# SEMI F78-0611 (Reapproved 0917)
# PRACTICE FOR GAS TUNGSTEN ARC (GTA) WELDING OF FLUID DISTRIBUTION SYSTEMS IN SEMICONDUCTOR MANUFACTURING APPLICATIONS

This Standard was technically approved by the Gases Global Technical Committee. This edition was approved for publication by the global Audits and Reviews Subcommittee on May 16, 2017. Available at www.semiviews.org and www.semi.org in September 2017; originally published July 2003; previously published June 2011.

SUPERSEDED

## 1 Purpose

1.1 The purpose of this Practice is to provide procedures for welding stainless steels and other corrosion resistant metals and alloys (CRAs) for fluid (liquid or gas) distribution systems in semiconductor manufacturing applications. Welds performed following these procedures are of sufficient quality to provide the required system purity, weld integrity, and weld strength for use in semiconductor manufacturing applications.

## 2 Scope

2.1 This Practice provides procedures for gas tungsten arc (GTA) autogenous butt joint welds of stainless steel and other CRAs in fluid distribution systems. The fluid distribution system includes tubing, pipe, fittings, valves, subassemblies and components that contain and distribute fluid.

**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 The stainless steels covered by this Practice are limited to the austenitic and super austenitic grades of stainless steel.

3.1.1 Corrosion resistant metals and alloys covered by this Practice are limited to solid solution grades of nickel alloys and solid solution grades of titanium alloys.

3.1.2 This Practice applies only to autogenous GTA circumferential butt joint welds performed on fluid distribution system components 15.24 cm (6 in.) or less in diameter.

3.1.3 This Practice applies only to automatic, mechanized, or machine GTA welding processes.

3.1.4 This Practice applies only to welds performed with no fillers and no fluxes.

3.1.5 This Practice does not apply to pressure vessel or process chamber welds.

## 4 Referenced Standards and Documents

NOTE 1: The following documents become part of this Practice to the extent that they are included herein.

4.1 *SEMI Standards and Safety Guidelines*

SEMI F20 — Specification for 316L Stainless Steel Bar, Forgings, Extruded Shapes, Plate, and Tubing for Components Used in General Purpose, High Purity and Ultra-High Purity Semiconductor Manufacturing Applications

SEMI F81 — Specification for Visual Inspection and Acceptance of Gas Tungsten Arc (GTA) Welds in Fluid Distribution Systems in Semiconductor Applications

4.2 *ANSI Standards*[1]

ANSI Z49.1 — Safety in Welding, Cutting, and Allied Processes

[1] American National Standards Institute, 25 West 43rd Street, New York, NY 10036, USA; Telephone: +1.212.642.4900, Fax: +1.212.398.0023, http://www.ansi.org



Documents Document Sharing Hub

Full document details: SEMI F78-0611-0917R

4.3 *ASME Standards*[2]

ASME BPE — Bioprocessing Equipment Standard

ASME B16.25 — Buttwelding Ends

ASME B31.3 — Process Piping Design

Boiler and Pressure Vessel Code — Section IX, Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operators

4.4 *ASTM Standards*[3]

ASTM A269 — Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service

ASTM A450 (§ 25) — Standard Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Steel Tubes

ASTM A632 — Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing (Small-Diameter) for General Service

4.5 *AWS Standards*[4]

AWS A3.0 — Standard Welding Terms and Definitions Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying

AWS B2.1 — Specification for Welding Procedure and Performance Qualification

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

## 5 Terminology[5]

5.1 *Definitions*

5.1.1 *angular misalignment* — the condition that exists when the tubing angle is changed at the weld.

5.1.2 *autogenous weld* — a fusion weld made without filler metal.[2]

5.1.3 *automatic arc welding downslope* — the time during which the welding current is reduced continuously from the final level until the arc is extinguished.

5.1.4 *axial misalignment* — the offset caused by tubing being in line but not coaxial at the weld.

5.1.5 *backing gas* — an inert gas (or gas mixture) on the interior of the weld joint used to prevent or reduce formation of oxides and other detrimental surface substances during welding, and to provide pressure for weld profile.

5.1.6 *bead* — non-standard term for *weld bead.*[2]

5.1.7 *bead overlap* — in a pulsed weld the amount of coverage of a weld pulse of the previous weld pulse, usually measured in percentage of the diameter of the pulse.

5.1.8 *bead variation* — the amount of change of ID bead width from one area to another.

5.1.9 *bead width* — the width of the weld bead on the ID, normally measured in units of $T$, where $T$ is the nominal tube wall thickness.

5.1.10 *center line shrinkage* — a profile-reducing defect or discontinuity normally formed by shrinkage during solidification.

[2] American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990, USA; Telephone: +1.973.882.1170, Fax: +1.973.882.1717, https://www.asme.org

[3] American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA; Telephone: 610.832.9585, Fax: 610.832.9555, http://www.astm.org

[4] American Welding Society, 550 N.W. LeJeune Road, Miami FL 33126, USA; Telephone: 800.443.9353; http://www.aws.org

[5] The terminology has been derived from the following sources: (1) Webster's New World College Dictionary Fourth Edition, (2) ANSI/AWS A3.0 Standard Welding Terms and Definitions, (3) ASME BPE Bioprocessing Equipment Standard.



SUPERSEDED

Documents
Document Sharing Hub

Full document details: SEMI F78-0611-0917R

5.1.11 *color* — the darkness of the oxidation of the weld or adjacent surfaces. Non-standard term for *discoloration.*

5.1.12 *color line* — acceptance criteria of the maximum amount of discoloration allowed on the weld or adjacent surfaces.

5.1.13 *concavity* — a condition in which the surface of a weld is depressed relative to the surface of the tube or pipe. Concavity is measured as a maximum distance from the outside or inside diameter surface of a weld along a line perpendicular to a line joining the weld toes.[3]

5.1.14 *convexity* — a condition in which the surface of a weld is extended relative to the surface of the tube or pipe. Convexity is measured as a maximum distance from the outside or inside diameter surface of a weld along a line perpendicular to a line joining the weld toes.[3]

5.1.15 *coupon* — weld sample which is inspected to insure that the weld meets specifications.

5.1.16 *coupon-in* — first coupon prior to production welding.

5.1.17 *coupon-out* — last coupon after production welding.

5.1.18 *discoloration* — any change in surface color from that of the base metal. Usually associated with *oxidation* occurring on the weld and heat affected zone on the outside and inside diameter of the weld joint as a result of heating the metal during welding. Colors may range from pale bluish-gray to deep blue, and from pale straw color to a black crusty coating.[3]

5.1.19 *downslope* — see *automatic arc welding downslope*.

5.1.20 *dross* — non-standard term for *slag.*[2]

5.1.21 *electrode* — non-standard term for *tungsten electrode*.[2]

5.1.22 *enclosed weld head* — weld head in which the weld joint is held and welded within a closed chamber containing a shielding purge gas.

5.1.23 *encroachment* — non-standard term for ID *convexity.*

5.1.24 *examiner* — a person who performs examination of a particular object, or evaluates an operation, for compliance to a given standard. The examiner performs quality control for the manufacturer, fabricator, or erector.

5.1.25 *fluid* — liquid or gas.[1]

5.1.26 *gas* — the fluid form of a substance in which it can expand indefinitely and completely fill its container; form that is neither liquid or solid.[1]

5.1.27 *gas tungsten arc welding (GTAW)* — an arc welding process that uses an arc between a tungsten electrode (nonconsumable) and the weld pool. The process is used with a shielding gas.[3]

5.1.28 *halo* — non-standard term for *discoloration* resulting from welding procedure.

5.1.29 *haze* — non-standard term for *discoloration* resulting from welding procedure.

5.1.30 *heat-affected zone (HAZ)* — the portion of the base metal whose mechanical properties or microstructure have been altered by the heat of welding.[2]

5.1.31 *heat tint/color* — non-standard term for *discoloration* resulting from welding procedure.

5.1.32 *inclusion* — entrapped foreign solid material, such as slag, flux, tungsten, or oxide.[2]

5.1.33 *inert gas* — a gas that normally does not combine chemically with materials. A protective atmosphere.

5.1.34 *lathe welding* — automatic or machine welding of tubes or pipes in which the electrode is stationary and the weld joint rotates. Lathe welding as defined here is a fusion process without the addition of filler.

5.1.35 *liquid* — having its molecules moving freely with respect to each other so as to flow readily, unlike a solid, but because of cohesive forces not expanding infinitely like a gas.[1]

5.1.36 *meandering* — of or pertaining to a weld bead that deviates from side to side across the weld joint rather than tracking the joint precisely.[3]

SUPERSEDED



Documents Document Sharing Hub
Full document details: SEMI F78-0611-0917R

5.1.37 *orbital welding* — automatic or machine welding of tubes or pipes in-place with the electrode rotating (or orbiting) around the work. Orbital welding, as it applies to this standard, is a fusion process without the addition of filler.[3]

5.1.38 *oxidation* — the formation of an oxide layer on a metal surface. When excessive oxidation occurs as a result of welding, it is visible as *discoloration.*[3]

5.1.39 *oxide island* — non-standard term for *slag.*

5.1.40 *pressure cylinder* — a metal cylinder used to store gases under pressure.

5.1.41 *profile defect* — any defect or discontinuity that reduces the wall thickness below that of the parent metal.

5.1.42 *pulsed gas tungsten arc welding* — a gas tungsten arc welding process variation in which the current is varied in regular intervals.

5.1.43 *purge* — the application of an inert gas or gas mixture to the OD or ID surface of the weld joint to displace non-inert atmospheric gases. A block purge is a non-flowing purge with positive pressure.

5.1.44 *purge gas* — an inert gas, or gas mixture, used to displace the ambient atmosphere from the inside (ID) of the weld joint.

5.1.45 *root* — non-standard term for *root surface.*

5.1.46 *root surface* — the exposed surface of a weld opposite the side from which the welding was done.[2]

5.1.47 *rotation delay* — time delay between when the arc is initiated and the rotor begins to turn.

5.1.48 *shield gas* — inert gas or gas mixture that protects the electrode and molten puddle from atmosphere and provides the required arc characteristics.

5.1.49 *slag* — a non-metallic product resulting from the mutual dissolution of non-metallic impurities in some welding processes.[2]

5.1.50 *tack weld* — a weld made to hold the parts of a weldment in proper alignment until the final welds are made.[2]

5.1.51 *tail-out* — non-standard term for *automatic arc welding downslope*.[2]

5.1.52 *tungsten* — non-standard term for *tungsten electrode*.

5.1.53 *tungsten electrode* — a component of the electrical circuit that terminates at the arc, molten conductive slag, or base metal. A non-filler electrode made principally of tungsten and used in arc welding.[2]

5.1.54 *undercut* — a groove adjacent to the base metal at the edge of the weld left unfilled by weld metal.[2]

5.1.55 *underfill* — a groove weld condition in which the weld face or root surface is below the adjacent surface of the base metal.[2]

5.1.56 *weld bead* — a weld resulting from a weld pass.[2]

5.1.57 *weld level* — a segment or portion of a weld schedule in which one or more weld parameters can be changed independently; part of a weld sequence.

5.1.58 *weld sequence* — a series of steps executed by the welding power supply to make a particular orbital weld.

5.1.59 *welder* — a person who does welding (sometimes used to refer to a welding machine or power supply).

5.1.60 *welding equipment* — power supply, weld heads, torches, and associated cables and accessories used for welding.

5.1.61 *welding operator* — a person who welds with an orbital or machine welding system.

## 6 Summary of Practice

6.1 The welding procedure is shown in the flow chart in Figure 1.

SUPERSEDED



Documents
Document Sharing Hub
Full document details: SEMI F78-0611-0917R

## 7 General Requirements

7.1 All welding performed under this Practice shall conform to the applicable requirements of the ASME Boiler and Pressure Vessel Code, Section IX, ASME B16.25, ASME B31.3 Chapter V, and AWS B2.1, to the extent that they are included herein.

7.2 All welds shall be based upon Welding Procedure Specifications (WPS) and be documented with associated Procedure Qualification Records (PQR) in accordance with ASME Boiler and Pressure Vessel Code, Section IX, or with AWS B2.1.

7.3 Qualification of the welding procedures to be used, and of the performance of welders and welding operators, shall conform to the requirements of the ASME Boiler and Pressure Vessel Code, Section IX, Articles II and III, or AWS B2.1.

7.4 All welding shall be performed only by certified welders and welding operators. Certification procedures shall include, at the minimum, producing three acceptable welds in a row of typical GTA weld joints of the smallest and largest diameters of each alloy to be welded. Welding parameters shall be set by the welder or welding operator. Certification shall expire after six months of inactivity.

7.5 The weld assembly shall be kept under a continuous purge until all welding is complete.

7.6 Welders shall use clean room-compatible gloves any time that the tubing or component to be welded is removed from protective covering.

## 8 Apparatus

8.1 Welding equipment shall be of the GTAW, constant current, direct current electrode negative (DCEN), and electronically controlled type with rapid dynamic response capable of 5 Hz (CPS) or greater pulsed welding.

8.2 All welding fixtures and weld heads shall be clean and free of any particulate and excessive discoloration. Weld heads shall rotate freely and smoothly at all speeds. All clamping and holding fixtures shall fit tightly around applicable fittings/tubing, allowing no movement after clamping in excess of 0.008 cm (0.003 in.). The welding fixturing shall allow viewing of the weld joint to insure proper fit-up.

8.3 Electrodes shall be precision ground to the factory specification for head and weld type. Electrode gap shall be set using tooling or procedures that provide accurate and repeatable gaps to be set to within 0.005 cm (0.002 in.). The use of 2% Ce-doped or 2% La-doped tungsten electrodes is recommended.

8.4 Purge gas apparatus shall be stainless steel tubing and components with face seal fittings, when possible. PFA plastic tubing is acceptable as the final run to allow flexibility for hook-up. Lengths shall be restricted to less than ten feet. All components that come into contact with the weldment shall be stainless steel. Only heavy wall PFA or stainless tubing shall be used on the ID purge. Only stainless tubing shall be used on HP systems.

8.5 Purge gas flow shall be measured and controlled.

8.6 Facing equipment shall be of the dry end machining style. The equipment shall be capable of tolerances of 0.008 cm (0.003 in.) from a plane perpendicular to the centerline of the tube, the OD and/or ID burr of less than 0.0127 cm (0.005 in.). The equipment shall be capable of controlling the cut curl so as that it does not enter the tubing or cause scratching of the ID surface. The equipment shall not use oils or lubricants in a way that may contaminate the tubing being faced. The cutting or facing shall not be of an abrasive type.

8.7 Severing or parting equipment shall be of the machining type that will separate the tubing without contaminating the ID of the tubing. Wheel type cutters designed to cut stainless steel and CRAs are allowed with purge. Dry saws of orbital type or cutoff are allowed only when followed by cleaning to ¶ 12.5. All cut ends shall meet the tolerances for facing equipment or be followed by end preparation with a facing tool.

## 9 Materials

9.1 All materials to be welded shall be manufactured to ASTM specifications and so certified by the manufacturer. Certification shall conform to ASTM A450, § 25.

9.2 All seamless austenitic stainless steel tubing shall be in conformance with SEMI F20 or customer specification.

9.3 A backing (ID) gas is required during welding, and while tacking (if tacking is used).

SUPERSEDED



Documents Document Sharing Hub
Full document details: SEMI F78-0611-0917R

9.4 Weld parameters are affected by the choice of shield gas. Argon, due to its effectiveness and material compatibility, is the most commonly selected shielding and purging gas. Argon and helium are inert and therefore have no effect on the weld metal. These gases do have very different ionization potentials, thermal conductivity, and reactivity.

9.5 Argon/hydrogen mix is a reducing gas that avoids the formation of oxides. It also reduces the amperage required for a given ID weld bead width while reducing the OD bead width. Argon/hydrogen mixes adversely affect high ferrite materials (above 80% ferrite). Use of argon/hydrogen mixes will shorten tungsten electrode life. The weld parameters will be affected by hydrogen to argon percentages. Hydrogen mixes above 5 vol% are not recommended for safety reasons.

9.6 Nitrogen will cause instability of the arc in mixes above 3 vol% in the shield (OD) purge gas. It is an acceptable backing (ID) gas for austenitic stainless and many CRAs. Nitrogen when exposed to welding temperatures will cause nitride formation in some high ferrite materials (above 80% ferrite). Use of nitrogen mixes in the shielding (OD) gas will shorten the tungsten electrode life.

9.7 The ID purge gas will be certified to 99.9997% purity, or less than 3 ppm total contaminants (moisture, oxygen, and other contaminants).

## 10 Safety Precautions

10.1 Welding equipment shall be operated in accordance with the manufacturer's operating and safety instructions.

10.2 All welding performed under this Practice shall conform to the applicable requirements of ANSI Z49.1.

10.3 Welding gas mixtures containing more than 5 vol% $H_2$ are not recommended due to the potential for fire hazard.

10.4 Do not re-weld stainless steel that has been used for corrosive gas delivery.

10.5 See Appendix 1 for information on stainless steel and welding fume.

## 11 Test Specimens: Couponing

11.1 Prior to the welding of a particular size, wall thickness, and alloy, a primary standard sample weld shall be made, sectioned, and analyzed at the job site. The primary standard sample weld shall become the on-site work sample against which other welds of the same size, wall thickness, and alloy are judged. This on-site work sample may be used indefinitely or reproduced each day at the discretion of the examiner.

11.2 The primary standard sample weld shall be checked for compliance with SEMI F81, Specification for Visual Inspection and Acceptance of Gas Tungsten Arc (GTA) Welds in Fluid Distribution Systems in Semiconductor Manufacturing Applications. Coupons shall be cross-sectioned and inspected visually. Weld coupon criteria are the same criteria for all system welds.

11.3 Once a sample weld is found to be acceptable, all essential and supplementary essential variables shall be documented in the procedure qualification record.

11.4 Any significant deviation(s) from the onsite work sample will cause the weld(s) to be rejected. Rejected welds shall be removed and replaced.

11.5 Sample test welds shall be made periodically. These sample test welds shall be compared to the on-site work sample and checked for compliance with SEMI F81. Deviation from the on-site work sample or SEMI F81 shall be cause for rejection. If the weld inside diameter is inspectable using a sight tube or other device, sample test welds may be production welds. Sample test welds shall be made when any of the following conditions exist:

11.5.1 Start of shift (in) or end of shift (out).

11.5.2 Change of weld parameters.

11.5.3 Change of material (heat number).

11.5.4 Change of tube size or wall thickness.

11.5.5 Change of ambient temperature ±11°C (±20°F).

11.5.6 Change of source of power to power supply to include addition or subtraction of extension cords.

SUPERSEDED



Documents
Document Sharing Hub
Full document details: SEMI F78-0611-0917R