

SEMI F98-0923

GUIDE FOR WATER REUSE IN SEMICONDUCTOR INDUSTRY

This Standard was technically approved by the Facilities Global Technical Committee. This edition was approved for publication by the global Audits and Reviews Subcommittee on August 21, 2023. Available at www.semiviews.org and www.semi.org in September 2023; originally published March 2005; previously published May 2021.

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1 Purpose

1.1 This Guide provides definitions and recommendations for design of industrial water treatment systems that reuse water in a semiconductor manufacturing facility. It is intended to establish a common basis for developing design specifications and decisions concerning planning and design of water reuse systems. This Guide also includes some considerations for the water reuse systems operation.

1.2 This Guide may be used by semiconductor factory engineers and suppliers for developing site-specific basis of design and performance criteria.

2 Scope

2.1 This Guide applies to water treatment systems designed for water reuse within semiconductor manufacturing facilities, with the purpose of supplying water for use in a variety of applications throughout the site. Such applications include directing reuse water to the front end of the ultrapure water (UPW) front end system, cooling systems, exhaust scrubbers, point of use (POU) abatement, thermal processes, and site irrigation. Choice of the reuse scheme depends on the reuse water quality, application requirements, and environmental regulations.

2.2 This Guide can be used to understand the design elements and functionality of water treatment systems that support reuse of water. Although existing factories can be retrofitted to implement water reuse, there is a broader range of opportunities available in new facilities that incorporate water saving applications in the basis of design.

2.3 The scope of this Guide is to provide recommendations regarding water reuse segregation strategy and possible treatment options.

2.4 This Guide reviews conditions and limitations for specific water reuse applications, as well as economic and environmental considerations. It also provides reference for typical wastewater composition.

NOTICE: SEMI Standards and Safety Guidelines do not purport to address all safety issues associated with their use. It is the responsibility of the users of the Documents to establish appropriate safety and health practices, and determine the applicability of regulatory or other limitations prior to use.

3 Limitations

3.1 This Guide is not intended to be used directly to define specifications that are otherwise negotiated between the user and the manufacturer of the water reclamation and reuse systems.

3.2 This Guide is not intended to define a specific water reuse scheme and treatment systems for a semiconductor factory, but rather is intended to be used as a general resource guide for best practices. Economics and environmental requirements as well as other location specific conditions may drive different solutions. If water reuse is added to the existing facilities, installed equipment may add physical and other constraints.

3.3 This Guide does not address maintenance and operation of water reuse systems.

3.4 This Guide does not intend to cover any of the important safety considerations that relate to the proper installation, operation, or maintenance of water reclamation and reuse systems. Safety considerations are expected to be addressed using industry and company specific safety specifications and guidelines.

NOTE 1: The SEMI Liquid Chemicals Global Technical Committee is developing a Standard to collect industry best practices on water reuse, including tool drain segregation and treatment.

4 Referenced Standards and Documents

4.1 None.

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 Abbreviations and Acronyms

5.1.1 *CMP* — chemical mechanical planarization

5.1.2 *HF* — hydrofluoric acid

5.1.3 *HFW* — hydrofluoric acid waste

5.1.4 *POTW* — publicly owned treatment works

5.1.5 *POU* — point of use

5.1.6 *RO* — reverse osmosis

5.1.7 *TACO* — total available conservation opportunity

5.1.8 *TOC* — total organic carbon

5.1.9 *UPW* — ultrapure water

5.2 Definitions

5.2.1 *cleanroom* — confined area in which the humidity, temperature, particulate matter, and contamination are precisely controlled with specified parameters. Cleanroom classes are defined in ISO 14644. [SEMI E70]

5.2.2 *reclaim water* — a product of water reclamation.

5.2.3 *UPW recycle* — the process of reclamation and reuse of water for UPW production.

5.2.4 *water reclamation* — a process of extracting/purifying water from wastewater for subsequent secondary use.

5.2.5 *water recycling* — the process that leads to water reuse at the system where it was originally used or produced from.

5.2.6 *water reuse* — the secondary use of water with or without reclamation for any purposes.

6 Water Reuse and Wastewater Segregation Strategy Considerations

6.1 There are two main platform reference strategies recommended for water reuse (refer to Appendix 1, Figure A1-1). Although site specific water reuse schemes may be different, it is recommended to decide on one of the two strategies below, then develop a site-specific water reuse plan based on that decision.

6.2 *Strategy 1* — Centralized: end-of-pipe reclamation, where the main fab effluent stream is collected and treated by a centralized reclamation plant and subsequently reused.

6.3 *Strategy 2* — Decentralized: segregation-based approach, where tool level segregation of the wastewater is provided at the manufacturing tool level. Then each stream is treated separately with subsequent reuse.

6.3.1 In the case of the decentralized strategy, it is recommended to consider POU recycling wherever it is cost effective and feasible.

6.4 Independent of the strategy chosen, some of the wastewater streams are not intended for reuse. They are collected and treated separately. Separate collection and treatment are usually due to regulatory requirements or cost considerations. Examples of such streams are wastewater containing heavy metals, concentrated solvents, high content

of suspended solids, and concentrated acids. Some of these waste collection sources can be repurposed or sold to outside service organizations if properly managed.

6.5 The choice of the segregation and reuse strategy for a new fab depends on a number of factors, including environmental regulations, corporate environmental sustainability goals, cost, composition of the streams, application specifications, and feasibility to segregate streams at the tool level. Application of single wafer processing tools can make the tool level segregation more complex, thus driving the centralized treatment strategy. This is an area of opportunity for the industry experts to work with single wafer tool manufacturers to improve segregation in the tools to optimize water reuse and chemical collection.

6.6 In the case of existing fabs where segregation was not part of the original base-build, there are still possibilities to collect and treat combined fab wastewater after diversion of the concentrated streams. In that case, implementation of the decentralized strategy may be difficult due to cost, and the complexity of making changes in the drain system of an operating fab.

6.7 Another important consideration when choosing the strategy is related to the factory technology roadmap. If the tool set is expected to change significantly in the future, associated drain systems/wastewater composition may change. For stable tool sets and consistent wastewater characteristics, use of a decentralized water reuse strategy may be possible and cost effective. Otherwise, adopting the centralized strategy may be the preferred option.

6.8 Each water or wastewater treatment system effluent may be considered for reuse opportunities. For example, UPW reverse osmosis (RO) reject can be treated and recycled back to UPW production. Cooling towers blowdown can be reclaimed and recycled or reused in other non-critical applications.

6.8.1 One of the key decisions to be made when determining the water reuse scheme is related to the environmental compliance for salt content. Many sites are regulated to the level of salinity in the site outfall. Often this issue becomes determining for the extent of the water reuse and the water management scheme. When salinity limit is exceeded, capital intense and energy intense solutions may be required to address this issue. This may include the following options:

6.8.1.1 Brine concentrators and crystallizers.

6.8.1.2 Evaporation ponds or other enhanced evaporating processes.

6.8.1.3 Off-site disposal via pipelines or hauled away.

6.8.2 New, more creative energy efficient, and low capital solutions may need to be explored. Specific examples exist, but are not listed in this Guide due to their proprietary nature.

6.9 *Recommended Strategy*

6.9.1 POU recycle systems are recommended where water can be recycled back to the tool for reuse in the process with minimal or no treatment.

6.9.2 A centralized strategy is recommended when extensive wastewater reclamation is required, segregation options are limited due to space constraints or other reasons, and when decentralized systems are cost ineffective. Due to the increased prevalence of organic contaminants in wastewater from semiconductor operations, treatment to remove organics by biological process has been successfully demonstrated, and should be considered as part of the treatment scheme.

6.9.3 A diagram illustrating the recommended tool water recovery, reuse, and recycle strategy is shown in Figure A1-3. Note that a centralized strategy may require installation of a dedicated segregated drain for wastewater that is not suitable for recovery or recycle due to regulatory constraints (e.g., US EPA Resource Conservation & Recovery Act [RCRA]), or due to the presence of contaminants in the wastewater that cannot be cost-effectively removed by treatment. The requirement for additional drains may impact tool and factory infrastructure design.

7 Design Considerations

7.1 *Collection of Wastewater Streams* — The most common collection system includes fab-wide gravity collection piping, as well as associated pipe racks and tunnels to the collection tanks. Choice of the piping material is a function of physical and chemical compatibility and cost. Proper venting is critical to sustain operation. The collection system typically includes a lift station, pumps, tanks, and controls. Separate holding tanks used for each grade of water so

routing of the effluent streams to specific types of treatment and reuse can be matched to specific needs (refer to Figure A1-3).

7.1.1 General interest in efficient water reuse by semiconductor fabs encourages tool manufacturers to include multiple drain lines within the tool so waste streams can be easily segregated. Divert valves can be used to segregate chemicals. In some applications, such as chemical mechanical planarization (CMP), tool manufacturers can also incorporate plumbing and treatment modules for recycling spent water discharge from a tool as feed water for that tool (POU recycling). Purchasing tools with recycle hardware already built-in eliminates the need for users to design and install customized water reuse systems unique to their site.

7.2 *Treatment of Wastewater Streams* — In addition to choosing the most effective and technically sound design solutions, other considerations for treatment options include easy access to major components for operation and maintenance, availability of consumables and spare parts, as well as the level of automation and reliability.

7.2.1 The level of automation and sophistication in the design may be influenced by availability of the trained operating personnel.

7.3 Depending on the choice of segregation strategy different treatment technologies may be used.

7.3.1 For the centralized strategy, the end-of-pipe reclamation commonly employs biological treatment followed by polishing with RO.

7.3.2 For decentralized strategy, the choice of the reclamation technology is a function of the quality of the treated water and the required performance efficiency of the treatment system for each segregated stream. In some cases, as simple as diversion control is sufficient for reuse, while in others use of organics removal and/or deionization processes may be required. Biological treatment is less common for this strategy. Main challenges related to this approach are due to organic composition and suspended solids content.

7.3.2.1 Low molecular weight organics may limit UPW recycling, while high molecular weight organics may cause organic fouling in the reuse equipment. Organics may also lead to biofouling. It is recommended to characterize organic content in the reuse streams and choose a treatment process accordingly to ensure cost effective operation.

7.3.2.2 Suspended solids may result in fouling and clogging of the treatment equipment.

7.4 *Monitoring* — Total organic carbon (TOC), pH, conductivity, and temperature are typical parameters that are monitored online and tracked over time to optimize performance. The set points for diversion/control and level of monitoring depends on the chemistries being used in the manufacturing process as well as the load of contaminants in each stream. To ensure adequacy of analytical data, sample equalization is recommended and can be provided using composite sampling or separate sample tanks. In case if the compliance requires controlling short-term or instantaneous variations, the sampling method should take those requirements into account. Parameters that cannot be effectively monitored online, specific organics, should be analyzed in grab sample.

8 Grades of Water Effluent and Applications of Water Reuse

8.1 There are different sources of reusable water from a semiconductor facility.

8.1.1 *UPW System Rinse Water* — Water used in the maintenance and upkeep of the UPW system, such as polish resin or filter rinses, is of high quality after initial discharge may be suitable for a wide range of applications based on the diversion criteria used with little or no treatment. Flows from analytical stations may also be considered for collection with this stream.

8.1.2 *Idle Tool Water* — Fab tools consume significant amounts of water when idle to maintain tool cleanliness. Collection of this water requires no treatment for reuse if such segregation is available.

8.1.3 *Wafer Rinse Water* — The second and third rinses from wafer cleaning processes are sufficiently high quality to be reused without further treatment either for facilities systems, make-up water in a UPW system, or directly for use in a lower grade application such as CMP cleaning. Use of this stream requires sophisticated segregation capability, as well as additional monitoring and control to mitigate the risks.

8.1.4 *Specialty Waste Treatment System Effluent* — Many semiconductor fabs now contain segregated treatment systems for wastewaters such as those containing high concentrations of fluoride or copper. The effluent of these treatment systems may be reclaimed and considered for reuse, subject to being permitted by local hazardous waste regulations.