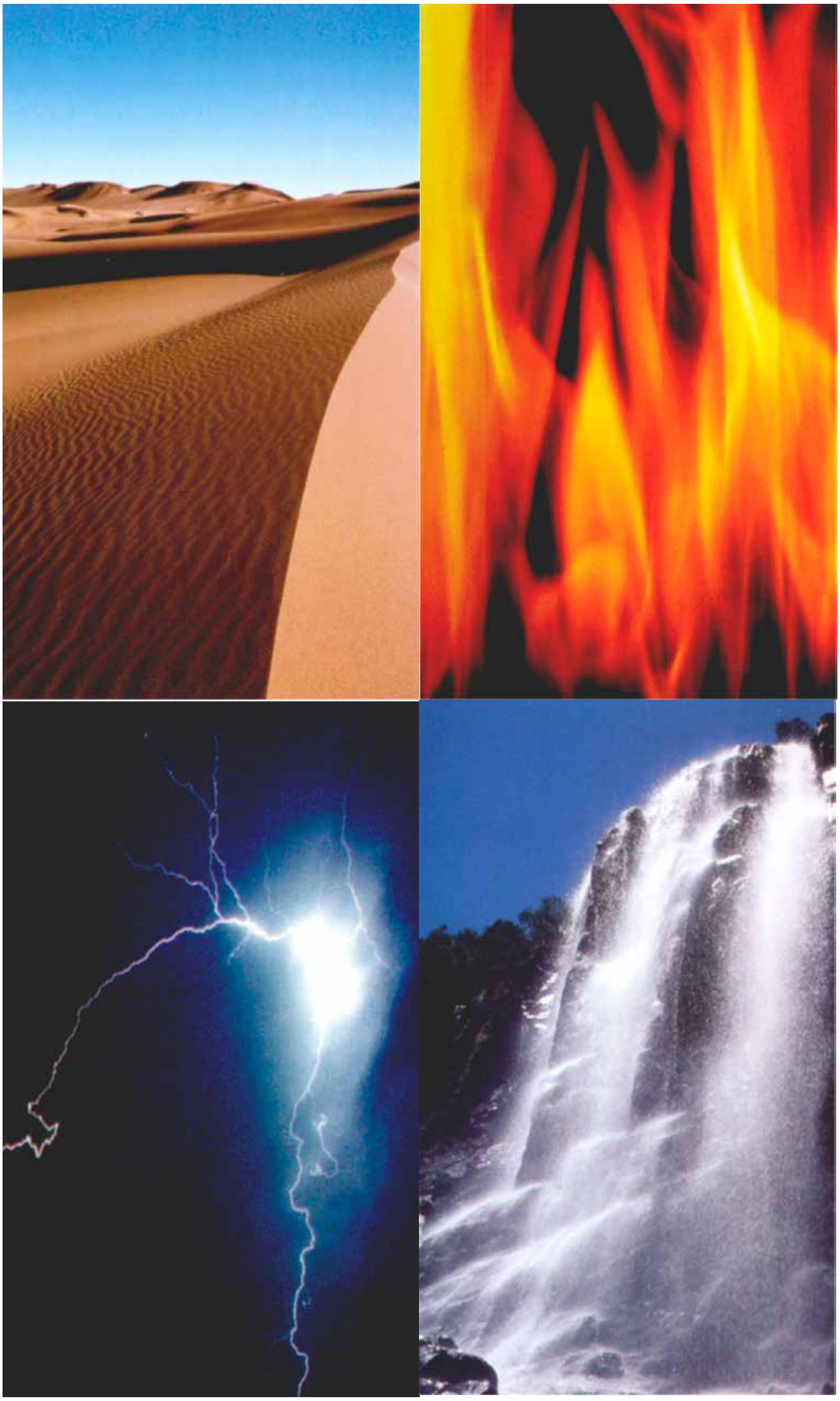
XZERO AB



The 4 most important elements in making microchips are silicon, heat, light, and water – lots of water

SUMMARY

Summing up

Ultra pure water (UPW) is used in the manufacture of integrated circuits also called semiconductors, microchips or simply chips. A chip has to be cleaned after each step of manufacture, which means that it is rinsed in UPW a hundred times or more. Any contamination on the chip will lead to short circuit and malfunction.

One factory may use 1-10 million liters of UPW per day. The use in the semiconductor industry worldwide is several billion liters per day.

XZERO has developed proprietary technology for the manufacture and recycle of UPW. The number of present suppliers of UPW-systems is less than a dozen. Xzero plans to co-operate with several of them.

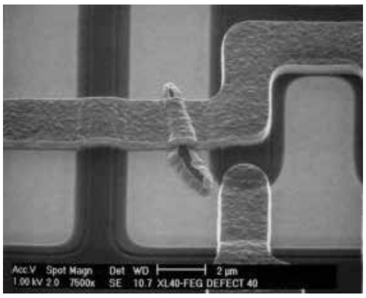
The total number of semiconductor manufacturing companies worldwide are a few hundred. Each one may have several factories at different locations.

The Xzero system

The Xzero system offers the following advantages:

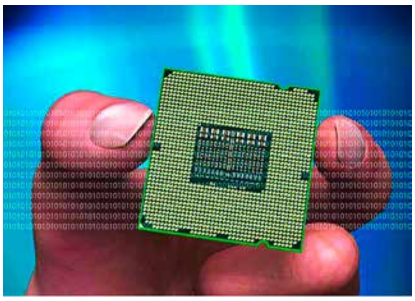
- Lower cost
- Less maintenance and down-time
- More consistent purity
- Zero discharge

450 mm wafer

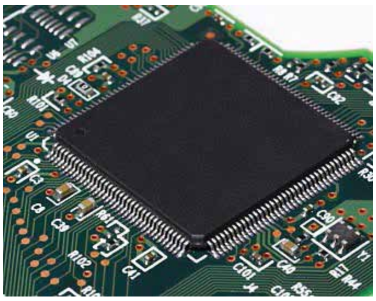


Electron microscope image of a contaminated IC, magnified 7500 times

A typical sterile environment of built-in "wet-bench" for wafer rinsing



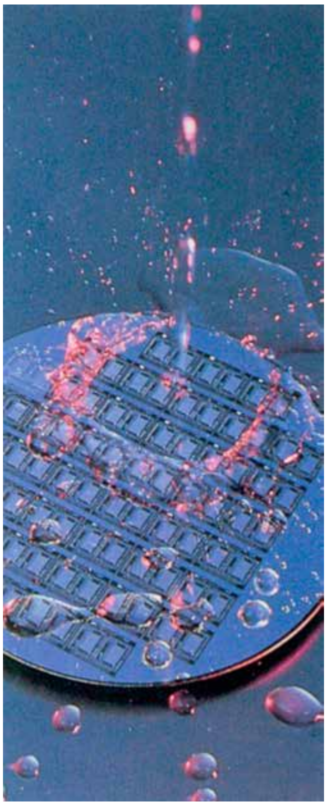
Chip after cutting of wafer



Chip after mounting

MARKET

The need for ultra pure water



Ultra pure water (UPW) is used in production of wafers and chips, which are washed more than 100 times during production. Water is used to remove chemicals and reaction products used in the process. Removing contaminants during manufacture is critical to commercial viability. Any type of contamination, no matter how insignificant, may short-circuit and ruin the resulting chip. A consistent supply of absolutely pure water is necessary in order to keep reject rates down. Also the water itself must be entirely free from contaminants. Even the smallest particle, bacteria or ion may be detrimental. At each step of the process, wafers are tested with specially designed equipment under computer control, some of which measure events on an atomic scale. When the metalization process is completed, all the chips on a wafer are tested again. Those that pass the rigorous electrical tests are then cut from the wafer with high-speed, water-cooled, diamond cutting saws and mounted in metal or plastic packages, called modules. These modules are then tested again. Each tiny memory cell that holds a bit of information, and every circuit must be tested.

A general guideline is that 10 gallons of UPW are used to wash every chip produced and this is regardless of whether it is accepted or rejected. To obtain purest water possible, the industry adopts major established water purification technologies in sequential steps where one step removes particular contaminants but introduces or allows others which have to be removed by a subsequent step. 15-20 purification steps or more in sequence will be required.

Another aspect is the sheer magnitude of water requirements. Since a chips factory may require from 1 to 10 million liters or more per day, the consumption of water is becoming a limiting factor in location decisions for new semiconductor plants. Many locations, otherwise considered suitable, may be ruled out due to lack of access to sufficient quantities of water.

Recovery of water is therefore necessary, if not to save water then, for not letting out contaminants in the environment.

TECHNOLOGY AND PROCESS

Present systems

The quality of UPW is measured by a number of criteria, probably the best known of which is a MegOhm count (measured resistivity where 18.3 MegOhm is the target) but equally important are others such as TDS (total dissolved solids) and TOC (total organic carbon) measurements. The UPW quality today is often so good that impurities are below the detection levels of existing equipment. The struggle is therefore not mainly to obtain purer water but to maintain a consistent quality in the face of changing qualities of feed water.

A typical state-of-the-art system is represented schematically below:

Feed Water

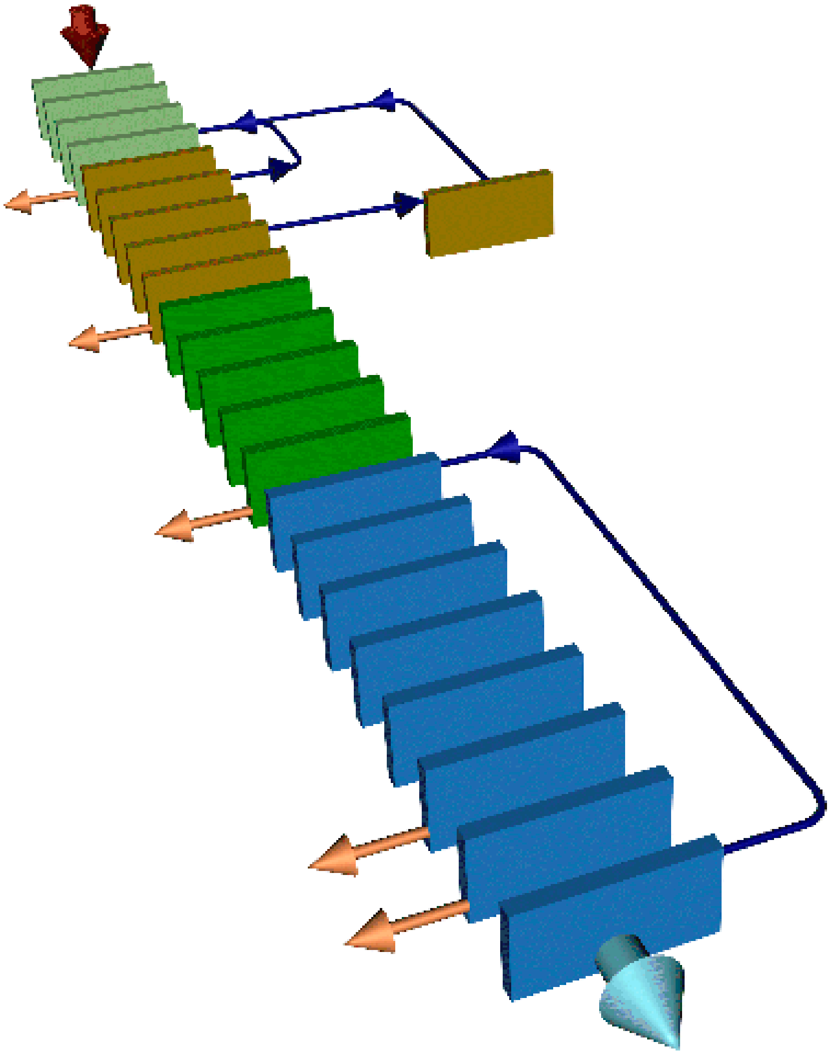
Pre-treatment System
Media Filtration
Activated Carbon
Softener
Ultra Filtration

RO Make Up System
Filtered Water Storage
Heat Exchanger
RO Pre Filtration
Primary RO System
-> Reject RO System
Secondary RO System

DI Make Up System
RO Permeate Storage
TOC Removal UV
Degasifier System
Mixed Bed IonExchange
Cartridge Filtration

Polishing Loop
UPW Storage
Ozone/UV
Heat Exchanger
Degasifier System
Mixed Bed Ion Exchange
Cartridge Filtration
Ultra Filtration System
Point of use

= UPW
= waste water



Xzero technology

Process

The Xzero process consists of four basic steps: degassing, membrane distillation, polishing and concentration. First, volatiles are removed from the feed by *degassing*. Then, non-volatile contaminants are removed from the feed through *membrane distillation* (MD). The permeate is then *polished* before use as UPW and the brine is *concentrated* to solid waste.

After simple pre-treatment, the water goes to the degasser. In the degassing step, the exposure area of the pre-heated feed water is optimized which allows volatiles to escape through evaporation. The heated water, which has to be at a temperature lower than boiling point, is then guided along a hydrophobic microporous membrane in a cassette. On the other side of the membrane, within the cassette, there is a cooling surface. The temperature gradient between the hot water and the cooling surface creates a vapor pressure differential that moves the vapor within a milieu of ambient pressure from the warm side to the cool side where it condenses. Thus the primary loop is completed. The condensed water is fed to a secondary loop (a polishing loop) in order to be kept absolutely pure. To keep feed water concentration at allowable levels, part of the brine is continuously tapped to be concentrated so that solid residue can be disposed of. The water from the concentrator is fed back into the primary loop.

The membrane

The membranes have more than one million pores per square centimeter. The pores are 20,000 times smaller than a droplet of water, but 700 times larger than a molecule of water. The membrane should be made of hydrophobic, i.e. water-repellent material. Vapor, however, will leave the surface of the water, pass through the membrane and be condensed on the other side. At the same time, the surface tension of the water keeps all types of organic and non-organic non-volatile components in the non-vaporized part of the water, which is then recirculated.

Requirements for the membranes and the process through the membranes is that no capillary condensation should take place inside the pores of the membrane, that only vapor should be transported through the pores, that the membrane must not alter the vapor-liquid equilibrium of the different components in the process liquids, that at least one side of the membrane should be in microscopic proximity with process water and that, for each component, the driving force is a partial pressure gradient in the vapor phase.

Because of the low temperature and ambient pressure, the vaporization does not create bubbles and no impurities or droplets will accompany the vapor. There is no entrainment through the membrane. The permeate is thus not only purer than what can be achieved with the best of other filter technologies but also several times purer than with conventional distillation.

Cassettes, modules and systems

A large exposure surface is required in a confined space. This is achieved by means of finely engineered cassettes that are made up of membranes, cooling surfaces, and frames with capillary systems for separated movement of feed, coolant and purified water allowing a modular structure wherein the capacity can be increased through use of numbers of cassettes in a module. The modules are then assembled into a system.

A full system will contain: degassers, modules, polishing loop, brine concentrator, energy recovery and an assortment of ancillary components such as piping, pumps, tanks, valves and instrumentation.

History

The membrane distillation technology strives to increase evaporation area to such an extent that an economical output of distillate can be obtained while operating at temperatures under 100 degrees Centigrade and at ambient pressure.

Although the intellectual origins of the theory are not new, only recent development of materials and technology makes commercialization viable today and so permits a radical departure from existing filter, distillation and chemical technologies for water treatment.

Commercialization of MD technology was anticipated by scientists already in the 1940s. Interesting rudimentary concepts were developed in the USA by 1967, in Belgium in 1968 and in Japan by 1969. The present theory of membrane distillation was developed in Sweden, Japan, Germany and the United States during the 1970s and in the beginning of the 80s.

Articles describing the technology using names such as Thermal Pervaporation, Thermopervaporation and Transmembrane Distillation started to appear in scientific publications until an international conference in the Netherlands in 1989 agreed on the name sponsored by Scarab Development AB of Sweden, Membrane Distillation.

All through the development stages, laboratory work on membrane distillation has been very promising. However, engineering aspects have posed difficulties and several attempts at commercialization have failed. These difficulties have been resolved by Scarab Development in cooperation with leading engineering companies, ABB and Electrolux among others.

Scarab Development's involvement with the technology goes back to 1977. In 1997, Xzero acquired use of Scarab's technology as a key proprietary component for use in the semiconductor industry to make UPW-water systems with zero liquid discharge.

The Xzero system

The Xzero-system reaches the same, or higher, purity and guarantees more consistent quality with considerably fewer steps than present state-of-the–art technology. Less complications means higher reliability, which is all-important in the industry.

First, volatile contaminants are removed by degassing. Then a portion of the water molecules in the degassed water is separated, leaving non-volatile matter in the reject. The permeate is therefore free from both volatile and non-volatile contaminants.

To ensure that the outcome is absolutely pure, several auxiliary aspects are included. Nitrogen blanketing and vacuum ensures that the water is not recontaminated by volatiles. And, careful design and selection of inert materials ensures that the process equipment itself does not contaminate water.

An Xzero system is represe

Feed Water

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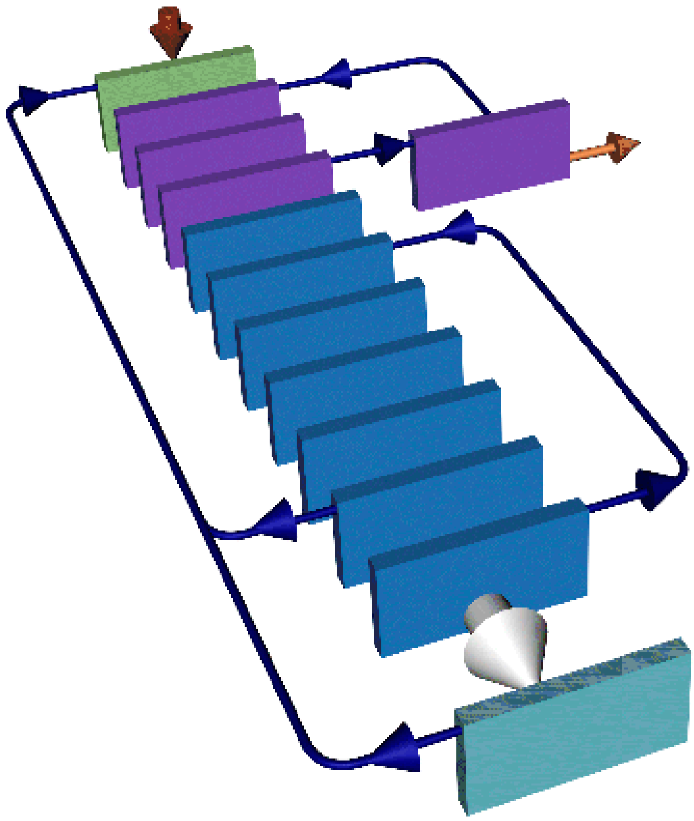
Media Filtration

MD Make Up System
Filtered Water Storage
Degasifier
Membrane Distillation
-> Evaporator

Polishing Loop
UPW Storage
Ozone/UV
Heat Exchanger
Degasifier System
Mixed Bed Ion Exchange
Cartridge Filtration
Ultra Filtration System
Point of use

= UPW – Rinse

= solid waste



Applications

There are two applications for which Xzero's systems are suited.

- Production of UPW
- Recovering of water after use

Production of UPW

Typical Chip Plant Water Use
Daily water consumption 1,5 million liters or 400,000 US gallons
Capital Cost $ 10 million
Cost per US gallon 2-3 cents

CENTRAL PLANT
1-2 million liters of UPW/day

CLEAN ROOM 2-5
Average 300,000-750,000 liters of UPW/day

WORK STATIONS
Average 40,000-60,000 liters of UPW/day

BATCH
Average 7,000 liters of UPW/day

High-purity water, by itself or as solvent to other chemicals, is used to remove chemicals and reaction products. The size of potential contaminants to be eliminated reduces as chips get more compact.

There are differences in pattern of use with all producers having a central plant where make up water is prepared. The average is 1.5 million liters (400,000 US gallons) but an increasing number of plants being set up are many times that size. Water is pumped from the central plant to fabs or clean rooms and the average plant may have two to five such points.

Actual consumption of UPW varies from plant to plant and over time with emphasis changing between processes and tools. Despite awareness that water consumption must be minimized, the industry is increasing water use, simply because more advanced chips need more rinsing.

Recovering of water after use

UPW is a valuable material to be used in an optimal way and simply dumping contaminated water is fast becoming unacceptable. In the US, utilities and regional authorities have made water use and dumping central to relations with the industry and the EPA is keeping a close watch on the situation.

Early attempts at reusing water took advantage of the fact that some of the water could be recovered to water lawns or in cooling towers and scrubbers. Achieving the first 40% reduction in water consumption is therefore far easier than reaching 70% and above. Of greatest interest is the possibility of re-using water for rinsing of chips. Most new plants take some initiative to lower water consumption at an additional capital investment. The Xzero system allows close to 100% recovery with little additional cost.

Advantages

Xzero offers the following advantages:

- **Simpler** — uses far fewer steps than existing systems.
- **Purer** — can remove all contaminants.
- **Consistent** — always removes all contaminants.
- **Zero discharge** — can recirculate water and concentrate contaminants to solid residue.
- **Economical** — lower capital and operating costs.

Demo - Stockholm, Sweden

Test - Jeddah, Saudi Arabia

Pilot - Doha, Qatar

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