry regularly, review the work done periodically and hold discussions with the operating personnel as well as the management team regarding further work to be done and what could be expected at the end.

In the beginning of the project, the contribution of IISc was significant as it had done laboratory-scale experiments and demonstrated to the industry how laboratory experiments are conducted. IISc provided knowledge and information to scale-up laboratory trials and technical information to establish a small pilot facility for the industry to operate and gain operational experience. After this initial phase, the industry played a pivotal role in scaling up the pilot tests to commercial levels. At this stage, the industry would look at IISc to provide necessary characterization facilities for the material produced as well as help in setting up analytical methods and laboratories for which generally industries are reluctant to invest. Thus at each stage, academic institution and industry moved together to establish the technology. This mantra of success, which has been in practice in the Western countries for long, should be emulated by India for developing indigenous technologies. The IISc and ARV's saga has successfully showcased this important aspect of development. This effort has also demonstrated that most of the plant and machinery required for polysilicon manufacture could be sourced from local manufacturers, thus establishing the capability and credibility of India in high-tech manufacturing.

Tail piece

As an industrialist, J. N. Tata, the founder of IISc knew the importance of developing Indian technology. He wanted to create an institution which would serve this need. IISc was started with this in mind. The success of the silicon project is a fitting tribute to the founder.

We can justifiably take pride that ARV and IISc fulfilled the vision of J. N. Tata.

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Edited by R. Srinivasan, and printed & published by G. Madhavan for Current Science Association, Bangalore 560 080.
Typeset by WINTECS Typesetters (Ph: 2332 7311), Bangalore and Printed at Lotus Printers, Bangalore (Ph: 2320 9909)