Bromine-Free Semiconductor Chips

COMPANY PROFILE

SILICON STORAGE TECHNOLOGY, INC. (SST)

Manufacturer of flash memory-based components.

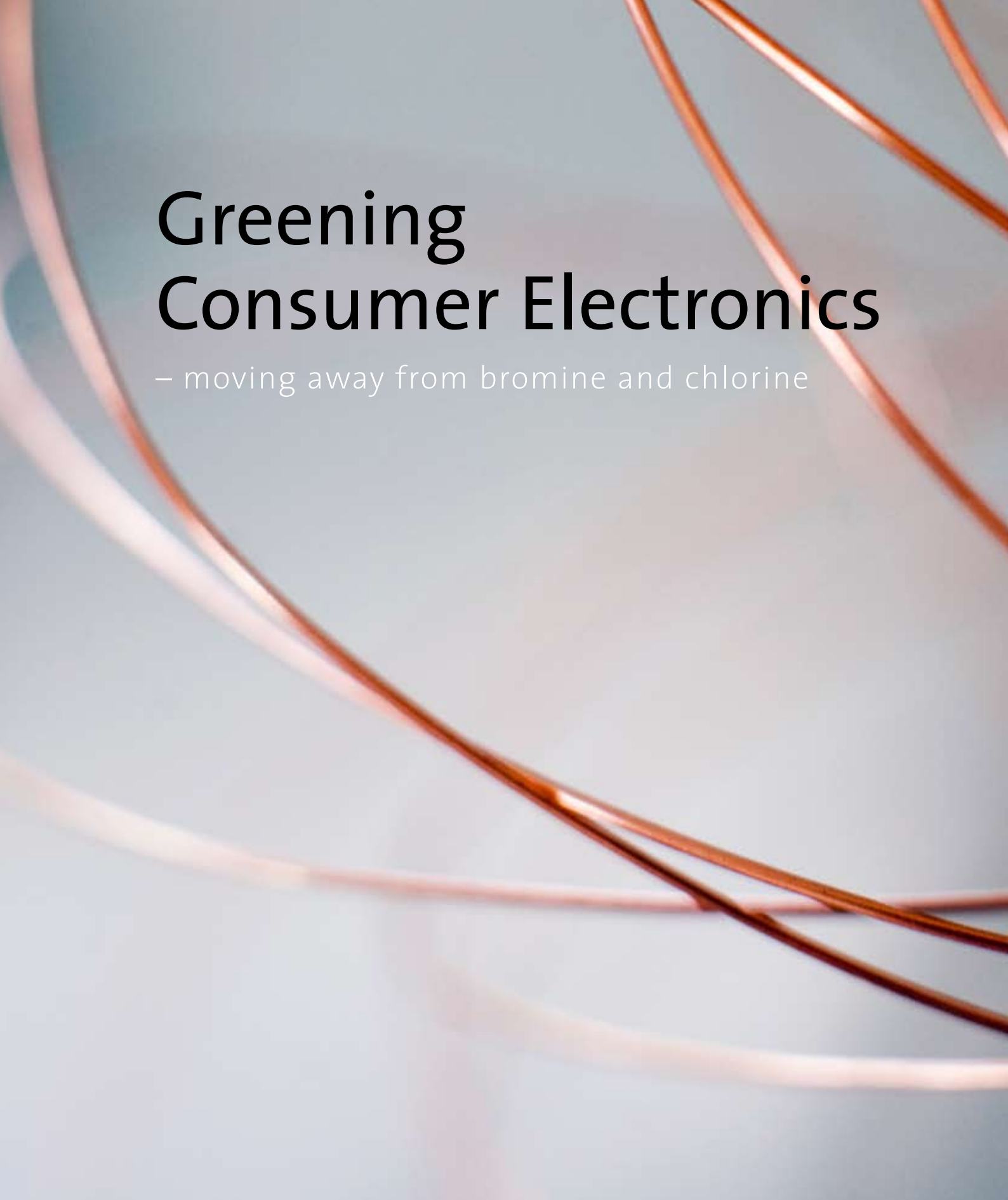
SST is a market leader in its niche, producing low-density flash memory semiconductors for storing the code required to boot electronic devices such as PCs and mobile phones.

Headquarters:	Sunnyvale, CA, USA
Design Centers:	Sunnyvale, CA, USA; Hsinchu, Taiwan; Shanghai, China
Sales:	$315.5 million (US dollars, 2008)
Employees:	614 worldwide

www.sst.com

"We are committed to preserving our environment by managing and eliminating the impact of harmful substances, as defined by industry standards, in the manufacture of SST products."

– Bing Yeh, Executive Chairman and CEO, Silicon Storage Technology, Inc.



Greening Consumer Electronics

– moving away from bromine and chlorine

CHEMSEC – FOR A TOXIC FREE WORLD

ChemSec (the International Chemical Secretariat) is a non-profit organisation working for a toxic-free environment. Our focus is to highlight the risks of hazardous substances and to influence and speed up legislative processes. We act as a catalyst for open dialogue between authorities, business, and NGOs and collaborate with companies committed to taking the lead. All of our work is geared to stimulating public debate and action on the necessary steps towards a toxic-free world.

CPA – STRATEGIC SOLUTIONS FOR GREEN CHEMICALS

Clean Production Action, CPA, designs and delivers strategic solutions for green chemicals, sustainable materials, and environmentally preferable products for a closed-loop material economy.

CPA engages with businesses and NGO leaders to hasten the transition to an economy without harm. We coordinate the US-based Business NGO Working Group for Safer Chemicals and Sustainable Materials and we research and promote companies' efforts to transform the toxic chemical economy.

Published in September 2009

Authors: Nardono Nimpuno, Alexandra McPherson, and Tanvir Sadique

Companies highlighted in this report have kindly contributed to the information provided in the substitution case studies. ChemSec and Clean Production Action are solely responsible for all other texts in this report.

Photo: Niklas Maupoix

INDEX

ABSTRACT

Silicon Storage Technology, Inc. was one of the first electronics companies to produce bromine-free semiconductors. The most formidable hurdle the company had to overcome was discovering a bromine-free molding compound to encapsulate its semiconductors. Eventually the company found a multiaromatic resin (MAR) formulation that was both bromine-free and able to withstand the higher solder temperatures needed to comply with RoHS' lead-free solder requirements. By 2008, 100 % of SST's semiconductors were bromine-free. As chlorine-based compounds are not used in the final product of semiconductor devices, they are not applicable to this case study.

Silicon Storage Technology, Inc. was one of the first semiconductor companies in the electronics sector to provide customers with bromine-free products. The company's impetus for developing its bromine-free semiconductor chips was its customers' increasing demand for halogen-free products, as well as the EU RoHS directive's requirement that materials be lead-free. Over a six-year time frame, SST was able to successfully remove both lead and brominated compounds from its product lines.

Of the numerous challenges that SST's engineering team succeeded in overcoming, the most formidable was identifying a viable molding compound that could be substituted for the readily available material that had been used in the industry for decades. SST invested in an approach that allowed the company to become one of the first semiconductor manufacturers to supply major customers, like Apple, with components that met new bromine- and chlorine-free supply chain specifications. By 2008, 100 % of SST's semiconductor devices were bromine-free.

SST's products meet the following goals that the company developed for substitute materials:

- **Compliant with international environmental standards;**
- **No compromise in reliability and performance of the structure of the package used to mount the semiconductor to a printed circuit board;**
- **Negligible increase in cost per unit;**
- **Achievement of UL94-V0 fire safety rating.**

It is important to note that because chlorine-based compounds are not used in the final product of semiconductor devices, they are not applicable to this case study.

OVERCOMING TECHNICAL CHALLENGES

SST's success in removing bromine from its products required a great deal of collaboration with other suppliers because the company sits in the middle of the electronics supply chain and does not own its own manufacturing facilities. The company's journey in eliminating bromine is inextricably tied to the semiconductor industry's use of antimony trioxide, another substance of high concern that was used in conjunction with bromine for 25 years to increase the flame retardancy of semiconductor chips.

At the turn of the millennium, industry restrictions on antimony trioxide forced resin manufacturers, such as Sumitomo Bakelite, to evaluate alternative flame retardants that could be used in the molding compounds needed to encapsulate semiconductor devices. Identifying reliable alternatives proved to be a real challenge. The first alternative to emerge used red phosphorous, but this formulation was discontinued after manufacturers discovered that it had a serious reliability flaw.

Eventually, continued research led to the development of a more successful alternative, multiaromatic resin (MAR). This resin reformulation took advantage of a blistering phenomenon that offered the same fire retardancy protections as the additives but without the use of brominated flame retardants (BFRs). Fortuitously, the resin's ability to withstand higher solder temperatures also resolved the industry's need to find a resin capable of complying with the RoHS requirement eliminating the use of lead. The main use of lead was in soldering materials. Lead-free solders, such as those that are based on 100 % tin, operate at higher temperatures. The significant cost increases initially required to use the MAR compounds were ameliorated in 2001. That year, increased availability from multiple sources made it cost effective for SST to use compounds that were free of both bromine and antimony trioxide in its new RoHS-compliant devices.

In addition to identifying safer flame retardants, the SST engineering team had to overcome the challenges of delamination, which can cause the material used to encapsulate the semiconductor to fail. SST initiated joint studies with key suppliers to engineer materials that would be moisture-resistant for each size and thickness of the various semiconductor packages used to mount SST's integrated circuits onto printed circuit boards. The company's close working relationship with its suppliers allowed it to identify cost-effective and reliable solutions ahead of its competitors.

Once the technical and availability issues were resolved, the challenge shifted to SST teams that dealt with manufacturing and inventory management issues. Since SST does not own its own manufacturing facilities, the company had to carefully manage the product revision cycle to ensure that its manufacturing partners were not burdened with the need to store old raw material inventory reserved for SST's forecasted volume. To maintain good vendor relations, SST implemented a slow phase-in of the bromine-free compound even though the new material was readily available.

PRODUCT	TIMELINE
SST semiconductors in "leadframe*" based mounting packages	2001 – first set of Pb-free products 2006 – 100 % Pb-Free 2006 – 90 % BFR-free 2008 – 100 % BFR-free
SST semiconductors in substrate-based leadless* mounting packages	2006 – 100 % Pb-free 2006 – BFR-free molding compound 2008 – 100 % BFR-free

** In this context, the term "lead" refers to the methodology used to connect the semiconductor's mounting package to a printed circuit board. It does not imply anything about the semiconductor product's chemical composition or whether the lead (Pb) element is used in it. (Leadframes can be lead-free (Pb-free).)*

SST's microprocessors have two different mounting package options, which are known in the industry as leadframe and leadless. The terms do not imply anything about the product's chemical composition. By 2006, 90 % of all the leadframe-based devices that SST shipped to its customers were bromine-free. The only remaining use of bromine was in the company's leadless substrate materials. In 2007, when Apple restricted the use of bromine in all homogeneous materials, SST's engineering and manufacturing teams removed the element from the company's remaining product lines and shipped its first set of products to Apple that were entirely bromine-free. Many companies run parallel product lines, but SST made the decision to sell entirely bromine-free product lines to avoid product mixing. Product mixing is very difficult to prevent in high-volume production facilities where non-conforming parts can inadvertently contaminate other lines, increasing the risk of shipping products that fail to meet specific material specifications.

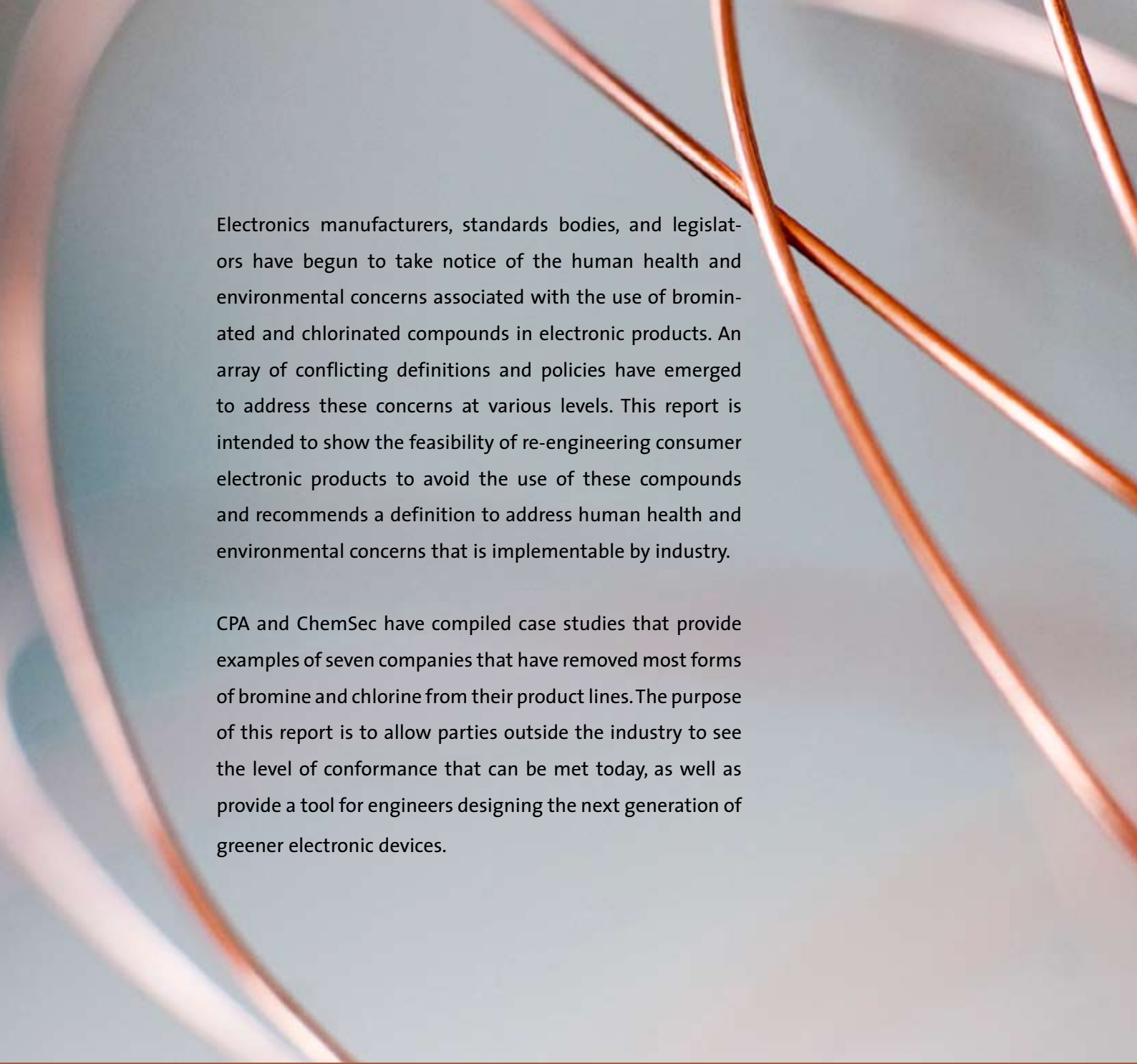
ENSURING COMPLIANCE WITH MATERIAL RESTRICTIONS

Since SST is situated in the middle of the electronics industry supply chain, the company had to submit documentation to its customers that ensured the products the company was providing to them met required technical and environmental specifications. The company conducted standardized qualification studies using guidelines produced by JEDEC (originally the Joint Electron Devices Engineering Council), the technical organization that oversees standards for the solid-state industry. These studies were summarized in Reliability Qualification reports, which SST provided to its customers. In order to prove compliancy to standards such as RoHS, SST was also required to produce chemical analysis reports of each homogenous material (molding compound, leadframe, and substrates) used in their products. The analysis tests were conducted at independent labs using standardized tests such as IPC (Inductively Plasma Coupling), a very accurate method of measuring the level of restricted compounds down to 5 parts per million (ppm). To easily provide SST's customers with analysis data, these test results were populated into a custom-designed database system that was available to the company's worldwide sales force. For compliance tests covering the six substances restricted under the RoHS directive, the reports typically cost $150 (US). It costs SST an additional $90 (US) to run tests for compliance with bromine-free specifications. This increase is negligible given that the complete qualification process for a new product typically costs $150,000.

MOVING FORWARD

SST's experience has shown that semiconductor manufacturers can attain an elemental restriction on bromine without incurring excessive research and development costs or affecting product reliability. As new chemical and material restrictions are developed for the electronics sector, it is critical that clear thresholds and definitions be established. Global harmonization of these thresholds and definitions using joint industry standards and/or new policy regulations allows companies like SST, which have limited research and development resources, to develop engineering solutions that successfully eliminate substances of high concern.

Many companies run parallel product lines, but SST made the decision to sell entirely bromine-free product lines to avoid product mixing.



Electronics manufacturers, standards bodies, and legislators have begun to take notice of the human health and environmental concerns associated with the use of brominated and chlorinated compounds in electronic products. An array of conflicting definitions and policies have emerged to address these concerns at various levels. This report is intended to show the feasibility of re-engineering consumer electronic products to avoid the use of these compounds and recommends a definition to address human health and environmental concerns that is implementable by industry.

CPA and ChemSec have compiled case studies that provide examples of seven companies that have removed most forms of bromine and chlorine from their product lines. The purpose of this report is to allow parties outside the industry to see the level of conformance that can be met today, as well as provide a tool for engineers designing the next generation of greener electronic devices.

International Chemical Secretariat

Box 7005, SE-402 31 Göteborg, Sweden
Tel: +46(0)31-711 04 95
E-mail: info@chemsec.org

www.chemsec.org

CPA (North America)

P.O. Box 153, Spring Brook, NY 14140, USA
Tel: +1 716-805-1056
E-mail: alexandra@cleanproduction.org

www.cleanproduction.org