SiGe MBE System

A Leader in the Innovation, Design and Production of MBE Technology

SVT MBE

Engines for Thin Film Innovation

SiGe GS4 MBE System

SVT Associates has been innovating Molecular Beam Epitaxy (MBE) technology for more than 18 years. SVT Associates' Model GS4 series of molecular beam epitaxial (MBE) systems has been specifically designed to satisfy the requirements of high quality MBE growth of silicon/germanium and related compounds. It combines electron-beam (EB) and effusion cell evaporation for epitaxial and doping deposition, and uses sensor feedback control to achieve highly reproducible thin film fabrication. The flexibility of the system configuration, and control of variables ensures the system will be used for a wide variety of application and development purposes. The Model GS4 is configured for 4" size samples (upgradable to 6"). It also contains a multi-ported buffer/transfer module so samples can freely be moved between this chamber and other modules.

Model GS4 incorporates a multiple-chamber design concept which includes a Substrate Introduction Module, Prep/Transfer Module, and a main growth chamber. Each module has its own independent UHV pumping system and each chamber may be isolated from the others via gate valves. This arrangement makes it possible to perform various system functions: substrate loading, sample treatment, film growth, and sample analysis independently and concurrently.

SVT Associates commitment to quality begins with supplying you, our customer the most technological advanced MBE instrumentation available backed by our experienced laboratory and engineering staff. Our delivered performance is met by stringent manufacturing standards, continued research and equipment development as well as comprehensive quality controls. SVT Associates' expert team of engineers provide world-class customer support to keep instrumentation performing at optimum levels and to help customers with system operation and maintenance issues.

Sample Introduction Load Lock

The wafer introduction chamber has a rapid access entry port for quick wafer cassette loading/unloading. A small turbopump pumps the chamber to $1x10^{-7}$ Torr in 30 minutes before the wafers are transferred to the preparation chamber which is separated by a pneumatically operated isolation gate valve. The result of this arrangement is the transfer rod is never exposed to the atmosphere. Other unique features of this module are: the wafer cassette may be outgassed to 200 ºC in this chamber to drive off adsorbed moisture, and a single wafer may be loaded onto or unloaded from the cassette without exposing the rest of the wafers in the cassette to air.

Preparation Chamber

The substrate preparation module has the capabilities of sample cassette parking, cleaning, and sample transfer into other modules. The entire cassette is lowered into this chamber from the introduction module; the two modules are then isolated from one another to allow the preparation module to be under true UHV conditions at all times. Wafers are picked off from the cassette individually and transferred onto the preparation stage for heating or sputter clean, or into the growth or analysis module; the transfer mechanism is operated by magnetic actuation. This is separated from other chambers by gate valves.

Growth Module

The growth chamber is designed specifically for SiGe MBE deposition. It is a double wall, water cooled, self-contained vacuum system large enough to handle up to 6" (150 mm) wafers. The pumping of the module is provided by a combination of closed loop liquid helium cryopump (2,000 l/s), an ion pump (400 l/s) and a titanium sublimation pump with its own liquid nitrogen panel. The cryopump and the ion pump may be individually isolated from the growth chamber by gate valves. An optional main liquid nitrogen shroud is available to provide additional pumping if desired.

Wafer Manipulator

The sample manipulator is designed to handle up to 6" wafers. There are two options for the manipulator. They both have self standing heating elements capable of 1000 ºC (1,200 ºC peak) temperature heating, electrical bias of > 2000 V and sample rotation of 60 rpm. The standard manipulator is mounted vertically from the top flange with a vertical travel so the distance between the source and the wafer may be varied.

Wafer heating is achieved with an efficient surface passivated graphite heater element which is machined to produce very uniform heating. There is no metal or insulator parts in direct contact with the heater element. Stable temperature of the substrate is maintained by feedback control using either a thermocouple or an optical pyrometer. Inside the manipulator there is provision for placing a thermocouple junction in physical contact with the back of the wafer or the wafer block to obtain a measure of its temperature. Wafer temperature may also be measured by using an optical pyrometer method through the viewport window. Figure 2 shows a plot of temperature profile measured by a thermocouple and an optical pyrometer. The correlation is extremely satisfactory over the range covered.

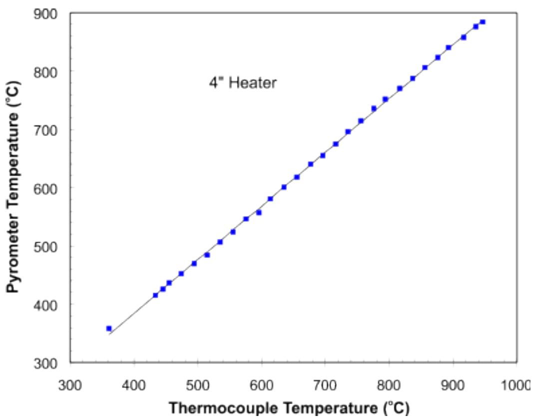

Figure 2 Pyrometer vs Thermocouple Temperatures of a 4" Silicon Wafer

E-B Source Configuration

The growth chamber is designed to accommodate multiple electron beam evaporators. The standard configuration consists of two 40 cc and one 150 cc Electron Beams. A 4 x 15 cc hearth multi-pocket EB source may substitute for the latter if desired; other combinations are possible. Each EB source is equipped with cryoshroud and shutter, and the deposition rates are controlled by feedback from the Inficon Guardian Sensors.

Figure 3a is a plot of the deposition distribution calculated for stationary and rotating substrate, respectively. Superimposed on the line which represents stationary substrate are actual data points; the measured is displayed in (c) and represents excellent agreement with the calculation. The positions of the sensors allow them to measure the fluxes form the sources at all times, even when the shutters are closed.

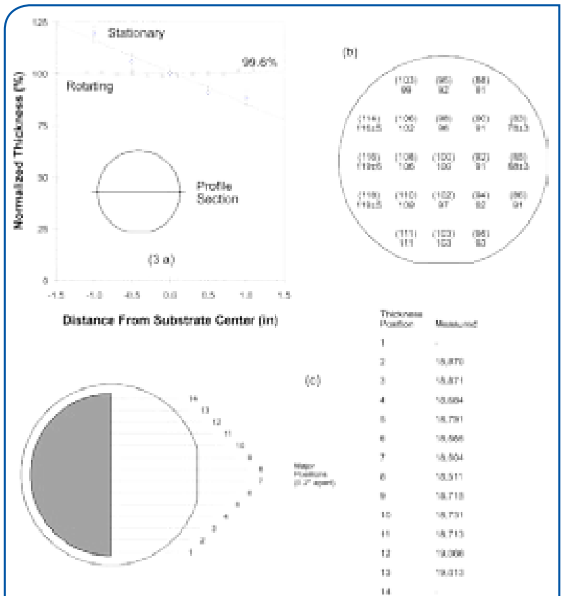

Figure 3a Wafer Deposition Uniformity

System Bakeout

System bakeout is a common technique in vacuum technology to achieve the base pressure more rapidly. In our design the bakeout is achieved by radiant heating elements placed around the system. During outgassing the system and the heating elements are enclosed inside tightly fitted insulating jackets, made to fit the chamber loosely to allow good air circulation. These jackets are made of soft, clean room compatible insulating fabrics and can be conveniently folded and stored after use. During bakeout the electrical connections to the sample heater and the effusion cells can be left on so these parts may be outgassed at higher temperatures. After the system bakeout is completed the base pressure should reach $<1x10^{-10}$ Torr.

System Performance

Several MBE systems of this design have been installed successfully and are actively being used in the field. They have been employed to carry out a variety of material research and device fabrication work. The system performance and material quality are briefly described below.

Material Quality

Excellent material quality has been demonstrated in terms of the crystallinity, material purity and doping control. Because of good base pressure and low residual hydrocarbon attained in the system, very high quality materials may be obtained at even relatively low growth temperatures. This may be best illustrated using results *(provided by Dr. R. J. Hauenstein, Hughes Research Laboratories)* which shows by combining several analytical techniques one can put together a composite picture of the layer properties. In Figure 4 the sample structure is shown, and the Auger profiling result is presented. By using Zolar rotation during sampling, good depth resolution was obtained for both the Si and Ge peaks; thickness of the individual layers could be calculated from the sputtering time. The cross section of the sample was examined by TEM and constant layer spacing, sharp interface and low defect density were demonstrated. High crystalline quality of the sample is indicated by the narrow line width in the high resolution x-ray diffraction measurement, where as many as 13 side peaks are resolved, indicating high lattice perfection. Comparing the line spacing with the simulation, both the superlattice period and the average bilayer strain have been accurately measured. It should be noted that the actual period thickness compares well with the design parameter.

Doping Control

It is possible to carry out co-evaporation and low energy ion implantation doping. Up to four effusion cells may be operated for doping purposes. Since the wafer can be electrically biased, certain dopant (e.g. Sb) incorporation may be significantly aided by the potentially enhanced doping or doping by secondary implantation (PED or DSI) technique.

There are two kinds of effusion cells available. The standard cells that can be operated to 1300 ºC, a temperature adequate for most dopant materials.

Process Automation

A modern MBE system is so complex that some degree of control automation is mandatory. Using the computer one can ensure run-to-run reproducibility by constantly monitoring and adjusting the various growth parameters. The microprocessor also takes over the repetitive tasks of ramping and maintaining the temperature profiles of the substrate and source ovens, sequencing and operating the shutters, and updating the growth progress. For example, the temperature stability may be maintained to within 0.2 ºC. Equally important is the fact that it may be programmed to serve as a sentry so when any of the vital signs of the system becomes out-of-order, a shutdown protocol could be immediately executed to protect the system and the operator. A PC is used for user interface where one may enter the operating parameters and growth sequence. The PC then interacts with a microprocessor unit that carries out the actual control function, from the bakeout procedure to flux control. An operating software package has the flexibility of allowing easy recipe entry of a complex structure and real time adjustment of the growth parameters. There is a data logging sub system that keeps status information and places data into file for later analysis.

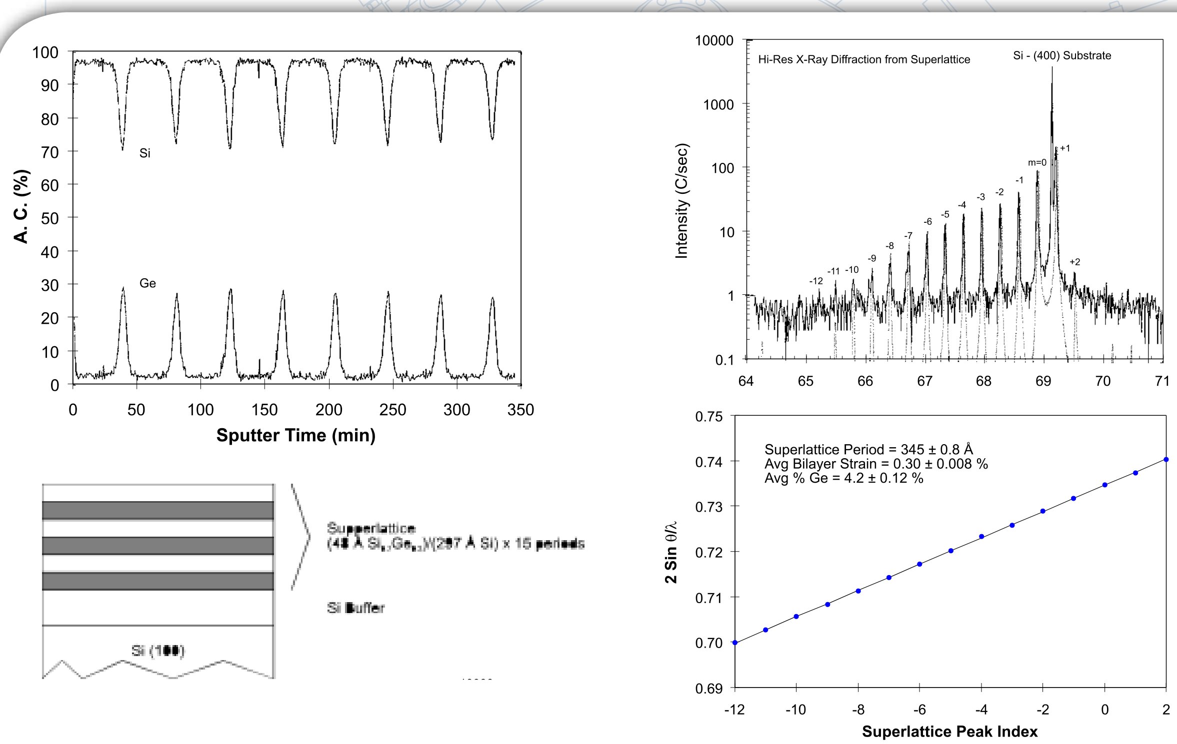

Figure 4 Structural Analysis of A Superlattice

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