The SC300 ultrapure water plant – a balance between investment costs, operational costs and quality requirements

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ABSTRACT

The article describes the SC300 ultrapure water (UPW) plant as an example how the project objective was realized and includes information about design aspects, water quality specification and vendor selection criteria's.

The UPW plant is one of the key elements of the production facility. Beside the cost aspects the plant has to meet stringent quality specifications to secure the wafer yield. Based on a calculated cost target, which was derived from Infineon's 300mm business plan and the experiences gained from earlier 200 mm Fabs, the UPW expert team developed different technical concepts and they investigated the resulting investment and operating costs.

INTRODUCTION

The fundamentals for Infineon's 300 mm wafer Fab in Dresden were developed with the project "Fab of the Future" (FoF). In the spring of 1998 several expert teams were commissioned to evaluate all aspects of a future 300 mm frontend production facility in a then undefined location and to identify possibilities and methods, which would lead to lower wafer costs. The team members from all relevant disciplines were recruited from internal Siemens departments and external well known companies. The timeframe to fulfill the project goal was one year. The focus on wafer costs, which includes capital costs for building and infrastructure, material costs (e.g. for raw wafer, test wafer, utilities like electrical power, ultrapure water, chemicals and gases) and personnel costs offered new perspectives and forced the process and construction teams to judge all cost related decisions very carefully.

THE CONCEPTUAL PHASE

Alternative technologies and procedures like raw water pre-treatment with Ultra- or Microfiltration units, Oxygen removal with Membrane Degasification, Continuous Electrochemical De-ionization (CEDI) or off-site re-generation for Mixed Bed resins were evaluated and the pros and cons were compared to conventional technologies. All discussions and considerations were focused on a well-balanced ratio between investment and operational costs and crosschecked with the process quality requirements.

The SC300 UPW (shown in schematic form in Figure 6) plant takes river water from the Elbe. The bank filtered water is pumped from a well directly into a water storage pit without further treatment. The well is regularly flooded during high water periods and the turbidity increases drastically. In these cases city water replaces the river water to protect the plant. The water hardness for both sources fluctuates on a yearly basis between 1 and 3.6 mmol/l CaO. Roughly 80 % of the hardness is caused by non-carbonates. Several design alternatives were discussed before two concepts were chosen as the most attractive ones in terms of costs and quality. The main differences between both alternatives were localized in the make-up section. The first concept included a Decarbonization unit, a Reverse Osmosis, a CO_2-Degasifier, a second Reverse Osmosis, an Oxygen Degasifier and the final Mixed Bed Exchanger. The second one was simpler, existing of a Cation/Anion Exchanger, a Reverse Osmosis, an Oxygen-Degasifier and a three-stage Mixed Bed exchanger. The use of a Continuous Electrochemical Deionization Unit (CEDI) was rejected, mainly due to the missing operational experiences for large UPW plants and the better Total Organic Carbon (TOC) and Silica removal efficiency of a standard Mixed Bed. Furthermore restrictions for the CEDI-system have to be considered in

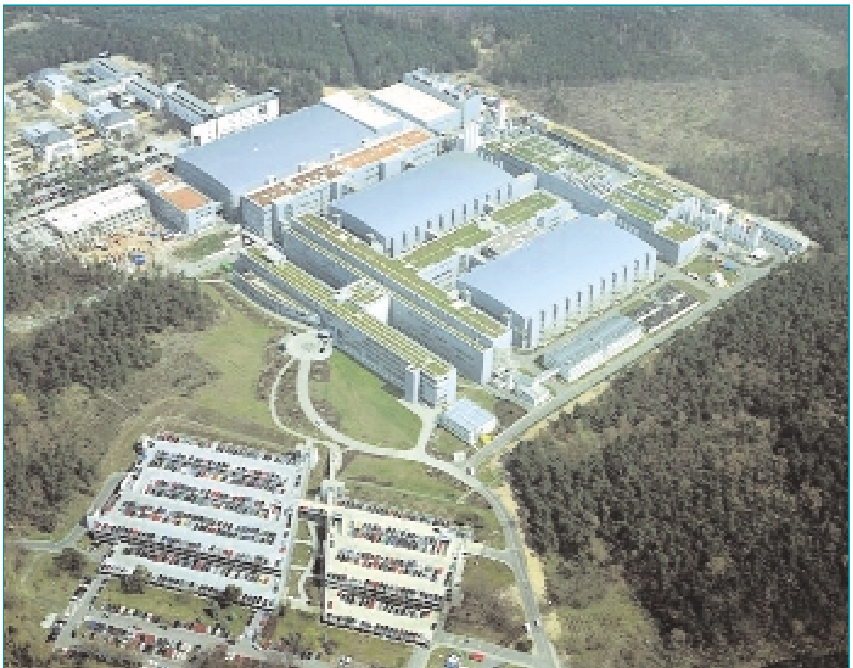

Figure 1. Infineon Dresden, 200mm and 300mm (left module) wafer production facility.

terms of the inlet and outlet water quality. An additional polisher behind the CEDI-system is required to guarantee a continuous resistivity parameter of 18MΩ-cm and above. This step neutralizes possible cost advantages.

Figure 2 and 3 show the calculated operational costs for both concepts, including raw water, waste water, chemicals, cooling, heating, electrical power, Nitrogen, pressurized air and consumables. It is obvious, that the two-stage Reverse Osmosis system uses much less chemicals and therefore produce less waste water. On the other hand, the higher raw water consumption of about 20 % increases energy costs. Despite of the different concepts, the final operational cost was very similar within a 3 % range. Based on the dominating operational costs for raw water, heating and waste water it was mandatory to implement rinse water recycling.

THE UP WATER SPECIFICATION

The UP-water specification was defined in close co-operation with the process engineers. The main focused centered around two questions: What are the real water quality requirements for a single process step and what water quality is achievable with a certain plant design. The following iterative approach was very helpful to avoid over-specifications and to recognize valuable cost potentials.

Figure 4 shows the measured ultrapure water parameters of the SC300 plant and the values given in the actual 2002 update of the International Roadmap for Semiconductors (ITRS, 1). Compared to the roadmap, the figures for dissolved oxygen and TOC are quite relaxed. Reviewing the past ITRS-roadmaps reveals especially for the dissolved oxygen parameter remarkable differences. The value was raised from 1 ppb in the year 2000 edition to 10 ppb for the current state-of-the-art 0,13µm technology. It is questionable, whether the proposed value of 1 ppb for the upcoming 90nm process is really required. The tighter specification will again lead to increased plant costs because of additional degasification units and higher operational costs for membrane changes, electrical power and other utilities. There is no doubt, that process steps like pre-metal clean, nitride etch, sulfuric clean or CMP processes will surely not require such a low oxygen level. Measurements in open wet process bathes showed, that the oxygen content varies between 90 and 130 ppb,

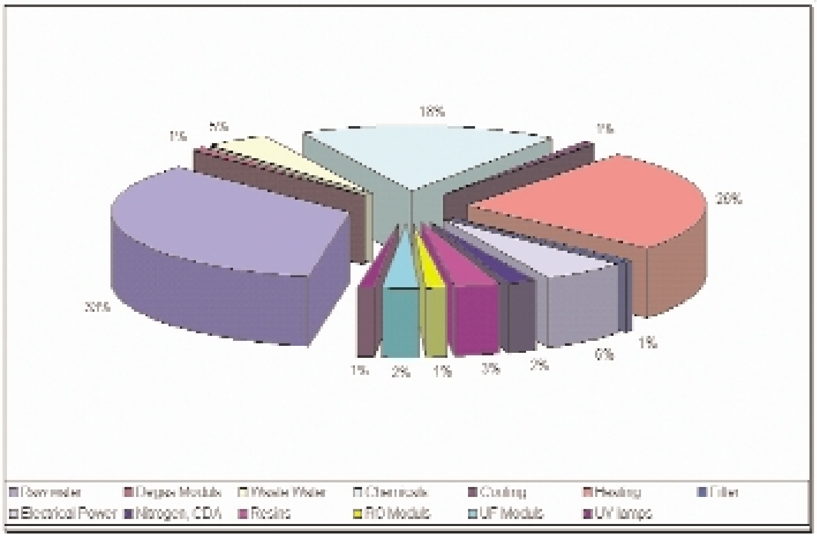

Figure 2. Operating Costs concept 1 (Ion Exchanger with single stage RO).

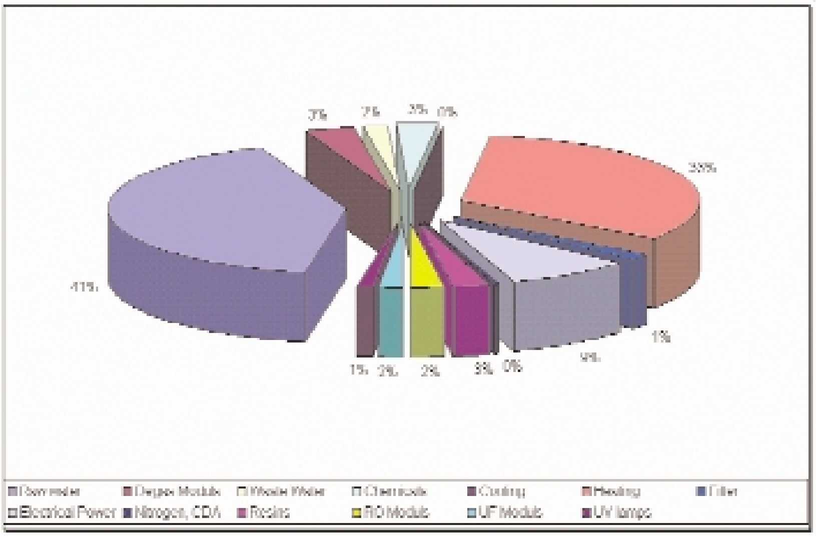

Figure 3. Operating Costs concept 2 (Decarbonization unit with two-stage RO)

Item	SC300 UP-Water Measured Values	ITRS Roadmap 2002 Update 130 / 115 / 100 / 90 nm Y01 / Y02 / Y03 / Y04
Resistivity [MOhm cm]	>18,2	
Temp. [deg. C]	22	
Temp. Stability [deg. C]	+/- 1	+/- 1 / 1 / 1 / 1
Point-of-use Pressure [bar]	4,0+/-0,5	
Particles/Liter [#]	< 500	<200 / <200 / <200 / <200
Reference Particle [nm]	50	65 / 58 / 52 / 45
TOC [ppb]	< 5	1 / 1 / < 1 / < 1
Viable Bacteria/Liter [CFU/L]	< 1	<1 / <1 / <1 / <1
Total Silica [ppb]	< 0.5	0,1 / 0,1 / 0,1 / 0,1
Reactive Silica [ppb]	-	0,05 / 0,05 / 0,05 / 0,05
Dissolved Oxygen [ppb]	< 50	<10 / 7 / 3 / 1
Boron [ppt]	-	50 / 50 / 50 / 50
Sodium [ppt]	< 5	<10 / <10 / <10 / <5
Calcium [ppt]	< 5	<10 / <10 / <10 / <5
Zn / Ni / CU / Al [ppt]	< 5	<10 / <10 / <10 / <5
Iron [ppt]	< 5	<10 / <10 / <10 / <5
Manganese [ppt]	< 5	<10 / <10 / <10 / <5
Fluoride [ppt]	< 20	<10 / <10 / <10 / <5
Chloride [ppt]	< 10	<10 / <10 / <10 / <5
Nitrate [ppt]	< 10	<10 / <10 / <10 / <5
Sulfate [ppt]	< 10	<10 / <10 / <10 / <5

Figure 4. UPW quality parameter, compared to ITRS roadmap.

Ultra Pure Water Plant Evaluation Parameter	Weight 1=min 10=max	Example Score 1=bad 2=less good 3=neutral 4=good 5=very good	Max. weighted Score (weight * score)
"Must"-Item			
Proven comparable experiences	true?	yes	
Time Schedule	true?	yes	
Financial Aspects			
Bid quality	3	2	15
Investment Costs	10	2	50
Operational Costs (per m³)	10	3	50
Sum (23 % of max. score)			115
Technical aspects			
Design (concept, redundancies etc.)	7	3	35
Raw Water treatment	7	2	35
Chemical consumption	3	4	15
Installation and startup duration	5	3	25
Selected components	3	3	15
Monitoring	4	3	20
Reference list	3	3	15
Sum (32 % of max. score)			160
Project Realization/After Sales Service			
Project management	6	3	30
Experiences during past projects	5	3	25
Flexibility (e.g. change orders)	5	3	25
ISO9001 Certification	4	3	20
Planning capacity	5	4	25
Local Support	9	4	45
Selected sub-contractors	6	3	30
Vendors site experiences	5	4	25
Sum (45 % of max. score)			225
Total Sum			500
Rang			

Figure 5. Decision Matrix (overview with max. possible scores).

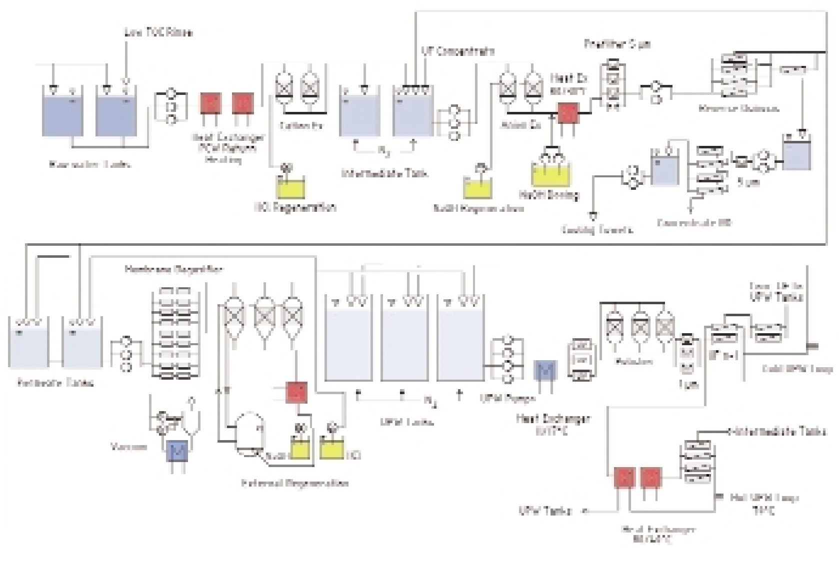

Figure 6. UPW plant, schematic overview.

depending whether the sample was taken near the bottom, in the middle or at the top of the bath. Even a higher oxygen concentration did not lead to a hydrophilic wafer surface.

THE PROCUREMENT PHASE

The SC300 project was realized with the help of the Integrated Project Design and Management method (IPDM) of Siemens IBC 2,3). The developed ultrapure water concept was transferred by the Design and Build Contractor (D&BC) M+W Zander into a detailed design and issued for quotation. The final vendor selection was a collective decision of the owner and the D&BC. Figure 5 shows the decision matrix, which is based on a weighted score method. The matrix is divided into three major areas: financial aspects, technical aspects and project realization as well as After-Sales support. The weights of the criteria were assigned using an iterative process, in which each criterion was compared to each other to determine the relative importance. Multiplying the criteria weight with a strength factor and summarizing all products achieved the final score. This exercise was done individually by all team members. Finally, all results were discussed until a team consensus was reached. Despite the subjective perspectives of each team member, the main value of this method is to avoid emotional discussions and to stay focused on hard facts. The maximum score for each area reflects the importance of that area. Project and technical related aspects are weighted higher than cost aspects.

THE PRE-TREATMENT SECTION

The raw water from the river Elbe is collected in two concrete tanks, passing a heat exchanger system and then demineralized by means of a strong acid cation and a weak base anion exchanger. An intermediate tank between the exchanger units is used to strip dissolved CO_2 with nitrogen and to collect the concentrate streams from the Ultrafiltration units. Sodiumhydroxide is used to raise the pH of the desalinated water before the water is feeded to the Reverse Osmosis (RO) units. Multiple benefits are accociated with the high pH of about 10. The RO removal efficiency for silica is increased, biofouling is avoided and particle settlement is limited because of the membrane saponification effect. While the permeate is sent to the permeate tank the concentrate is treated by a concentrate RO unit. The permeate of the concentrate RO is collected and used for cooling towers and scrubbers. The concentrate stream goes to drain.

THE MAKE-UP SECTION

In the make-up section gases like oxygen and CO_2 are removed with a membrane degasification system. The gases are removed by passing the water through a hydrophobic high-molecular-weight membrane that only allows the water molecules to pass through. Nitrogen is used as carrier gas. A vacuum pump is employed on the permeated side. The degassed water passes an additional demineralization step to achieve the theoretical water resistant value of 18.2MΩ -cm. A so-called Merry-Go-Round (MGR) configuration secures a stable ultrapure water quality after the treatment unit. Two units are operated as parallel working Mixed Beds, the third one is used for polishing purposes. When the working exchanger with the lowest capacity is exhausted the polishing unit becomes to be a working exchanger. The regeneration of the Mixed Bed is carried out in a separate regeneration station. Afterwards, the unit is used as a polisher. The demineralized water is stored in three ultrapure water tanks with a total storage capacity of one hour. The tanks are made from fiber reinforced plastic with a polypropylene

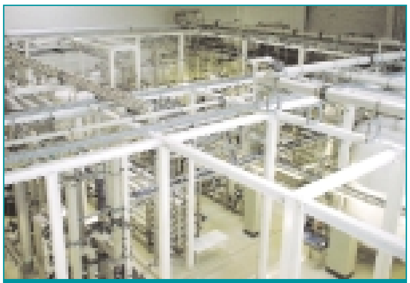

Figure 7. Infineon Technologies Dresden, SC 300: Top View Make-up System.

(PP) inliner. The same material PP is also used for the loop return line.

THE POLISHING SECTIONS

Variable frequency pumps are used to feed the water to the polishing units and the Fab distribution loops. After a heat exchanger and a UV system the water passes the Halar coated polishing ion exchanger to remove traces of ions build during the previous TOC oxidation step. The final Ultrafiltration units reduce the particles to the required level. About 14 % of the polished cold water is fed to the hot polishing section which consists of heat exchangers and an Ultrafiltration system. The plant has a net consumption capacity of 250 m^3/h (cold: 220 m^3/h, hot: 30 m^3/h) and a loop supply factor of 1,5.

FUTURE TREND

The basic design of standard ultrapure water plants are pretty much comparable and they all have three process steps in common: pre-treatment, make-up and polishing. The design of the pretreatment section is driven by the incoming raw water quality. Most of the differences between the individual plants are found in the make-up section or primary treatment system and various concepts were realized. The polishing system or secondary treatment section is often similar. Specific process requirements (e.g. Boron Spec, very low TOC levels) will influence the design as well as site specific operational costs for utilities. However, independent of all process steps, at the point of use the Ultrapure water quality has to meet a single specification, which is often directly derived from the ITRS roadmap according to the manufactured product and line structure size.

The disadvantage of this approach is obvious. The water quality gained with complex treatment technologies and by use of high-grade materials is not needed for all wafer manufacturing processes. This is especially true for parameters like oxygen and Total Organic Carbon. The reduction of these parameters below to the sub-ppb level are very cost intensive. But usually, the application with the highest quality requirement rules the overall UPW specification. A step to reduced investment and operational costs would be to provide different UPW-qualities, processed in dedicated decentralized treatment systems and depending on the real process requirements. For example, the large sized polishing system would be split up into smaller units, which are located close to the process area like Wet, CMP or Parts Clean where the water is needed. This approach would also reveal the possibility to use lower grade installation materials like Polypropylene (PP) or Polyvinylchloride (PVC) instead of the expensive Polyvinylidenefluoride (PVDF).

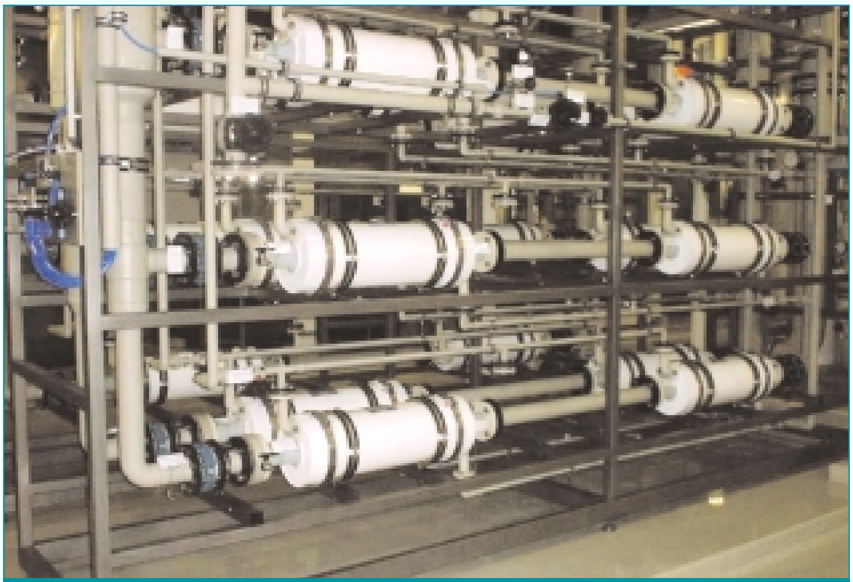

Figure 8. Infineon Technologies Dresden, SC 300: Membrane Degasification units.

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ABOUT THE AUTHOR

Dr. Martin Weltzer received his Doctorate in Chemistry at the University of Cologne and joined Siemens in 1991. He is in charge of developing advanced process facility systems. After realizing several 200 mm Fabs and the worlds first 300 mm mass production facility in Dresden, he is now engaged in building a new 300 mm Fab for the Infineon-Nanya Joint Venture HWA YA.

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