

**2008 European Field Emission Sources Technology Innovation of the Year Award****El-Mul Technologies**

The 2008 Frost & Sullivan European Technology Innovation of the Year Award in field emission sources for semiconductor analytical instruments goes to El-Mul Technologies for its E-Beam On-a-Chip™ Technology. The system essentially employs a single electron beam source based on El-Mul's CNT-based structure. El-Mul's initial electron source device is targeted primarily for next generation scanning electron microscope (SEM) and transmission electron microscope (TEM) systems. The new device is expected to result in 30 percent higher resolution, a four-fold increase in scanning speeds, and a significant cost reduction in both manufacturing and maintenance of SEM and TEM systems. E-Beam On-a-Chip™ is a system-on-chip (SoC)-based solution, which enables highly-customized electron microscopy (EM) and electron beam lithography (EBL) techniques to be embedded directly into standard fab equipment.

**Company Background**

Israel based El-Mul Technologies is a privately held firm established in 1992 for developing electron and ion beam solutions for requirements in semiconductor manufacturing, industrial SEM and mass spectrometry tool markets. The company, in the past decade, has extensively focused and research efforts that serve technology and market demands in fields like fast inorganic scintillators and nano-electron emitters. One of their flagship technologies, E-Beam on a Chip™, is a technology which addresses critical challenges in the semiconductor manufacturing industry.

**Technology Relevance in the Market Place**

It is becoming increasingly difficult, with conventional technologies and processes, to keep progressing along the Moore's Curve in the semiconductor industry. The next generation of semiconductor manufacturing processes are highly dependent on path-breaking platform evolutions; and it is evident that mere performance enhancements in existing manufacturing solutions will not support the manufacturing of future semiconductor technologies such as like strained silicon technology and Three Dimensional Integration Technologies. One of the key developmental challenges for advanced manufacturing lines in the semiconductor space is the integration of EM and EBL processes at critical points in semiconductor manufacturing lines. As part of the semiconductor manufacturing process in the current scenario, the EM and EBL

processes in many cases are performed offline. With technologies such as wafer level packaging carrying a lot of sophisticated processing closer to the wafer, the industry is now trying various ways to eliminate the offline handling and transfer of wafers. In this regard, there are efforts to integrate processes such as electron microscopy and electron beam lithography into the process online, in contrary to the process currently being carried out offline.

### How the Technology Works

Addressing the aforementioned challenges, El-Mul Technologies, a long-time developer of electron detection solutions for major semiconductor manufacturing toolmakers, has developed a new E-Beam Tool technology, which produces highly precise and efficient electron beams for use in EM and EBL that are used in the manufacture of advanced semiconductors and other devices. The technology will also enable the reduction of costs, and making these processes integral to the manufacturing line in order to improve yields and eliminate excess wafer handling. El-Mul's proprietary, patented approach embeds a single carbon nanotube (CNT) inside an etched cathode well structure, creating an electron source field emitter that combines high-E-beam brightness with a more narrow energy spread for near-laminar results. The patented CNT structure utilizes the field emission characteristics of a multiwalled CNT to produce high-quality electron beam sources. The process involves the stacking of silicon, silicon oxide, and conductive poly silicon layers. A cathode well is etched through the poly and oxide layers to the silicon substrate, using conventional semiconductor processing techniques, resulting in formation of a capacitor-like gating structure. Further processing involves the placement of single or multiple CNTs in each well, depending on intended device specifications.

The E-Beam On-a-Chip™ solution has been built in two configurations to cover a very broad spectrum of applications. The first of these is called E-Beam On-a-Chip™ fine beam device. These fine beam devices produce beams that can also be used as Field Emission (FE) sources for SEM, TEM, and similar high-performance E-beam tools, FE sources for flat panel displays, X-ray sources for medical applications, true random number generators, E-beam induced deposition (EBID) applications, ionizers and irradiation devices. The fine beam devices are evolving to become critical platforms for applications such as E-beam lithography, metrology, and inspection in sub-40 nanometer semiconductor manufacturing nodes. The development group alternately is also developing a broad beam class of solutions based on its CNT-based structure, for applications such as ionizers and irradiation devices, FE sources for mass spectrometry tools, and FE sources for general industrial E-beam tools.

While conventional solutions for E-Beam generation require very high-voltage levels (on the order of kV), the EI-Mul CNT-based E-Beam requires voltage of tens of volts only. This makes the E-Beam SoC especially attractive as a way to dramatically reduce energy consumption in many devices that currently use E-Beams. The most important benefit of the solution is that it has resolved certain challenges which have restricted the penetration of electron beam lithography in the semiconductor manufacturing industry. E-beam lithography is not subject to optical diffraction problems, but has been shown as problematic to semiconductor manufacturing due to insufficient brightness and excessively wide energy spread. While other types of non-optical Field Emitters being developed would be suitable only for small fragments of the market, the E-Beam On-a-Chip™ is expected to have applications in a wider spectrum of the market. This includes niche sectors such as vacuum electronics. Furthermore EI-Mul's design requires less stringent vacuum conditions as compared with conventional E-beam lithography, as well as reduced ion-emitter interference.

### **Business, Patents, & Partnerships**

Currently, the company is extensively collaborating to initially make an entry into the electron microscope market. At this stage of evolution, EI-Mul has uniquely demonstrated customer specific product demonstration of the new E-Beam devices, partnering with electron microscope original equipment manufacturers. These initiatives are expected to broaden its foothold in the market sector. EI-Mul plans to leverage the largely untapped application potential in sectors such as displays and vacuum electronics for their technology solutions. Most of their partnership efforts actually focus on exploring these capabilities in their partners' market who develop applications that utilize electron beam sources, The company's efforts have been predominantly supported financially by the Office of the Chief Scientist (OCS), Israel, and partners who intend to incorporate EI-Mul's technology.

EI-Mul sees the greatest market potential in flat panel displays, X-ray sources, analytical tools, and ionizers. Over the long term, there is a high probability that a growing variety of markets for EI-Mul's devices will develop. These markets could be either in off-the-shelf solutions for chosen application domains, or a generic line of E-Beam SoC devices that can be customized directly by a customer to meet the needs of a specific application. EI-Mul currently holds around seven approved patents for their developments around electron and ion detection solutions.

### **Conclusion**

With a very strong technology platform and a practical market oriented technology development approach, EI-Mul Technologies is expected to evolve as a leading

technology player in the FE devices industrial space. Recognizing the above efforts, Frost and Sullivan is pleased to present the 2008 European Technology Innovation of the Year Award in field emission sources for semiconductor analytical instruments to El-Mul Technologies.

### **Award Description**

Frost & Sullivan's Technology Innovation Award is bestowed upon a company (or individual) that has carried out new research, which has resulted in innovation(s) that have or are expected to bring significant contributions to the industry in terms of adoption, change, and competitive posture. This award recognizes the quality and depth of a company's research and development program as well as the vision and risk-taking that enabled it to undertake such an endeavor.

### **Research Methodology**

To choose the award recipient, Frost & Sullivan's analyst team tracks innovation in key hi-tech markets. The selection process includes primary participant interviews and extensive primary and secondary research via the bottom-up approach. The analyst team shortlists candidates on the basis of a set of qualitative and quantitative measurements. The analysts also consider the pace of research and technology innovation, and the significance or potential relevance of the innovation to the overall industry. The ultimate award recipient is chosen after a thorough evaluation of this research.

### **Measurement Criteria**

In addition to the methodology described above, there are specific criteria used to determine the final rankings. The recipient of this award has excelled based on one or more of the following criteria:

- Significance of the innovation(s) in the industry, and across industries (if applicable).
- Potential of the products of innovation(s) to become industry standard(s).
- Competitive advantage of innovation vis-à-vis other related innovations.
- Impact (or potential impact) of innovation(s) on company or industry mind share and/or company bottom line.
- Breadth of intellectual property related to the innovation(s), that is, patents, scientific publications, and papers in peer-reviewed journals.

**About Best Practices**

Frost & Sullivan Best Practices Awards recognize companies in a variety of regional and global markets for demonstrating outstanding achievement and superior performance in areas such as leadership, technological innovation, customer service, and strategic product development. Industry analysts compare market participants and measure performance through in-depth interviews, analysis, and extensive secondary research in order to identify best practices in the industry.

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