TYTAN 1600

HORIZONTAL FURNACE SYSTEM

for

ATMOSPHERIC & LOW PRESSURE PROCESSES

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Chapter 1

TYTAN 1600 FURNACE SYSTEM OVERVIEW

Figure 1.1: A typical TYTAN 1600 system

TYTAN furnace systems are field-proven furnaces that have served the semiconductor industry since the early 80's. They are now proving their worth not only in the semiconductor but also in the MEMS industry. The TYTAN systems are used for a variety of processes such as diffusion, oxidation, anneal, and most importantly low pressure chemical vapor deposition (LPCVD).

The systems are based on a patented isothermal chamber design that offers a number of benefits. Thanks to this innovative design, the system requires considerably less floor space and electrical power than conventional furnaces of equal capacity. The isothermal feature also offers superior process uniformity. The systems are now well accepted as a solidly reliable and super-performing production tool in the industry. The TYTAN design incorporates several of the most advanced concepts required for high performance processing equipment.

Tystar boasts of its large installed customer base. Tystar has about 1,700 process tubes installed around the world, and most of them are still operating well. The large customer base is a testament to Tystar's adamant dedication to customer support and strong commitment to customer satisfaction. Process guarantees and specifications are per customer agreement. The process results are highly accurate and predictable by virtue of its integrated control system. The system controls eliminate possible human errors to a large extent.

1.1 Applications

TYTAN systems were primarily used for semiconductor device manufacturing in the 1980's. Over the years, semiconductor process technology has proliferated to other areas such as:

- solar photovoltaic (PV) cells
- microelectronic mechanical systems (MEMS)
- bio and chemical sensors
- optical waveguides and optoelectronic devices.

TYTAN process capabilities are mainly diffusion, oxidation, nitriding, deposition, passivation, anneal and *etc*. These processes may be performed either under an atmospheric or a low pressure condition. A copy of the Tystar Standard Processes handbook may be ordered by email info@tystar.com

or by phone (+1 310 781 9219). Any specific question about a non-standard Tystar process may be directed to Tystar's Engineering Department support@tystar.com.

New TYTAN processes have recently been developed to fabricate a variety of nano materials. It has been proven at many customers sites around the world that TYTAN systems are the most powerful tools for use both in research and in production. TYTAN systems can be used to produce nano materials such as nanowires, nanotubes, graphene, and others with the material specifications under precise control.

Nanowires are believed to play a key role in the next generation electronics and are also being investigated for their potential use in other areas such as:

- Bio and chemical sensors
- batteries, energy storage/harvesting systems
- Photonic crystals, optical waveguides and light trapping devices
- Quantum dots, MOSFET, logic gates and interconnects
- Thermoelectric and photovoltaic cells
- Photocatalysis

A TYTAN system can also be used for the research and production of carbon nano materials. Depending on the recipe used, the diameter and the length of CNT or the thickness of graphene can be precisely controlled. The type of nano materials produced varies from a single-walled to a multi-walled of up to a few tens of nm, and the length from a few nm to a few mm. The graphene thickness may vary from a single layer to a few hundred nm. CNTs can be produced in a variety of forms such as vertically aligned, horizontally aligned, and entangled. Graphenes may also be produced in various forms ranging from a single-layered sheet to platelets. Potential applications of carbon nano materials are diverse. Just to name a few,

- Solar cells
- Batteries and super capacitors
- Displays and field emitters
- AFM tips
- Composite materials and fabrics
- Biomedical materials
- Conductive materials
- Air and liquid filters

1.2 Wafer Ecology

Wafer contamination and particle deposition are key concerns of furnace system users. High-purity, chemically resistant materials are carefully selected for the gas distribution system and for all components coming in contact with the wafers inside the hot wall reactor chamber. Great care is exercised in pre-cleaning and assembling furnace parts. Point-of-use gas filters are used for all process gases entering the hot reactor tubes.

1.3 Safety Features

The highest priority of all is the safety for the users and the equipment itself as well. Safety features of the TYSTAR systems are integrated into, not simply afterthoughts. Toxic and hazardous gas leakage is reduced to an absolute minimum by using high quality components, orbitally welded gas lines and safety shut-off valves for each gas loop and for each manifold line. Gas controls are designed in a fail-safe manner with a minimum of operator dependence. Systems will automatically default to a nitrogen purge mode in case of an emergency. Safety interlocks are widely used in the gas control system to provide adequate gas purge cycles, time delays and temperature interlocks. The operator and equipment safety is assured by the 30 year experience of Tystar engineering staff in the matter.

1.4 System Layout

Figure 1.2 shows a typical TYTAN 1600 system layout:

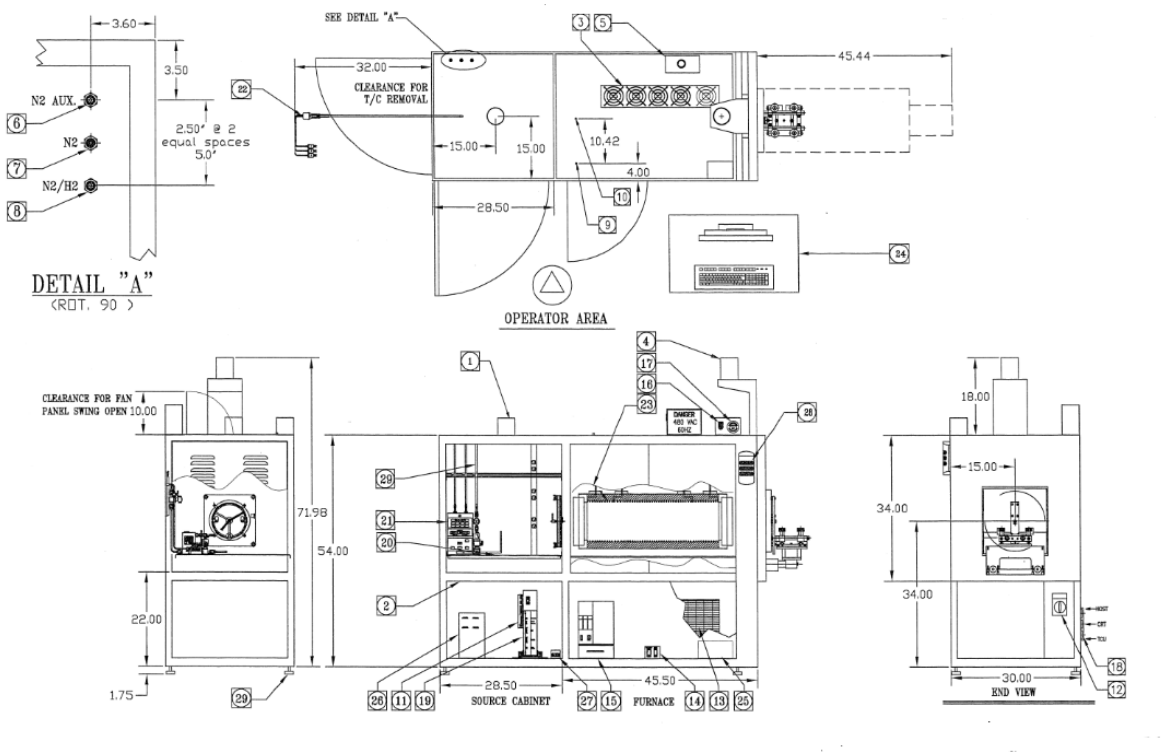

Figure 1.2: Layout of a typical TYTAN 1600.

1. Source cabinet exhaust duct: 4" O.D. 100 CFM customer-supplied blower required
2. Source cabinet drip pan
3. Heat exchanger exhaust fans 6 total
4. Scavenger exhaust duct: 4" O.D.100 CFM customer-supplied blower required
5. Power entry
6. Gas inlet: auxiliary 3/8" compression seal fitting 60 to 100 psi
7. Process gas inlets for N_2, 1/4" face seal bulkheads.
8. Process gas inlet for mixed forming gas, 1/4" face seal bulkheads
9. Heat exchanger water inlet 1/2" compression seal connection
10. Heat exchanger water return 1/2" compression seal connection
11. FCS-10/30 Touch screen panel pc process tube computer board
12. Main power switch(LOCK OUT0
13. Air intake pre-filters
14. Circuit breakers for FCS-10 tube computer and boatloader
15. Power module
16. Start Switch
17. Emergency power off switch(EMO)
18. RS-232 Connectors for host communication
19. Digital temperature control unit(TCU)
20. Gas panel for alloy Assembly
21. MFS-460 gas controller
22. Thermocouple temperature control 3-point type R.
23. Heating element 3-zone
24. FCS-10/30 + DCS-30 host computer and data collection system
25. Line conditioner
26. Boat loader control board
27. Clean power outlet strip
28. System status light tower
29. Leveling feet

1.5 Specifications

1.5.1 System Specifications

- Maximum number of tubes 1
- Number of heat zones 3
- Flat zone 18" (457 mm)
- Wafer size: round 6" (150 mm)
- Wafer Thickness: For standard wafers, please refer to Appendix C. For non-standards, please contact info@tystar.com
- Process temperature up to:
  - 1,150 °C for non-contact boat loaders
  - 1,300 °C with SiC internal components
- Wafer/boat handling
  - boat/tube transfer fully automatic
  - loading/unloading/transfer/stocker fully automatic (optional)
- Wafer Load capacity
  - 100 wafers per tube for atmospheric processes
  - 50 wafers per tube for low pressure processes
- System Dimensions (W×D×H):
  - without footings and blower module 74" × 30" × 54" (1.88 m × 0.76 m × 1.37 m)
  - footings add 2" to the height.
- Estimated weights
  - Typical Tytan 1600 Furnace: 760 kg

1.5.2 Process Specifications

The tubes of a TYTAN system can be configured to perform any of the following processes:

- Atmospheric Wet Oxidations
  - flash vaporizer oxidation
  - pyrogenic oxidation
  - deionized water bubbler oxidation
- Atmospheric Dry Oxidation
- Silicon Nitride LPCVD
  - stoichiometric silicon nitride LPCVD

    - low-stress silicon nitride LPCVD
- Silicon Oxy Nitride LPCVD
- Polysilicon LPCVD
    - silane
    - disilane
- P-Doped Polysilicon LPCVD
- Low Temperature Oxide LPCVD
- P-Doped Low Temperature Oxide LPCVD (PSG)
- B/P-Doped Low Temperature Oxide LPCVD (BPSG)
- TEOS Oxide LPCVD
- High Temperature Oxide LPCVD
- Semi Insulating Polysilicon LPCVD
- Silicon Carbide LPCVD
- Silicon Germanium LPCVD
- Epitaxial Silicon LPCVD
- Atmospheric Anneal
- Carbon Nano Tube
- Graphene

Tystar guarantees standard process specifications attached as Appendix A. Post-process characterization mostly shows better results than guaranteed specifications. For further details of Tystar processes, a copy of the "Tystar Processes" handbook may be ordered by email info@tystar.com or by phone (+1 310 781 9219). Any specific question relating to a non-standard Tystar process may be directed to Tystar's Engineering Department support@tystar.com.

1.6 Unique Features

Tystar's isothermal system design makes TYTAN systems very affordable while keeping the quality of job and parts used at the highest standards. The unique isothermal design concept also offers other benefits such as a smaller foot print, which saves expensive cleanroom space and offers higher cost efficiency by reducing gas and electricity more than 50 %.
Not all furnace brands are the same. In addition to the benefits of the isothermal feature, a TYTAN system comes with a multitude of unique

proprietary features that are absent in our competing brands. These unique features offer many advantages that are listed in the Appendix B (33 Reasons to Pick Tystar).

Chapter 2

HEATER CABINET

The furnace heater cabinet contains heater canisters, heater power modules and a forced air-to-water heat exchanger. Heater canisters can be selected to match the desired wafer size and are designed for optimum recovery performance. Heater power modules are designed for adequate heater power, ease of maintenance and replacement. The heater cabinet also contains the over-temperature sensors with independent power supplies for alarm and shut down in the event of excess temperature conditions. Radiation heat shields are provided to protect sensitive components in the gas/source cabinet. The thermal plug design yields radial and lateral temperature uniformity of better than $\pm 0.5\,^{\circ}\mathrm{C}$ throughout the temperature flat zone. Maximum power dissipation in each tube at 1,100 °C is 13 kVA, power consumption by TYTAN controllers, 5 kVA, and so the total required power for a 1-stack system is $1 \times 13 + 5 = 18$ (kVA) at 1,100 °C. Although the system is operated at much lower temperatures, we use this number for the required power capacity for a 4-stack system. The actual power consumption for wafer processing typically remains at about 50 to 60 % the maximum required power capacity. TYTAN systems outperform in energy efficiency thanks to its unique design features.

- Flat zone length: 18"
- Temperature uniformity: $\pm 0.5\,^{\circ}\mathrm{C}$
- Power exchanger: forced air to cooling water
- Maximum power consumption per tube: 13 kVA at 1,100 °C
- Maximum power consumption: 18 kVA at 1,100 °C (for fully populated system)

- Thermocouple R-type
- TCU temperature resolution: $\pm 0.1\,^{\circ}\mathrm{C}$
- Temperature accuracy:
  - $\pm 0.5\,^{\circ}\mathrm{C}$ for $300 - 1,300\,^{\circ}\mathrm{C}$
- Temperature range: $300 - 1,300\,^{\circ}\mathrm{C}$
- Closed-tube cooldown rates:
  - 13 °C/min for $1,300 - 1,100\,^{\circ}\mathrm{C}$
  - 8 °C/min for $1,100 - 900\,^{\circ}\mathrm{C}$
  - 5 °C/min for $900 - 700\,^{\circ}\mathrm{C}$
  - 3 °C/min for $700 - 500\,^{\circ}\mathrm{C}$
- Recovery time at 450 °C: 30 min
- Temperature stabilization time at full load:
  - 20 min at 450 °C
  - 15 min at 1,000 °C

Chapter 3

LOAD STATION

Typically there is no Load Station on a Tytan 1600 furnace.However,one can be supplied.The load station can be equipped with HEPA vertical or horizontal laminar flow units.The cantilever, non-contact wafer loader, is driven by a vibration-free variable speed motor. The short heater guarantees minimum deflection for wafer loads up to high temperature. Stainless steel scavengers are installed for the safe disposal of exhaust process gases.

- Laminar flow: vertical or horizontal
- Cleanliness: Class 10 or better
- Wafer loading/unloading: Cantilever
- Boat loader drive:
    - motor type: DC
    - drive speed: 1" to 25"/min (25 to 625 mm/min)
    - drive resolution: 0.04" or 1 mm

Chapter 4

GAS/VACUUM/EXHAUST HANDLING

In a TYTAN system, each stack is individually supported by a Gas/Vacuum/Exhaust handling system designated to the stack. In other words, failure of a stack will never interfere with the processes being performed in other stacks. Described in this chapter are the source cabinet, vacuum handling components, and exhaust handling component.

4.1 Source Cabinet

The source cabinet contains all gas controls and distribution manifolds. Vacuum pumps may be installed in the source cabinet or on separate pump stands at the customer's option. Two different size source pump cabinets are available.

4.2 Gas Loops

Shut off valves are incorporated into each gas line and gas panel. Point of use filters are installed for all process gases. Pumps of different capacities and makes are available.

- MFC Type $\cdots$ MKS, Horiba, Brooks or Customer Specified
- Bellows or diaphragm valves $\cdots$ Nupro (Swagelok) or equivalent
- Gas control method $\cdots$ MFS 460 closed loop microprocessor control

- Gas monitor $\cdots$ MFS 460 Electronic controller, tolerance bands and alarms
- Tubing $\cdots$ S.S. 316L Ra 7 μin. finish or better, orbital welds
- Leak rate $\cdots$ $< 10^{-9}$ cm^3 He/s
- Membrane filters $\cdots$ 0.003 μm at gas manifold and point of use
- Toxic gas line purging $\cdots$ N_2
- Safety interlocks $\cdots$ EPROM based

4.3 Gas Panel

The TYTAN gas panel comprises gas flow controllers that permit precise control, mixing, and blending of gases. Modular construction and compact design of the gas control system in connection with an advanced microprocessor-aided control provide for a stable and reliable production environment.
The microprocessor-aided control allows for either manual or automatic control from a remote PC compatible controller unit. The safety interlocks, flow rates, tolerance bands, ratio control of gas mixtures, constant total gas flow of gas mixtures, variable gas flow as a function of temperature, and pressure can be all pre-programmed.
The gas pipings are fabricated in a clean room environment using only pre-cleaned components with internally micro-polished, wetted, 316 L stainless steel tubings. VCR fittings and tubing are orbitally welded to ensure the ultimate gas purity, low particulate generation, and minimal maintenance requirements. Positive gas flow shut-off is accomplished with reliable pneumatic bellows sealed valves. Gas systems are Helium leak tested to 10^{-9} cm^3/min. Prior to shipment, systems are purged with nitrogen and all gas connections are sealed.

Chapter 5

CONTROL & DATA COLLECTION SYSTEMS

The TYTAN furnace control systems have been refined over the past few years to a high degree of perfection as a result of our pioneering efforts in furnace control. Temperature sensing inside the process tube, adaptive temperature control algorithm, integration of gas controls, pressure control, timing and sequencing, and wafer loading/unloading have led to one of the most advanced control systems for furnace processing. All operator controls are placed in a control console including the FCS 10/30 Tube computer to the MFS-460 electronic gas controller, the temperature control unit (TCU) and the boat loader electronic controls.

5.1 Tube Controller

The FCS 10/30 Tube computer is the most advanced Tystar tube controller. It provides a programmable sequence and timing control of all system components. It communicates with other furnace control systems via RS 232 communication link. The FCS 10/30 permits communication with a host computer through a node controller and is completely compatible with the SEMI SECS I & II protocols. Menu driven recipe generation, editing and operation can be performed either at the tube level or from a remote terminal. Figure 5.1 illustrates how a tube computer communicates signals from and to the control components assigned to a stack.

5.2 Temperature Control Unit

TCU is a microprocessor-driven closed loop control system, and uses an adaptive control algorithm to seek conditions for optimum recovery and steady state control. The TCU control parameters can be varied over a wide range. TCU accommodates different heater types, such as high temperature or low thermal mass heaters. TCU permits temperature control to the resolution of $\pm 0.1\,^{\circ}\mathrm{C}$.

5.3 Gas Controllers

Tystar's electronic gas controller, MFS 460, provides precise control and mixing of process gases used in the semiconductor manufacturing industry. Combined with a vaporizer, it can also control vapor flow rates and carrier gas flows of liquid source materials. The gas panels use compact, modular designs and are fabricated from 316 stainless steel with orbitally-welded joints and connections. They are leak tested to $10^{-8} cm^3/s$ with helium. MFS 460 provides safety interlocks and other critical gas control features. MFS 460 activates and controls up to 6 independent gas flow loops with individual mass flow controllers. For LPCVD systems, this unit performs system purge, leak check, and reactor chamber pressure read out. MFS 460 allows for both manual and automatic gas flow control. For automatic control, it can be interfaced with Tystar's FCS 10. Gas interlocks, error bands, flow fault indication, gas flow ranges and gas combinations are configured in an EPROM definition file. The EPROM definition file can be modified by Tystar at any time later. The MFS 460 controller provides user programmable soft-start on any gas loop, self diagnostics with display of the fault condition, battery back up and gas or vapor flow totalizing.
MFS 460 controller specifications are:

- Mass flow controllers $\cdots$ all standard models are accepted
- Set point out $\cdots$ 0 - 5 VDC
- Analog signal in $\cdots$ 0 - 5 VDC
- Output impedance $\cdots$ 6 Ω
- Input impedance $\cdots$ On/Off TTL level with 4.7 kΩ pull-up resistor
- Digital input $\cdots$ 6 Ω
- Gas flow loops $\cdots$ up to 6

- Shutoff valve ··· +24 VDC out; output open collector
- Thermocouple input ··· Type R, 300 – 1,375 °C range
- Parallel remote control keyboard ··· 0 – 5 VDC contact closure, input/output membrane switch 4 x 4 matrix
- Alpha numeric display ··· 10 digit, 14 segment vacuum fluorescent

5.4 Data Collection System

Tystar expanded TYTAN control software capability by adding the DCS-30 software package for supervisory control, automatic tube selection, and complete continuous data capture. The DCS 30 data capture collects all temperature, pressure, flow and boat loader data and displays them graphically for any heater zone or gas flow you choose. The system uses a (stand alone or networked) PC connected to the FCS 10/30 controller to collect data. The DCS 30 is geared toward a manufacturing environment and is meant to give information on furnace behavior on a run to run basis.

5.5 Other Control Related Units

Each TYTAN system comes with a number of other control and instrumental functions. Some of them are standard while the others are optional. A special pressure control system is incorporated for excellent wafer uniformities. CAL Star 400 Mass Flow Calibrator is a portable, secondary standard calibrator for all commercially available mass flow controllers and meters with better than one percent accuracy. It offers quick and easy calibration of mass flow devices. Standard flow ranges are up to 10 SLPM (Standard Liters Per Minute). Higher flow ranges are available. A Windows-based data collection software is also available. The Tystar MFC Tester is an inexpensive, light-weight, hand-held tester for mass flow devices. It's compatible with all commercially available mass flow devices and displays set points, flow rates and control voltages to an accuracy of 0.02 %.

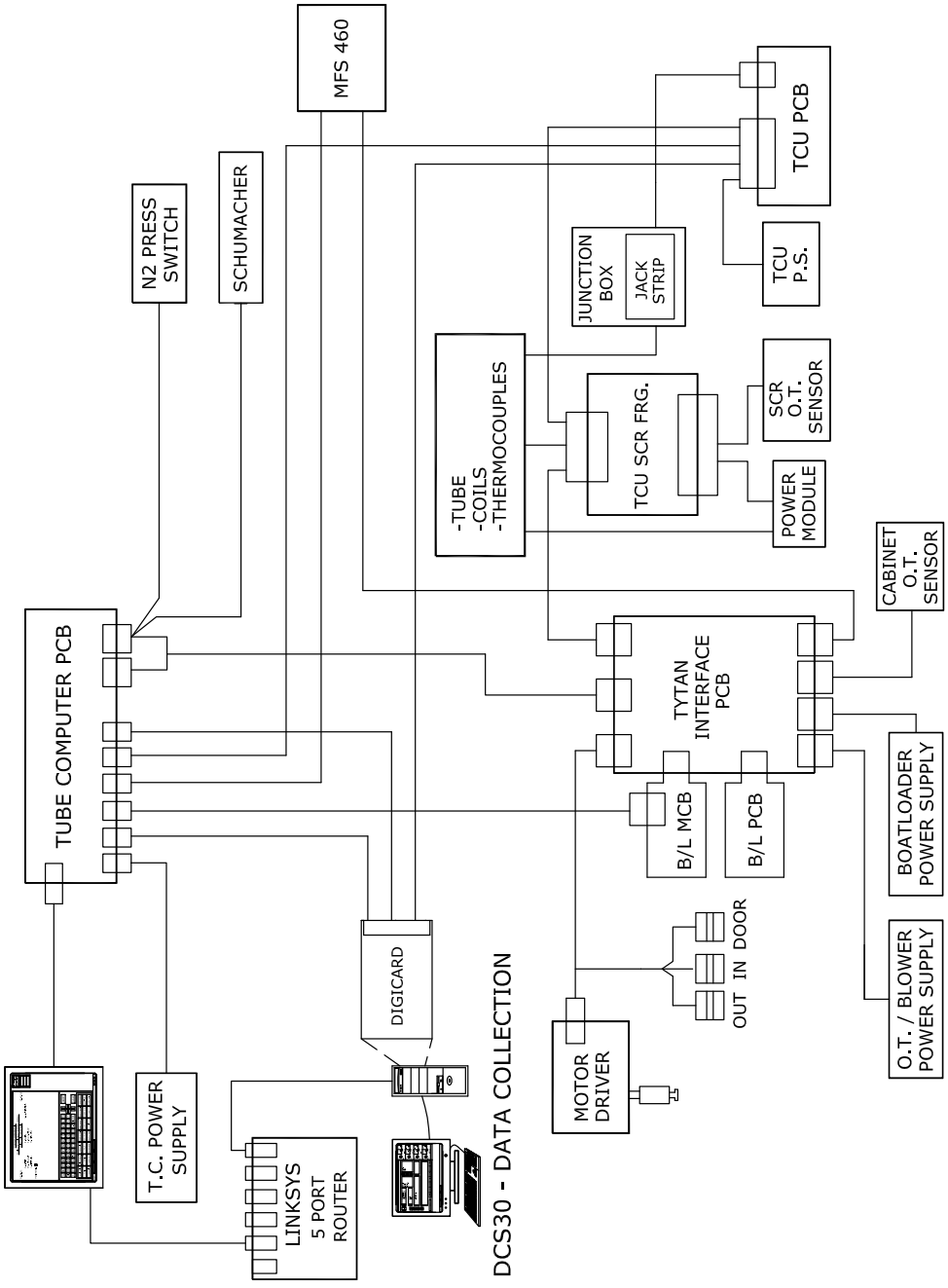

Figure 5.1: A block diagram of the TYTAN controller system. Only one tube computer is shown here for the purpose of architectural illustration. In actuality, the system includes more tube computers networked in parallel.

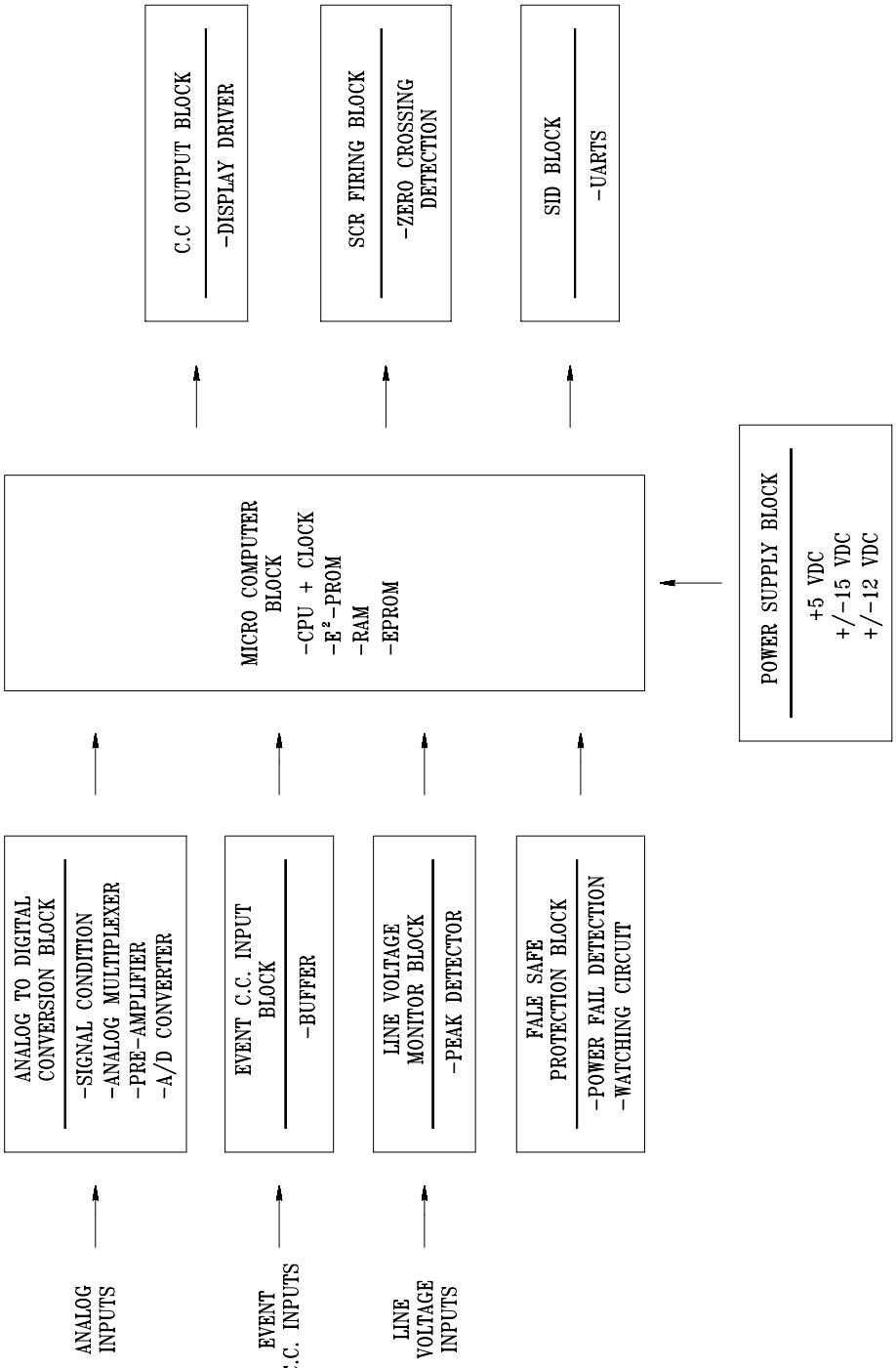

Figure 5.2: A block diagram of the TCU control logic hardware.

Chapter 6

SYSTEM SECURITY & PERSONNEL SAFETY

Tystar engineering design team took a great care in accommodating security and operator safety in all aspects. All TYTAN systems are fool-proof ensuring maximum security and safety. A variety of sensors are implemented in the design to protect the system and the operator in case of any unexpected component failure. As all tubes are operated and controlled independently, failure of any single tube will not lead to a shutdown of the entire system until a process cycle is complete. Error messages are displayed on each touch screen. The operator is also allowed to preprogram desired responses to a component failure if it is necessary to modify the standard set of responses. With minimal training, the operator can easily reconfigure the responses right on the touch screen.

Chapter 7

CUSTOMER SUPPORT

7.1 Warranties

The system comes with one year warranty on parts and labor. The customer may purchase an extended warranty service at an additional cost.

7.2 Training

Customer training is provided in 3 areas:

- System operation
- Process
- Maintenance

The standard training program includes 5 days of lectures and demonstrations at Tystar on a mutually agreed to schedule. For any variation to the standard training program, the customer may contact Tystar's Sales Department (sales@tystar.com) or call us at +1 (310) 781-9219.

7.3 Remote Access Service

Tystar offers an option of a fully developed remote service feature. In case of a system malfunction, Tystar engineers can remotely inspect, diagnose the system, and fix the problem. The engineers can visually inspect the

trouble spot on their monitor with the assistance from the user. They can also run the system remotely from their computers just as if they were doing it right from the system computers. One of the big advantages this feature offers is that response to a service call is immediate.

Chapter 8

REQUIRED UTILITIES

For safe and stable operation of the system, the following facilities are required:

- Electrical power supply:
  - power input: All standard line voltages, 3 phase, 50 or 60 Hz
  - control power: 5 kVA
  - maximum power per tube (w/o vacuum pump): 13 kVA
  - maximum system power (w/o vacuum pump): 18 kVA
- Process gas pressure: 20 to 40 psi (or 1.4 to 2.8 bar)
- Aux. N_2/CDA: 80 to 100 psi (or 5.5 to 6.9 bar)
- Exhaust system
  - scavenger exhaust: 250 CFM (7,000 LPM)
  - source cabinet exhaust: 250 CFM (7,000 LPM)
- cooling water: 2 to 4 GPM (7 to 14 LPM) at 15 to 20 °C

Appendix A

TYSTAR GUARANTEED PROCESS SPECIFICATIONS

Notes on Tystar Process Guaranty:

1. **Confidentiality:** The contents and data presented in this document and attachments are provided solely for intended recipients and may contain confidential or privileged information. Disclosure, duplication, use, or distribution of any portion of this report and attachments is strictly prohibited.

2. **Disclaimer:** Tystar Corporation is not responsible for any loss, injury, disruption or damage that may result from using data contained herein.

3. **Reference Wafer Size (200 mm):** For smaller wafers, better or comparable uniformity may be achieved.

4. **Definition of Non-uniformity:** One σ standard deviation from the average value.

5. **Wafer load:**
   - 50 wafers in 18" LPCVD flat zone
   - 100 wafers in 34" LPCVD flat zone
   - 100 wafers in 18" AP flat zone
   - 200 wafers in 34" AP flat zone

6. **Variability:** Each data presented in the attached sheet is only guaranteed for a process demonstration to be performed under a certain reference process condition. The actual data may vary depending on the choice of customer's process condition.

7. **Resistivity Data:** Unless specifically mentioned, the non-uniformity refers to thickness non-uniformity. For $POCl_3$ and Doped Poly, the non-uniformity refers to resistivity non-uniformity.

8. **Best Process Guaranty:** Tystar has an extensive library of process data and offers the best process guaranty. No comparisons should be made of Tystar data to others' data without careful regards to specific process conditions because Tystar's superior furnace design is much different than others in terms of temperature control, pressure control and gas flows.

Table A.1: Tystar Standard Process Verification

PROCESS	TEMP ° C	THICKNESS nm	RESISTANCE Ω/□	NON-UNIFORMITY in wafer	NON-UNIFORMITY W to W	NON-UNIFORMITY R to R
ATMOSPHERIC						
pyro oxidation	1,000	500	N/A	2%	2%	2%
		< 50	N/A	4%	4%	4%
dry oxidation	1,100	500	N/A	2%	2%	2%
		< 50	N/A	4%	4%	4%
$POCl_3$	950	N/A	10	10%	10%	10%
BBr_3	950	N/A	10	10%	10%	10%
LPCVD						
Si_3N_4	790	150	N/A	3%	3%	3%
LSN	840	150	N/A	3%	5%	3%
polysilicon	620	300	N/A	3%	3%	3%
flat poly	620	300	N/A	3%	10%	3%
doped poly	620	300	N/A	5%	10%	5%
LTO	450	450	N/A	5%	5%	5%
DLTO	450	450	N/A	5%	10%	5%
BPSG	450	450	N/A	5%	10%	5%
TEOS	725	450	N/A	5%	5%	5%
HTO	725	450	N/A	5%	5%	5%
SiC	800	300	N/A	5%	5%	5%
SiGe	725	450	N/A	5%	5%	5%

Appendix B

33 REASONS TO PICK TYSTAR

1. **Layout Flexibility:** Tystar furnace layouts can be configured specifically to fit into a customer's clean room floor plan.

2. **Autonomous Control of Tubes:** Each individual tube has its own control computer which can run autonomously without affecting other tubes in case of computer failure.

3. **Auto/Manual Switching:** Gas, boat loader, and temperature controls can run in the manual mode should there be a failure of the tube computer.

4. **Isothermal Chamber:** Our patented isothermal chamber design results in outstanding process control which guarantees superior uniformities and low operation costs.

5. **Multiple Recipe Loading:** The tube computer can accommodate multiple recipes so no downloading is required when changing recipes.

6. **Battery Backup:** Each tube computer has a battery backup to retain the configurations and recipes for 30 days and no downloading is required when a power failure occurs

7. **Multi-Step Abort Sequence:** A multi-step abort sequence is utilized to protect the product and equipment in case the process cannot salvaged.

8. **Auto/Manual Display** & **Control:** In the event all computer controls fail, it is still possible to monitor and control the gas panel in the manual mode.

9. **PID Closed Loop Pressure Control:** Tystar's MFS-460 gas controllers do not require external set points for closed loop pressure control.

10. **Local TCU Control/Diagnostics:** In the event all computer controls fail, the temperature controller runs in the manual mode.

11. **Flat Temperature Ramping:** An algorithm is built into the TCU logic for synchronizing each temperature zone.

12. **Recipe Guarantee:** Tystar offers starter recipes for every process utilizing its extensive library of process recipes with guaranteed process verification.

13. **Small footprint:** Tystar's patented isothermal design creates the smallest footprint furnaces, which utilize lessclean room space.

14. **High Efficiencies:** Tystar's patented isothermal design creates low gas and electricity usage.

15. **Maintenance Friendly:** All Tystar furnaces are designed for easy access to all parts for ease of maintenance. We designed easily removable back panels for hard-to-reach parts. Electronic and electrical components are placed in sliding drawers, along with a slide-out interface plate. All other components are very easily accessed.

16. **Adaptable Quartz Boat Design:** The TYTAN furnace systems can accept all wafer sizes from chips to 8" wafers and still maintain excellent uniformity by just changing the wafer boat. No equipment changes are necessary.

17. **Rigorously Tested Parts:** All parts used on TYTAN furnace systems are name brand and certifiable. They have been rigorously tested over an extended period of time.

18. **Proven Supplier Record:** Tystar has a large worldwide installation base with over 1700 tubes installed. We can supply excellent customer references.

19. **Strong Customer Network:** Tystar's customer network is comprised of prestigious universities, laboratories and corporations, including a National Institute of Standards and Technology, Harvard University, Jet Propulsion Lab, Communication Research of Canada, National Research Council of Canada (NINT), University of Alberta, UC Berkeley, Georgia Tech., Stanford University, University of Texas, Dallas and Arlington, UCLA, USC, UCSB, Princeton University and many more.

20. **Rapid Response:** (24 Hour) Tystar will respond to any service or support request within 24 business hours.

21. **Lifetime Support:** Complete process and technical support for the entire lifetime of the equipment.

22. **Dedicated Team:** Tystar's primary engineers have worked together for over 25 years.

23. **Top-Rated Performance:** Tystar has affordable pricing for top-rated equipment performance and technical support.

24. **Support on Peripherals :** Other vendor clean room fab peripherals can be purchased through Tystar.

25. **SCE II Protocol:** Each control component has Semiconductor SECS II protocol embedded in the software.

26. **Multiple Safety Features:** Examples include a door must be closed to continue processing, gas flows must be accurate and mixed properly, proper pressure must be present before processing and many more. Customer designed safety features can be included.

27. **Dual T/C:** Temperature is controlled by a profile T/C, using spike T/Cs as backup and power measurements as tertiary backup so no wafer load is lost due to T/C failure.

28. **Power On Diagnostics:** Each process tube has extensive Power On diagnostics.

29. **Remote Access Diagnostics:** Available for quick analysis and rectification from Tystar's facility.

30. **Clean Exhaust:** A unique proprietary exhaust system for Silicon Nitride has been developed, with the help of UC Berkeley, to lower maintenance and prevent hazing on wafers.

31. **Built In Door Torque Down Logic:** Tystar's boat loader has a built in torque down routine which assures a good, tight door seal.

32. **Low Particle Generation:** Tystar furnaces are designed for low particle generation

33. **Dedicated Engineering Support Team:** Tystar's engineering team has a proven record of excellence in furnace design.

Appendix C

Standard Wafer Dimensions and Weights

Table C.1: Silicon Wafer Size-Dimensions-Weight

Diameter	**Nominal Thickness**	**Wafer Area**	**Wafer Weight**	**Weight-200 wafers**
in./mm	mil/mm	cm^2	Grams	kgs/lbs
3"/75	15/0.381	45.6	4.17	.834/1.86
4"/100	21/0.525	78.54	11.78	2.356/5.19
5"/125	25/0.625	122.7	18.4	3.68/8.11
6"/150	26.6/0.675	176.7	28.6	5.72/12.61
8"/200	0.725	314.2	54.3	10.86/23.95
10"/250	0.725	490.9	114.3	22.86/50.41
12"/300	0.775	706.86	127.53	25.506/56.24