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Product Note

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The Titan Effusion Cell: The Latest in Group III Cell Design from E-Science

Abstract

The Titan effusion cell has been developed by E-Science to give MBE growers added performance by providing lower defect counts, improved uniformity, high capacity, reduced shutter transients, and a shorter source conditioning time. This sealed two-piece graphite crucible design provides distinct advantages over one or two piece PBN versions. Operation and maintenance of the cell and crucible is appealing with the ability to run on one filament, accept a single piece of charge material, and operate over multiple campaigns. The Titan cell and crucible set offer superior performance over others available on the market today.

Source Design

Over the years, crucibles used for Group-III materials have undergone a number of changes. These changes proved necessary to keep up with the increasing demand for large area, high quality, uniform epilayers.

The earliest crucibles were straight walled, providing high capacity but lacking the ability to uniformly distribute the flux. In an attempt to improve uniformity, tapered conical crucibles were developed to better distribute the flux across the substrate. The improvements in uniformity, however, came at a cost of substantially reduced capacity and increased depletion transients.

Working to combine the qualities of both designs, two piece crucibles emerged that utilized a straight walled crucible with a tapered insert that fit loosely into the top of the crucible. The insert solution worked as intended, providing a broad taper to distribute the flux as it left the crucible. However, problems still remained.

Because the insert extended into the crucible, it was thermally shielded from the heating filaments. This allowed a greater accumulation of source material on the inner surface of the insert which resulted in a reported increase in epilayer defect levels over single piece crucibles. Furthermore, the insert design permitted source material to condense between the insert and the crucible preventing the separation and reuse of the two pieces in many cases.

The E-Science Titan crucible design addresses many of the issues encountered when using an insert. The Titan two piece design consists of a cylindrical reservoir threaded tightly to a conical nozzle that extends out towards the substrate. Because the nozzle extends away from the crucible, all crucible surfaces have line of sight exposure to the heating filament.

Fig. 1. The E-Science Titan effusion cell incorporates a two-piece graphite crucible that provides lower defect counts, improved uniformity, high capacity, reduced shutter transients, and a shorter conditioning time.

The Titan crucible is graphite based and has excellent thermal properties, including isotropic thermal conductivity and efficient radiative coupling to the heating filament. These properties enable the realization of strong temperature gradients that are desired in many applications.

Additional heat-shielding is added over the front surface of the effusion cell and crucible to reduce the thermal load on the growth chamber and to minimize the thermal transient when the effusion cell shutter is opened.

The nozzle on the Titan crucible is threaded to the bottom reservoir and is easily removable. Removing the nozzle opens the bottom reservoir completely, allowing users to load a single piece charge material. This reduces the handling required to fill a crucible and minimizes the amount of surface area of the charge that is exposed to the atmosphere.

The nozzle portion of the crucible is tailored to the unique geometry of each MBE system. E-Science uses proprietary models to determine the shape of the nozzle to optimize layer uniformity and material consumption rates, has a library of nozzle designs for many of the standard MBE reactors, and can custom design nozzles for most reactors.

Titan crucibles have been successfully operated with both single and dual filament effusion cells. The dual filament offers the highest performance and flexibility whereas the single filament is the most efficient to operate since it requires only one power supply and controller. E-Science engineers can work with you to determine which type of cell will be best suited for your requirements and budget.

A key component of achieving high performance from the Titan crucible is the manufacturing and conditioning process. We have developed a proprietary coating process that helps stabilize the crucible materials. A special conditioning process further stabilizes the crucible to the point where no outgassing is observed during normal operation of the cell. Furthermore, the effects of this process are not susceptible to wear or abrasions while in use.

The lifetime of the cell and crucible have been excellent, capable of running through multiple campaigns. Arizona State University has been operating the same crucible for over three years and has seen no degradation of performance. The only maintenance necessary between campaigns is to simply wipe out any remaining material and outgas prior to reloading source material.

There are cost savings when replacing the crucible. For example, in the event that the top part of the crucible set is damaged, only the nozzle has to be replaced or if the crucible is fractured during solidification of the source material, only the reservoir has to be replaced.

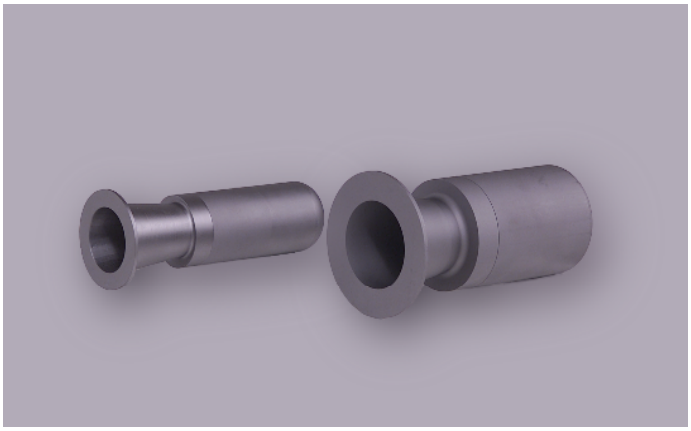

Fig. 2. Two Titan crucibles are shown; one for a VG V80 reactor on the left and one for a Riber Epineat reactor on the right. The two–piece crucible design consists of a material reservoir and a distribution nozzle. The design of the nozzle is determined by the geometry of the growth chamber.

Shutter Transients

In the closed position, the shutter used to block the source flux also acts as a radiation shield that reduces the amount of thermal radiation lost from the open end of the effusion cell. When the shutter is opened, additional radiation escapes and the heater control circuit increases the input power to maintain the source temperature. This unavoidably leads to fluctuations in the source temperature as the system comes to a new equilibrium. The resulting flux transients are commonly called shutter transients. The Titan cell is designed to reduce shutter transients by minimizing thermal fluctuations during shutter operations. Flux measurements done at OSEMI, Inc. confirm the performance advantage of the Titan cell over a conventional cell with a PBN crucible. The flux variation owing to shutter transients was reduced and almost non-existent in the Titan cell.

Uniformity

Uniformity is critical for many applications, for example, the emission wavelength of vertical cavity surface emitting lasers is very sensitive to layer thickness. A radial map of epilayer thickness uniformity across a 3 inch wafer grown at Lytek Corp. using a 215 cc Titan effusion cell is shown in Fig. 3. The conical nozzle portion of the crucible was designed for the geometry of the Riber Epineat system that this wafer was grown in. A proprietary flux model was used to determine the proper angles and length of the nozzle. The uniformity achieved is remarkable, which shows a less than ± 0.1% variation over the entire wafer. The uniformity was determined by measuring the spectral shift in the mode of a resonance cavity structure (shown on the right-hand y-axis); which is proportional to the variation in layer thickness (shown on the left-hand y-axis).

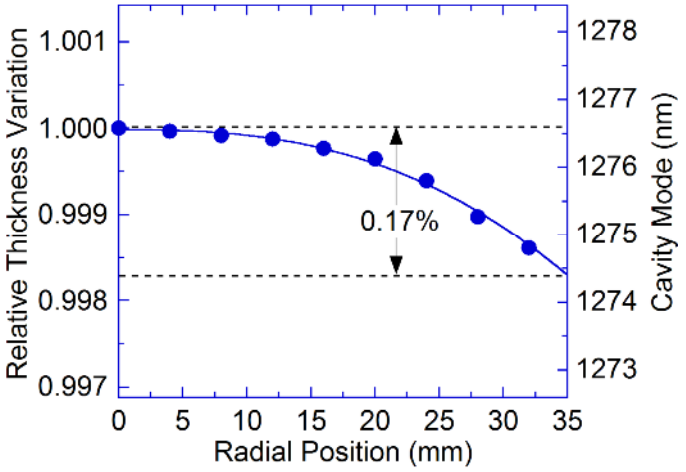

Fig. 3. Radial map of the epilayer thickness uniformity across a 3 inch wafer grown in an Riber Epineat MBE system using a 215 cc Titan effusion cell.

Defect Density

Epilayer defect densities have been linked to the condensation of Ga or In droplets on the lip of the crucible. Maintaining a high temperature gradient from the lip to the base of the crucible is one way to minimize these defects. The 1 - 2 µm sized defect levels observed at OSEMI, Inc. were about 8/cm^2 using the Titan effusion cell; a factor of five lower than the defects previously observed using PBN crucibles. The accumulation of large Ga droplets near the crucible lip decreased to zero when Arizona State University switched from PBN to the Titan crucibles. These results indicate that larger thermal gradients are achieved as a result of the improved thermal properties of the Titan crucible.

Background Doping

Though the crucible has a graphite base material, there is no evidence of unintentional carbon doping in films grown with the Titan cell. In comparing two 20 µm thick GaAs samples grown at OSEMI, Inc., the measured background doping levels for growths using the Titan cell were the same as those for a PBN crucible. Fig. 4 shows SIMS measurements of the Si, O, and C concentrations in a 2.9 µm thick GaAs layer grown using the Titan effusion cell at Trion Technology. The O and C values shown are at the SIMS detection limit of 15 x 10^{15} cm^{-3} for O and 5 x 10^{15} cm^{-3} for C, except for the Si doped region where there is a small increase in the C level that originates from the Si cell at the highest Si doping levels. The left-hand peak is due to surface contamination that occurs after growth and the peak at 2.9 µm is the substrate/epilayer interface.

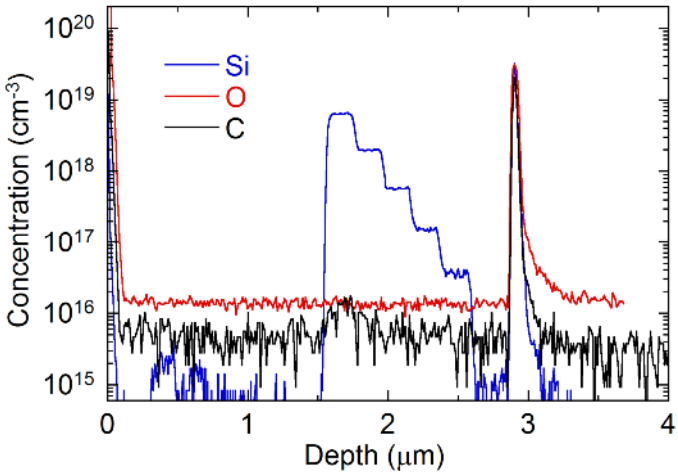

Fig. 4. SIMS measurements of the background O and C concentrations in Si doped GaAs grown using the Titan effusion cell. The O and C levels shown in the film are at the SIMS detection limit.

Summary

The Titan Effusion Cell has been shown to provide superior performance in uniformity, defect levels, and shutter related flux transients. The ability to load a single piece charge greatly simplifies loading.

Acknowledgements

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Veeco				
GenII /III Systems	**Gen 20**	**Gen 200**	**Gen2000**	
EC-125-450-1140-T	EC-125-450-1250-T	EC-200-600-1250-T	EC-700-800-1250-T	
Riber				
32P	**Compact 21**	**Epineat**	**Riber 49**	**Riber 6000/7000**
EC-035-275-1116-T	EC-125-450-1250-T	EC-125-450-1250-T	EC-700-600-150-T	EC-700-800-130-T
VG/ Oxford				
V80	**V90**	**V100**	**V150**	
EC-085-450-1285-T-L	EC-150-450-1150-T-L	EC-200-600-1150-T-L	EC-700-800-1890-T-L	

E-Science offers Titan designs for most standard MBE systems and can adapt the design to fit custom systems. Model numbers are given above for the more common sizes of Titan Cells. Contact E-Science for more information on this cell or any of its other products.

Company Background

E-Science has been providing components for deposition reactors for over 10 years. Our primary focus is the development and sale of epitaxial components for both MOCVD and MBE systems. The close relationship we maintain with our customers allows us to keep current with developing technologies and the requirements of the marketplace. We have built a solid reputation of delivering working solutions to customers quickly and efficiently.

E-Science products include effusion cells, substrate heaters, specialty valved sources, and accessories for MOCVD and MBE reactors. Whether it is a specialty designed product or one of our standard products, our knowledgeable sales associates are committed to helping you select the product that is right for you. Once your order is placed, you can be assured that our engineering and manufacturing staff will work quickly to deliver the products to you.

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