

M/A-COM & the GaAs Industry Maturing Together

by Jo Anne Dalton

M/A-COM has been servicing customers in the GaAs industry since 1979. For 17 years, it has been devoted to the growth and prosperity of the entire GaAs community. M/A-COM focuses solely on the supply of Semi-Insulating Gallium Arsenide (SI-GaAs) Substrates for integrated circuit applications. This article describes the history of M/A-COM as a substrate supplier, their facilities, technology, recent successes in the areas of crystal growth and surface properties and basic business philosophy.

History

M/A-COM and the GaAs IC industry have matured together. From their initial business of supplying material for discrete FETs and then to the fledgling pilot lines, to our current position as a high volume supplier of substrates to some of the world's largest GaAs device producers. M/A-COM has consistently worked with our customers to provide business advantages. Throughout the highs and lows in the marketplace, over almost two decades, M/A-COM has been ranked in the Top Five suppliers of SI-GaAs substrates in the world by independent market research firms.

In March of 1994, M/A-COM was recipient of the largest DPA Title III Award Program, designed to incentivize growth of the GaAs Substrate business. This critical Government support has helped place M/A-COM on a path of renewed growth. M/A-COM has increased production capability by more than three times its 1993 level. They have added personnel in the areas of customer service and engineering to provide increased business and technical support, as well as, to drive process improvement and yield enhancements. All of these efforts are aimed at providing the highest performance product at the lowest cost.

In June of 1994, M/A-COM, Inc. was acquired by AMP, Inc. AMP,



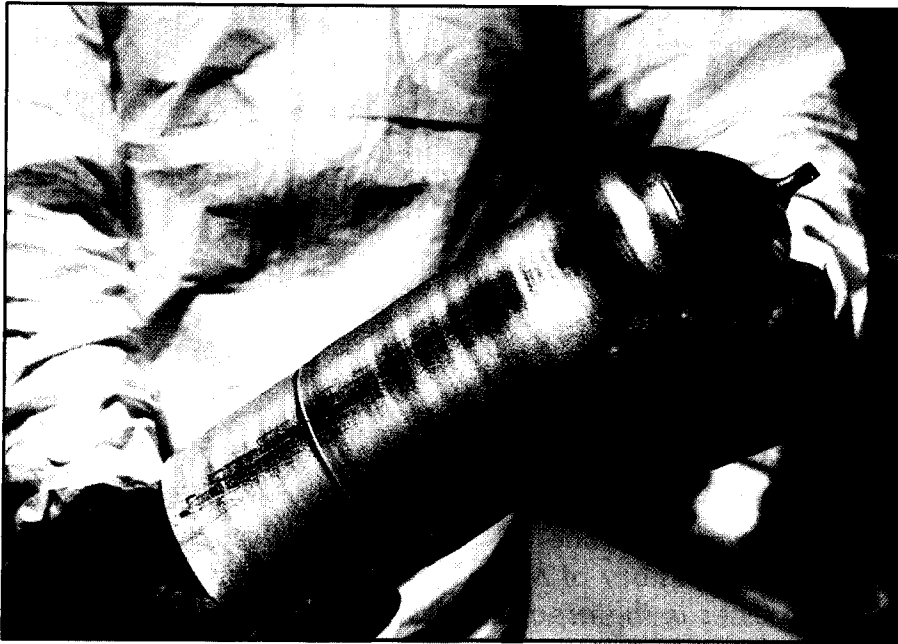
M/A COM facility at 100 Chelmsford Street, Lowell, MA, location of the GaAs Materials Group.

headquartered in Harrisburg, PA, is a leading supplier of connector products to the world marketplace. AMP's global vision and commitment to wireless technology as the new connection to the future has strengthened M/A-COM's unwavering commitment to GaAs technology.

Facilities

The GaAs Materials Group is one of three independent product lines housed in the Walker Advanced Technology Center located in Lowell, Massachusetts, USA. The building was

designed and constructed as a state-of-the-art semiconductor fabrication facility with over 40 000 square feet of cleanroom space. The facility offers a unique advantage to the production of GaAs substrates. The building was designed for vibration isolation, providing the ultimate in stability for the crystal growth process. The cleanroom environment tightly controls temperature and humidity leading to increased process reproducibility in the polishing area. These are critical advantages that have contributed to M/A-COM's continued success.



17 kilograms of single crystal SI-GaAs at 100mm diameter grown in M/A-COM's SG 15/25 HPLEC crystal growth system.

The Right Business Choices

All businesses have to make choices that shape their future. Every technical and business decision M/A-COM has made is aimed at developing a flexible, cost effective operation that can respond to market fluctuations and competitive pressures without jeopardizing profitability. The critical and most basic component that supports this business philosophy is M/A-COM's technology of choice, High Pressure Liquid Encapsulated Czochralski crystal growth. HPLEC has allowed M/A-COM to increase capacity through development of large melt, high yield crystal growth processes, without requiring large amounts of additional capitalization or facility expansion. This means more value added output per machine and per employee. This business philosophy is evident throughout the operation from wafer processing to packaging material to finished product. The bottomline - high manufacturing efficiencies that translate into lower cost per wafer and more value per dollar for the customers.

Over the years, M/A-COM has sized the business to the market and to the resources available. During periods of slow market growth, M/A-COM managed the business not to grow in

advance of the market. However, now that the market is showing signs of more steady growth, is investing proportionately. Three additional Cambridge Instruments 358 pullers have been added to the crystal growth area. Increased polishing capacity is being added with the purchase of additional, large capacity SpeedFAM double-side polishing machines. The balance between capital investment and market demand is the key to longevity when your concern as a business is not only to service your customers, but also, to provide a financial and technical advantage to your company that does not outweigh the investment. The GaAs Materials Group at M/A-COM has done that, and their longevity in this industry demonstrates an ability to strike this balance.

The Right Technical Choices

Crystal Growth

M/A-COM's technical efforts have consistently been directed toward providing the highest value to the GaAs IC Industry. The crystal growth technology is exclusively HPLEC growth producing undoped SI-GaAs boules. This technology has set the standard of the GaAs Industry. This high volume production technology

has the following advantages:

- In-situ synthesis for ultra-high purity and accurate control of stoichiometry,
- Control of electrical properties,
- Superior process and diameter control for manufacturing efficiency, and
- Scalability leading to increased boule sizes and high production yields.

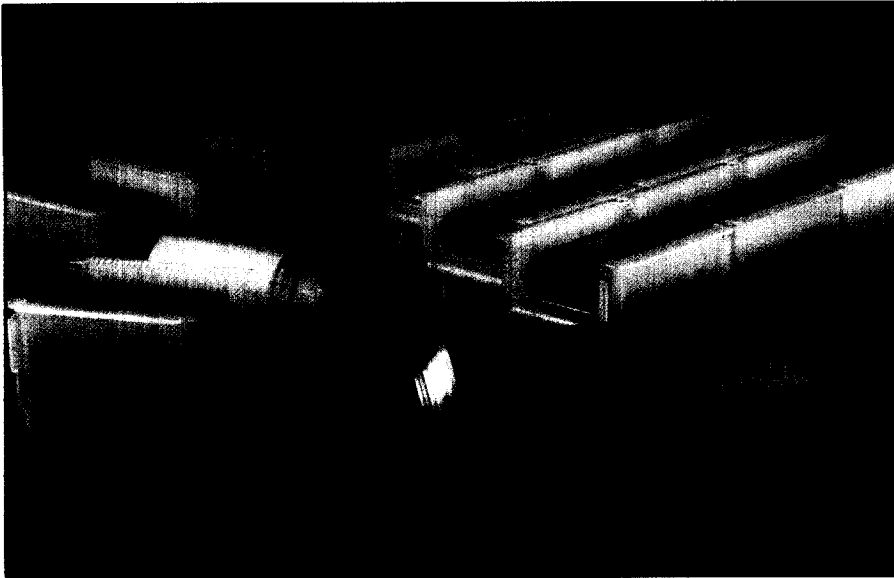
As practiced at M/A-COM, HPLEC processes support the efficient production of 3 Inch, 100 mm and 150 mm ingots.

Crystal growth development at M/A-COM is directed towards two broad areas: electrical property control and large melt growth. These continuous improvement efforts have lead to the development of techniques for dynamically controlling the carbon concentration in boules. This process allows M/A-COM to tailor substrate electrical properties to meet specific customer requirements. This high degree of control over electrical properties has resulted in a product which is ideal for ion implant applications.

M/A-COM's efforts in large melt development have resulted in several achievements in the last year. M/A-COM's baseline 3-inch diameter growth process has experienced a 100% increase in wafer yield per ingot. Boules yielding approximately 200 wafers are now a routine part of production. The main and most impressive development effort, however, has been directed at increasing the melt sizes used for the growth of 100mm boules. Crystal growth process development is directed by one of the most respected names in the GaAs industry, Rowland Ware, and has lead to a 17 kg process which results in approximately 240 wafers per boule and a 22 kg process which results in approximately 350 wafers per boule. Ingots from the 22 kg process are larger than any GaAs ingot development published to date! This emphasis on large melt development provides two distinct advantages:

- lower production costs are realized by maximizing the value added time of the process, and
- boule qualification costs are minimized.

These two advantages provide value to the user while assuring



One of the many new developments at M/A-COM, a new large melt HPLEC crystal growth process yielding 2.5 times more than 100 mm wafers per ingot than conventional manufacturing technology.

M/A-COM's ability to address the future.

Other developments that were achieved early at M/A-COM are in the areas of reduction of crystal stress and background impurities. M/A-COM utilizes a proprietary boule annealing process which results in very low crystalline stress. This process provides advantages to their customers through low line breakage and predictable performance during thermal processing. M/A-COM has implemented a continuous improvement program aimed at increasing the integrity of the crystal growth environment. The results of this effort have been the reduction of impurities which originate at many points in the growth process. At M/A-COM, each crystal puller is housed in its own environmentally controlled room with strict procedures in place to facilitate proper handling and contamination avoidance. M/A-COM has had a long standing philosophy to use only the purest, virgin raw materials. We do not ship device quality material from reprocessed or reclaimed raw materials. "We cannot guarantee the integrity of our device quality undoped material for the most demanding IC applications unless we start with the most stringent quality of material," states Dr. Douglas Carlson, Operations and Engineering Manager.

In summary, M/A-COM's finely engineered crystal growth process capability has provided many advantages to their customers including superior activation efficiency, superior electrical uniformity and reduction of thermal effects caused by crystalline stress.

Surface Properties

Crystal growth is not the only key area in which M/A-COM has focused. Wafer surface quality is another area that is receiving much attention. "Every customer has product and material requirements which are critical for their particular process. For some customers, surface properties are not critical. However, for other customers, the surface properties can control the substrate performance. This is the case with epitaxial growth. The surface can make or break you" states, Dr. Carlson. "The term Epi-Ready is a misnomer. The suitability of the wafer surface is process dependent. For one customer, a substrate can be used without any pre-growth treatment with no negative results, for others, the level of contamination, which is a result of interaction with the container materials and the atmosphere, will lead to deleterious device results. We have developed a 'Process Ready' wafer with a stable surface oxide which can be used out of the box or receive the

customers' own surface prep if required by their process."

Consistent, high yield epitaxial growth requires substrates with consistent and controlled surface properties. It has been speculated that the crystal growth technology used to manufacture the substrate provides a technical advantage for epitaxial growth. Experiments examining the parameters which control post-epitaxy morphology indicate that this is not the case. It is the properties of the substrate surface which effects the quality of the epitaxial growth process.

M/A-COM has investigated the effect of various surface treatments on the nature of the substrate surface. As indicated in Table 1, the chemistry to which the substrate surface has been exposed to has a direct effect on both the native oxide composition and the surface stoichiometry. These data, obtained from XPS analysis of the Si-GaAs surfaces indicates that near stoichiometric surfaces can be obtained with alkaline treatments. The stoichiometric surface has been found to result in reduced post epitaxial growth haze and particle levels as compared to both untreated LEC-grown substrates and VGF-grown substrates. Accurate control over the properties of the substrate surface is critical for high yield epitaxial growth.

Chemistry	Native Oxide (Ga-Oxide)/ (As-Oxide)
As Polished	1.8
Alkaline	1.1
Acidic	0.8

"As far as slip? We have addressed that issue. Our material has been proven to exhibit minimal to no-slip in both MOCVD and MBE growth," states Dr. Carlson.

M/A-COM will release a new product directed at epitaxial applications in the near future. This product will feature a slip free wafer with a stabilized surface. It will have the best of both worlds. Look for this announcement in an upcoming issue.



SG 15/25 HPLEC crystal growth system and 150mm diameter GaAs Ingot.

Customer Satisfaction

— A Partnership

M/A-COM's Quality policy is intimately linked to customer satisfaction. The Operation is dedicated to achieving customer satisfaction through continuous improvement. To improve, M/A-COM recognizes that they must learn from their

customers, their vendors and their employees. This philosophy was the underlying principle which lead M/A-COM to become the first US supplier of Si-GaAs to obtain ISO9001 registration.

M/A-COM's entire staff is aligned to support the customer. Whether standard or custom parts are required, they have the expertise to analyze

the user requirements and provide the best solution. To support its customers' needs, M/A-COM is implementing several major improvements to its business systems. To make the interface with M/A-COM's sales force as easy as possible, M/A-COM is implementing "SAP" (Systems, Applications and Products in Data Processing). This business system will assure the timely response to customer requests. The "SAP" system will be linked to "Promis", a material management and shop floor control system. Both systems are designed to assure that the customer gets what they want, when they want.

M/A-COM views the relationship with its customers as a partnership. Valuing straightforward, open communication with customers to ensure that the selection the material that provides the best 'fit' for their specific needs and to help each party improve. M/A-COM calls this concept 'co-engineering'. Customers must be successful in their own markets and the supplier wants to be a contributing factor to the success as they strive to compete in today's fast moving marketplace.

Closing

In 1995, M/A-COM experienced strong business growth. Shipments were up 46% and order commitments were up 114%. However, 1996 is the year to watch for M/A-COM. Although the company is forecasting steady growth, similar to that experienced last year, 1996 will prove to be even more significant, due to advancements made in the technical and manufacturing areas. Three new products will be introduced and these will expand our technical and manufacturing capabilities even further. After over 15 years in this business, the wave of growth has arrived and we're going to ride it!

For more information and a list of M/A-COM's Worldwide Sales Offices, please contact:

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