

The Use of the Series 959 Hot Ion Gauge Controller with Continuous I²R Degas for CIGS PV Processing

PROBLEM

Over the past 15-20 years manufacturers of photovoltaic (PV) devices have advanced from conventional crystalline solar cells to second generation “thin film” devices. The photoactive materials in these new devices are compound semiconductors such as CdTe, CuInSe₂ or CuInGaSe₂ (“CIGS”). CIGS-based PV devices are interesting since they have high efficiencies and can be used on flexible substrates. This opens up a vast array of applications for PV power sources.

A critical processing problem exists that can threaten the repeatability of CIGS PVD deposition and consequently the ability to successfully manufacture commercial devices. The problem arises from the following factors: The elemental constituents of the CIGS film are all deposited by PVD processes such as evaporation or sputtering. These processes require high vacuum ($\sim 10^{-6}$ Torr base pressure) and the use of Bayard-Alpert (B-A) ion gauges (Figure 1a and Figure 1b) for vacuum measurement rather than the conventional capacitance manometers or resistance gauges commonly found in higher pressure deposition processes.

The gauge functions as follows. It has three electrodes: the cathode or filament, the collector and the anode grid. Energetic electrons emitted from the cathode (biased at about 30 Vdc) are accelerated towards the anode grid (typically 180 Vdc) colliding with and ionizing molecules present in the gas phase. The positive ions that are created in the collisions are accelerated towards the collector (0 Vdc) located along the axis

of the anode grid producing an ion current that is measured by the gauge electrometer. The ion current is proportional to the ion density in the gas phase and is an indirect measurement of the pressure in the system. There are well-defined mathematical relationships for determining the system pressure from B-A measurements.

Traditional B-A gauges suffer from repeatability problems in CIGS deposition processes. In this process, the different metals are deposited sequentially. The copper, indium and gallium targets used in the PVD deposition processes have relatively low vapor pressures and there is “line-of-sight” transport of the depositing species from target to substrate. This means that it is easy to position the B-A gauge so that no deposition occurs on any of the gauge components. However, when the selenium phase is deposited a problem occurs that affects the gauge performance. Selenium has a high vapor pressure in the PVD system (Figure 2) producing greater gas phase diffusion of the selenium. This creates high gas phase selenium concentrations near the B-A electrode surfaces and elemental selenium deposits on the cold grid and collector. These deposits degrade the accuracy and repeatability of the B-A gauge since they affect the electric field characteristics and thus the electron path within the gauge. When this happens, the complex relationship between emission voltage and ion current no longer holds. Figure 3 shows the manner in which the gauge accuracy degrades as a selenium coating gradually builds up on the cold electrodes within the B-A gauge.

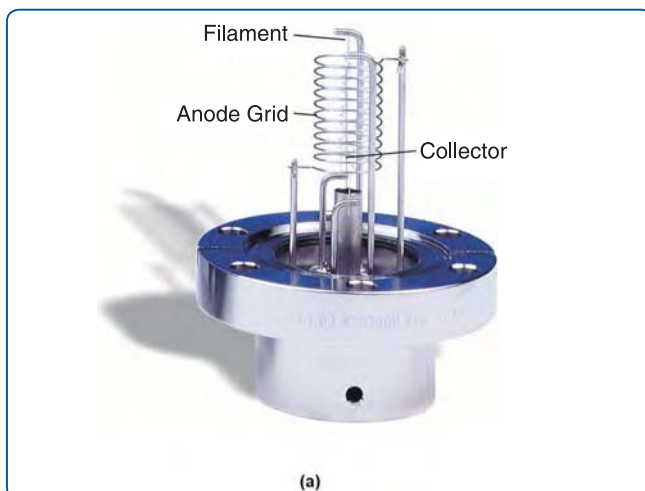


Figure 1a - Typical Bayard-Alpert Hot Ionization Gauge showing the different gauge components.

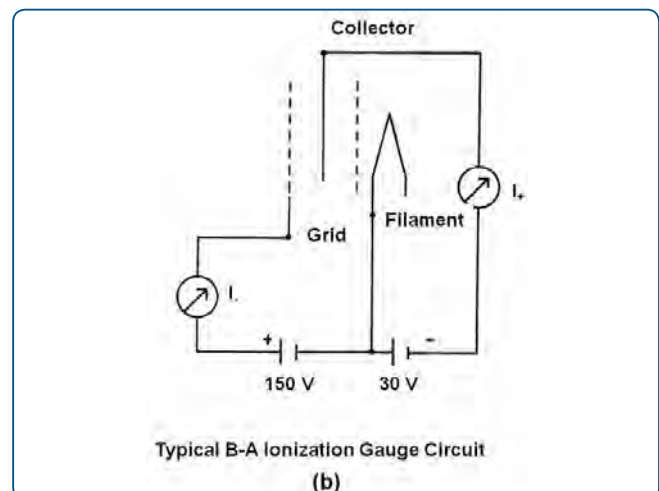


Figure 1b - Typical Bayard-Alpert Hot Ionization Gauge showing the gauge circuit.

PROBLEM (CONT.)

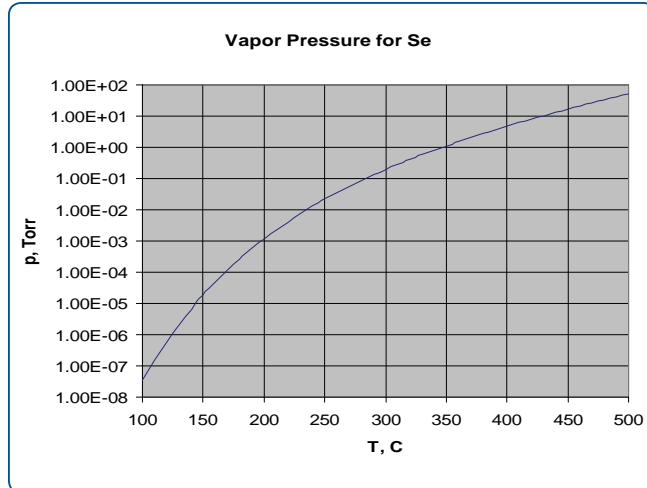


Figure 2 - The vapor pressure of selenium vs. temperature.

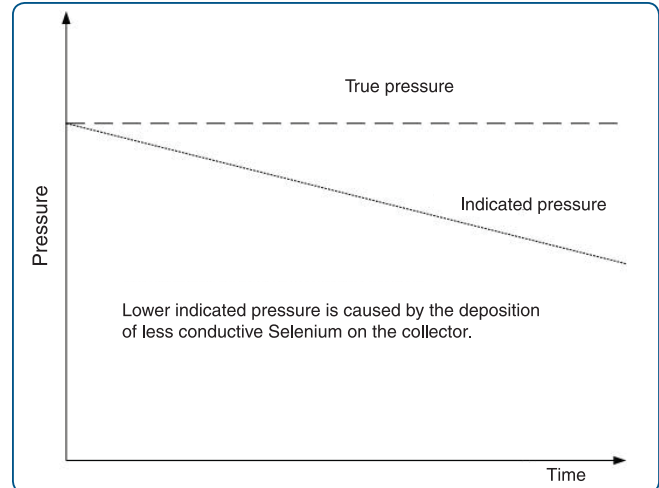


Figure 3 - The variation of pressure reading over time as selenium deposits build up on B-A gauge components.

SOLUTION

Heating the grid and collector electrode during B-A gauge operation can solve this problem by preventing the condensation of Se (filament temperatures during operation are high enough to avoid Se condensation). A temperature of about 200°C on the surfaces of the collector and grid is sufficient to eliminate the deposition of selenium at CIGS processing pressures of less than 1 Torr. Simply keeping the normal E-Beam degas on during operation will not work to keep the grid and collector hot. E-beam degas operates the gauge with the collector and grid biased at, typically, 500 Vdc and the filament at 30 Vdc for about 10-20 minutes and the increased emission current causes increased production of photoelectrically induced electrons from the collector. This “X-ray induced” current cannot be distinguished from the current that arises due to the gas pressure within the system, and thus it produces erroneous pressure readings.

A better solution is provided by the MKS Series 959 Hot Cathode Ion Gauge and Controller System (Figure 4).

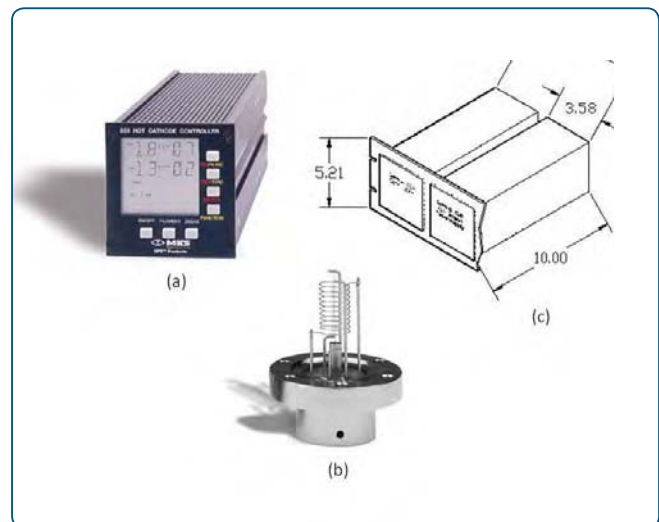


Figure 4 - System components of the Series 959 Hot Cathode Ion Gauge and Controller: (a) controller; (b) nude ion gauge with dual tungsten filaments; (c) controller with P/R external power supply showing rack mount configuration and dimensions.

SOLUTION (CONT.)

In this system a continuous, low power I²R degas heats the grid and ion collector. With I²R, the gauge potentials, such as grid to filament for electron acceleration, are at standard values, not at increased levels which might affect calibration. The easily controlled and relatively moderate heating supplied by I²R is sufficient to prevent Se condensation. Figure 5a and Figure 5b show images of the sensor under the different degas modes.

The system consists of an MKS HPS[®] Low Power Nude Tube ion gauge and the MKS 959 Hot Cathode Controller with an added power supply that allows for continuous I²R degas of the anode grid and collector while the controller is in operation and reading pressure. A special cable connects both the power supply and the controller to the sensor. The added

power supply is mounted outside of the existing 959 housing and the entire assembly occupies one half of a 19" rack, with a height of 5.21" and an overall length not exceeding 10".

Degas is controlled by the 959's set point relay and is turned on and off with the filament. The front panel of the power supply has a switch for local degas control. During operation, degas is on whenever the filament is on.

Production comparisons of the I²R system with conventional B-A gauge/controller configurations showed that, while conventional hot cathode gauge sensors had lifetimes of less than 2 weeks in CIGS service, the MKS Hot Ion Gauge System with I²R continuous degas had lifetimes between 4 and 6 months.



Figure 5a - MKS CIGS Ion Gauge Sensor showing sensor with filament on and degas mode on.

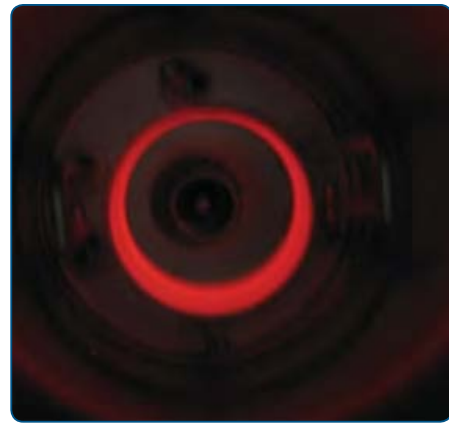


Figure 5b - MKS CIGS Ion Gauge Sensor showing sensor with filament off and degas mode on, showing elevated temperature of the grid (as evidenced by the thermal glow).

CONCLUSION

The deposition of selenium on cold surfaces within Bayard-Alpert Ion Gauges during the CIGS PVD processing degrades the repeatability of the deposition step and therefore the reliability of the PV device production process. This problem is solved by mild heating of the grid and collector electrode surfaces. The MKS Series 959 Hot Ion Gauge System with I²R

heating prevents the deposition of selenium on the ion gauge's cold electrodes during CIGS processing without degrading the accuracy of the B-A gauge, enabling better consistency. With a component lifetime 10x greater than conventional gauge sensors, this robust loadlock solution provides increased uptime, reduced operating costs and improved process control.

For further information, call your local MKS Sales Engineer or contact the MKS Applications Engineering Group at 800.227.8766 (US only) or 978.645.5500. HPS[®] is a registered trademark of MKS Instruments, Inc., Andover, MA.