Restriction of Elemental Bromine and Chlorine to Achieve Elimination of BFRs and PVC in Consumer Electronics Products

COMPANY PROFILE

APPLE INC.

Consumer Electronics Manufacturer.

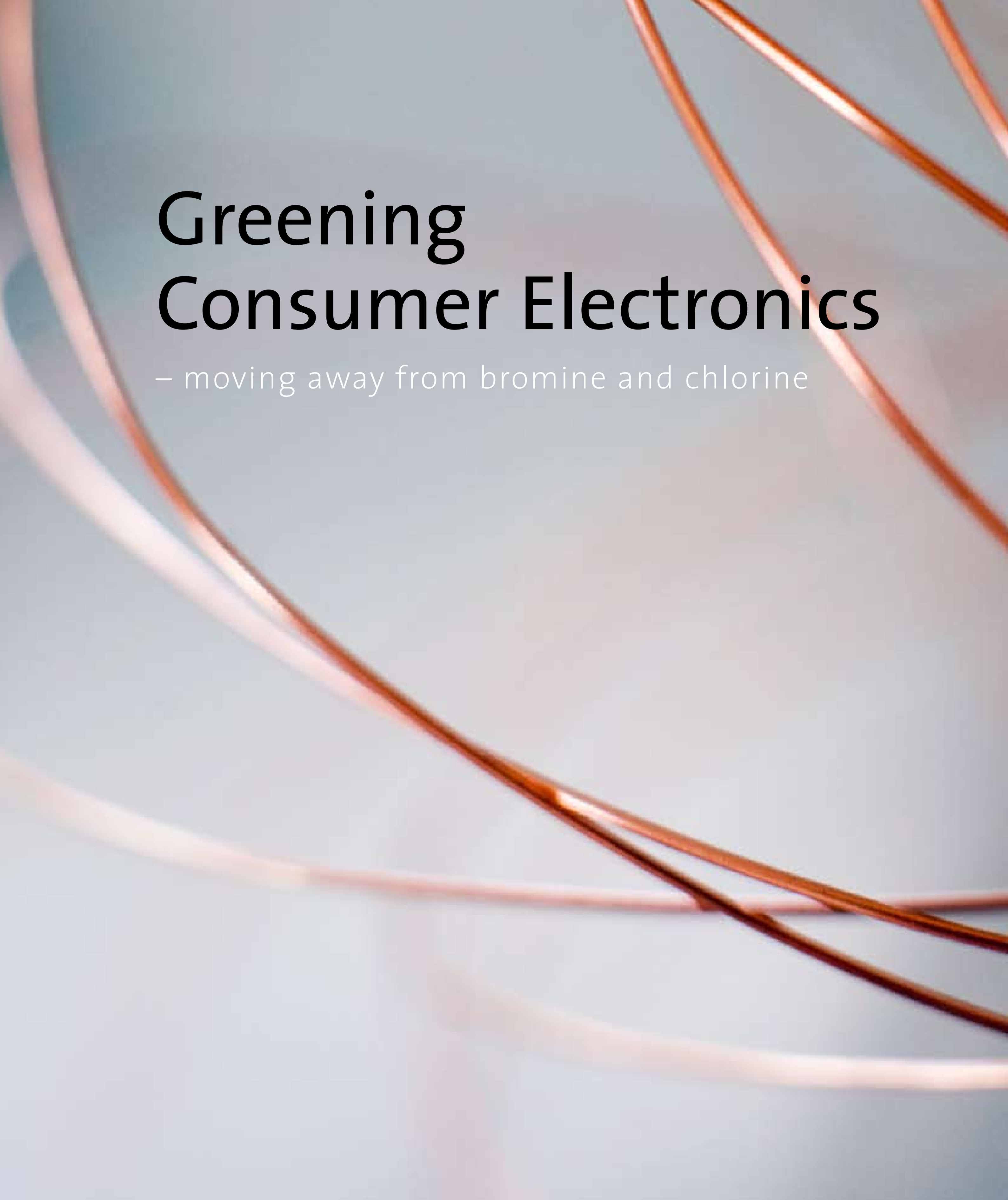
Apple Inc. is a world renowned manufacturer of various consumer electronics devices, including portable and desktop personal computing systems, as well as portable music devices and mobile communication devices.

Headquarters:	Cupertino, CA, USA
Design Center:	Cupertino, CA, USA
Sales:	$33 billion (US dollars, 2008)
Employees:	32,000 worldwide

www.apple.com

Greening Consumer Electronics

– moving away from bromine and chlorine



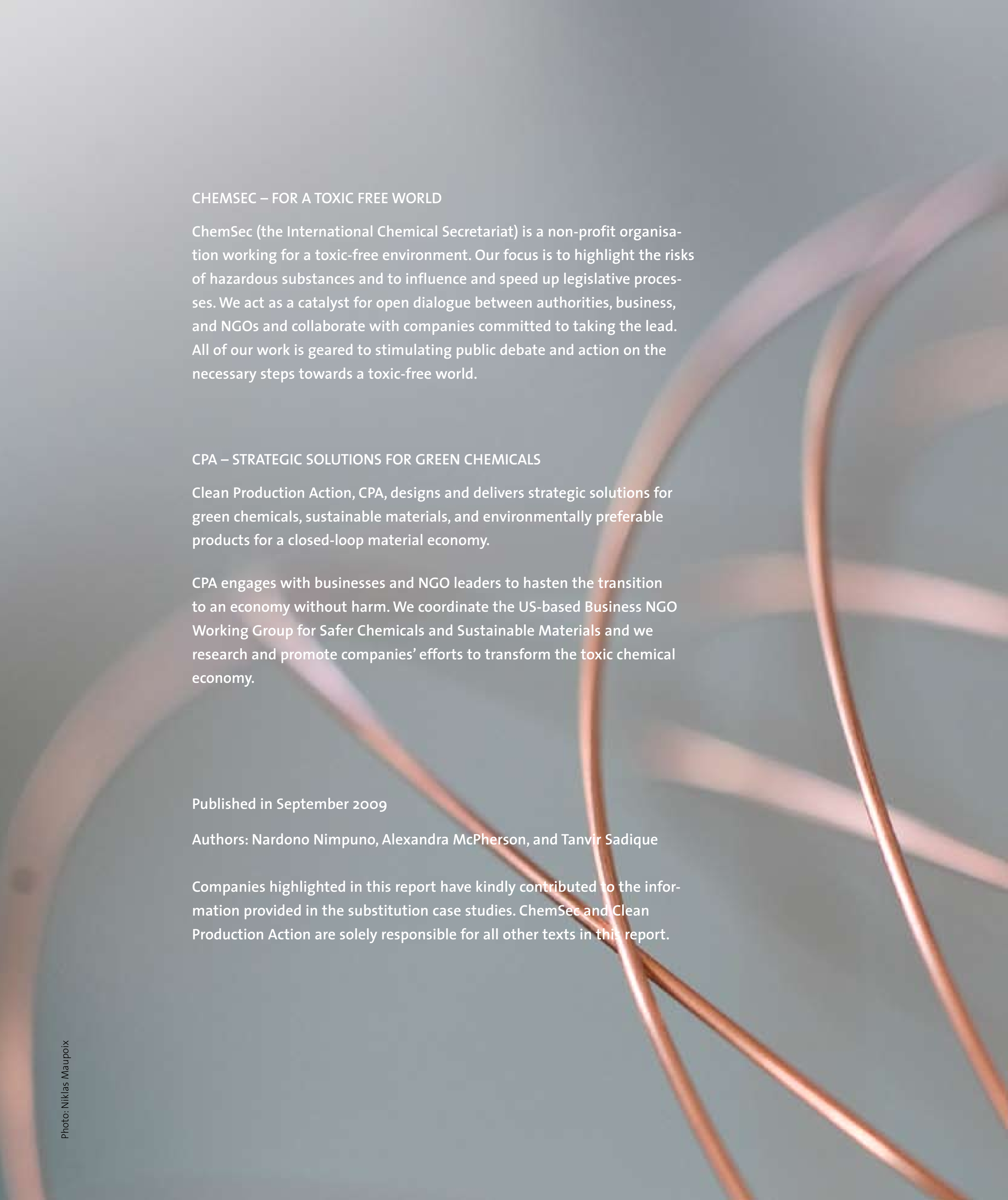


Photo: Niklas Maupoix

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

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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.

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"Apple is committed to phase out the use of bromine (Br) and chlorine (Cl) in its products with the intent to minimize impact on the environment and human health during manufacturing, use, and disposal."

– Apple Specification on the Restriction of Bromine and Chlorine, 069-1857-D

Apple has a long history of working to improve the environmental footprint of the materials designed into its products. For the past decade, the company has worked to reduce the use of substances of concern. By embedding the concept of continuous improvement into its design strategy, the company has become an industry leader in providing customers with a wide range of electronic products that contain safer chemicals and more sustainable materials.

In accordance with its commitment to eliminate substances of high concern, Apple has spent the last several years investing in new designs, tools, and materials to provide customers with the world's first complete range of BFR-free notebook and desktop computers and handheld products. With the exception of external AC and DC cables, Apple also offers the world's first range of PVC-free products.

Apple also recognized that other substances beyond BFRs and PVC that contain bromine and chlorine are likely candidates for future regulatory restrictions in Europe and the U.S.A. Accordingly, the company imposed restrictions on all materials containing brominated and chlorinated compounds, not just BFRs and PVC. This was the first time that a manufacturer attempted to eliminate the use of nearly all brominated and chlorinated compounds in complex electronic equipment. The approach, colloquially referred to as the "elemental approach" because the restrictions are imposed on bromine and chlorine regardless of what compound may contain them, represents the most rigorous basis for restrictions on chlorine and bromine use in electronic products.

ABSTRACT

Apple restricts nearly all uses of brominated and chlorinated compounds, at the elemental level, from its products. Customers can now purchase products like the iPod shuffle, nano, and touch, and the iPhone that are free of brominated flame retardants (BFRs) and polyvinyl chloride (PVC). Apple's iMac and Macbook products are free of all BFRs and PVC with the exception of PVC use in external wires. Apple had to work with suppliers to change the composition of hundreds of parts, including printed circuit boards (PCBs), connectors, fan impellers, cable insulators, adhesives, films, inks, dyes, flexible printed circuits, and enclosures. To implement its restrictions, Apple required its suppliers to establish strict compliance management programs.

Apple's elemental approach helped simplify verification and testing of parts being qualified for new products. The company's extensive research showed that elimination of only specific BFR compounds, such as TBBPA, would be more difficult from a validation perspective since many BFRs are difficult to detect; moreover, testing for PVC can be challenging at low concentrations. In contrast, the methods for detecting bromine and chlorine were well-established and relatively inexpensive to carry out. By using these methods, the company was able to develop robust and transparent compliance programs for its suppliers.

APPLE PRODUCTS	ELIMINATING SUBSTANCES OF CONCERN
MacBook Air	Mercury-free LCD display Arsenic-free display glass BFR-free PVC-free internal cables
MacBook Pro	Mercury-free LCD display Arsenic-free display glass BFR-free PVC-free internal cables
iMac	Arsenic-free display glass BFR–free PVC-free internal cables
iPhone 3G and iPhone 3GS	Mercury-free LCD display Arsenic-free display glass BFR-free PVC-free
iPod touch	Mercury-free LCD display Arsenic-free display glass BFR-free PVC-free
iPod nano	Mercury-free LCD display Arsenic-free display glass BFR-free PVC-free
iPod shuffle	BFR-free PVC-free

The widespread use and complex nature of brominated and chlorinated compounds in BFRs and PVC required Apple to completely eliminate (rather than just reduce) these substances of concern from thousands of parts, including printed circuit boards (PCBs), connectors, fan impellers, cable insulators, adhesives, films, inks, dyes, flexible printed circuits, and enclosures. Apple's goal was to have all products compliant by the end of 2008. With the exception of PVC-free replacements for external wiring in some computers and displays, Apple has met its goal and now has many BFR- and PVC-free products available to consumers. Apple continues to work with suppliers to develop PVC-free alternatives that not only meet the necessary technical and safety specifications for external cables, but also meet Apple's stringent cosmetic requirements.

OVERCOMING TECHNICAL CHALLENGES

To provide clear guidance to its supply chain, Apple developed a new specification in 2006 that outlined the company's intention to eliminate bromine- and chlorine-based compounds in all homogeneous materials used in Apple products. When Apple initially released its 069-1857 specification, the company referenced and revised widely accepted standards such as the IEC 61249-2-21:2003 standard for low-bromine and low-chlorine printed circuit board laminates. Apple defined bromine- and chlorine-free by using the same limit established in these standards, namely that of 900 ppm (0.09 %) of bromine and chlorine, and 1500 ppm (0.15 %) of the combined total of the two elements. This threshold essentially closes the door on all intentionally added BFR compounds and PVC applications, because chlorine and bromine in BFR and PVC applications are not effective at such low concentrations. Bromine is typically used in concentrations above 50,000 ppm to flame retard plastics and the chlorine content in PVC is even higher.

New supply chain specification

SUBSTANCE	RESTRICTIONS FOR HOMOGENEOUS MATERIALS (SUBSTANCE CONCENTRATION LIMIT BY WEIGHT)
Bromine (Br)	≤ 900 ppm (0.09 %)
Chlorine (Cl)	≤ 900 ppm (0.09 %)
Total concentration of bromine (Br) + chlorine (Cl)	≤ 1500 ppm (0.15 %)

Unlike the IEC specification, which only applies to printed circuit board laminates, Apple's specification requires that its established thresholds be met for all homogeneous materials. This ensures that every material used in the company's products can be tested and verified with readily available and inexpensive test methods and procedures.

Apple's suppliers were required to establish strict compliance management programs, which included using certified laboratory testing to demonstrate that they were complying with the new requirements. This approach is analogous to that required by many electronics manufacturers to demonstrate RoHS compliance. Throughout the transition, Apple monitored its suppliers' compliance via internal audits, and the company repeatedly found instances where brominated or chlorinated materials were used in parts that suppliers claimed to be compliant with Apple's limits on bromine and chlorine. A transparent compliance program, which allows for quick and inexpensive material testing, enabled Apple to identify problems early on and take corrective action. This would not have been possible if Apple had relied solely on the paper trail of supply chain declarations – which is commonly used to demonstrate compliance by OEMs in the electronic sector – nor would it have been possible if Apple had only restricted BFRs and PVC because compliance tests for these substances are either more complex or do not exist. An extensive auditing program in a supply chain is critical to increasing compliance and ensuring full implementation of new material specifications, particularly during the early stages of the transition.

TECHNICAL CONFORMANCE AND RELIABILITY

An important aspect of Apple's achievement in eliminating bromine and chlorine was the company's success in ensuring that the new environmental specifications do not interfere with the strict quality, reliability, safety, and performance requirements that are critical to the dependability of its products.

Apple's conversion to BFR- and PVC-free products was not without cost, but the company's expenses were reduced by employing widely accepted strategies: implementing the transition in phases; leveraging new product development cycles to introduce new materials; and partnering with suppliers on new materials development and qualification. To minimize disruptions to production, Apple phased out the use of chlorine and bromine over four transition phases coinciding with new product releases (four phases listed below).This approach had the advantage of sharing the research and development costs of using alternative materials with the fixed cost of developing new products.

PHASE ONE >>>>
User-inaccessible (i.e. internal) cable jackets and internally-designed PCB laminates

PHASE TWO >>>>
Insulators, films, and enclosure plastic parts

PHASE THREE >>>>
User-accessible (i.e. external) cable jackets and externally-designed PCB laminates

PHASE FOUR >>>>
Connectors and electrical components soldered to printed circuit boards

Apple worked with suppliers to overcome manufacturing and design challenges that inhibited the replacement of BFRs and PVC. This partnership allowed the company's suppliers to manufacture parts that met its reliability, performance, and quality requirements. In many cases, bromine- and chlorine-free alternatives were not "drop-in" replacements and required process or design changes to accommodate their differing material characteristics:

- **Bromine- free laminates for printed circuit boards:** The electrical and mechanical characteristics of bromine- and chlorine-free PCB laminates, including the dielectric constant, peel strength, and glass transition temperature, differ from traditional BFR based laminates. Designers had to address these differences by designing PCBs specifically tailored for bromine- and chlorine-free materials. Extensive testing had to be conducted to ensure that signal integrity, reliability, electromagnetic compatibility, and manufacturability met internal standards.

- **Chlorine-free cables:** The transition to PVC alternatives for internal cables was not trivial. Many of the alternative materials for external cables that were available did not meet Apple's strict cosmetic and mechanical requirements. In some cases Apple was able to avoid the use of cables altogether by simplifying the internal design of its equipment. Such an approach allowed Apple to replace over six feet of cables in the Mac Pro with more material-efficient connectors that allow easy disassembly at end of life.

- **Bromine/chlorine-free solder paste and flux:** Apple conducted trials with several suppliers comparing traditional brominated fluxes with bromine-free alternatives to quantify changes in manufacturability. Process conditions had to be adjusted to determine the optimal soldering conditions for the solder paste and flux selected for Apple's manufacturing process.

During the initial phases of the transition, availability of bromine- and chlorine-free parts was an ongoing concern. The schedules of the company's supply chain partners had to be considered since it typically took several months for the suppliers to complete qualification testing and ramp-up volumes of new bromine- and chlorine-free materials. Suppliers subsequently used Apple products as a launch vehicle for offering new bromine-free and chlorine-free materials to other equipment manufacturers.

Technical challenges remain. For example, identifying suitable PVC alternatives for external AC and DC power cables has proven to be extremely difficult due to regional variations in external safety standards. The variance in international safety standards poses a major challenge to electronics manufacturers who support a worldwide customer base, and it can force the development of multiple alternatives to meet differing standards. Apple has been working with resin manufacturers and cable extruders to develop customized resins that meet its requirements. Apple has already shipped millions of products with PVC-free alternatives. For example, the company has been shipping PVC-free USB cables and headphone cables for iPod and iPhone products since the summer of 2008.

Apple has worked closely with suppliers to develop new alternatives for its desktop and notebook products and is in the final stages of developing and certifying PVC-free AC power cables.

USING SAFER CHEMICALS AND MORE SUSTAINABLE ALTERNATIVES

"Materials that adversely affect human health or the environment must not be substituted in place of bromine or chlorine."

– Apple Specification on the Restriction of Bromine and Chlorine, 069-1857-D

Since 2001, Apple has led the industry in increasing the use of inherently fire-resistant metals for enclosures, such as titanium, steel, and aluminum, to avoid the use of any flame retardant. The company has also used new polymers that have higher inherent flame resistance and therefore reduce dependency on flame retardants.

Apple encouraged the use of environmentally benign, cost-effective, and widely available alternatives. The company continued its ban on potential flame retardant substitutes like antimony trioxide and red phosphorous because of their high environmental risk. Apple also conducted toxicity assessments on preferred alternatives to ensure that the company was moving toward safer substances. For example, components in Apple products use flame retardants such as ammonium polyphosphate (or APP, which is often used as a food additive), metal hydroxides (which are used in antacids), and other safer substitutes.

Apple's success in overcoming technical challenges is increasing the market viability of new chemicals and materials that previously could not compete with low-cost applications dependent on bromine and chlorine compounds. This ground-breaking work allows manufacturers to debut chemicals and materials that are designed to have a lower environmental impact yet perform well and meet critical reliability specifications.

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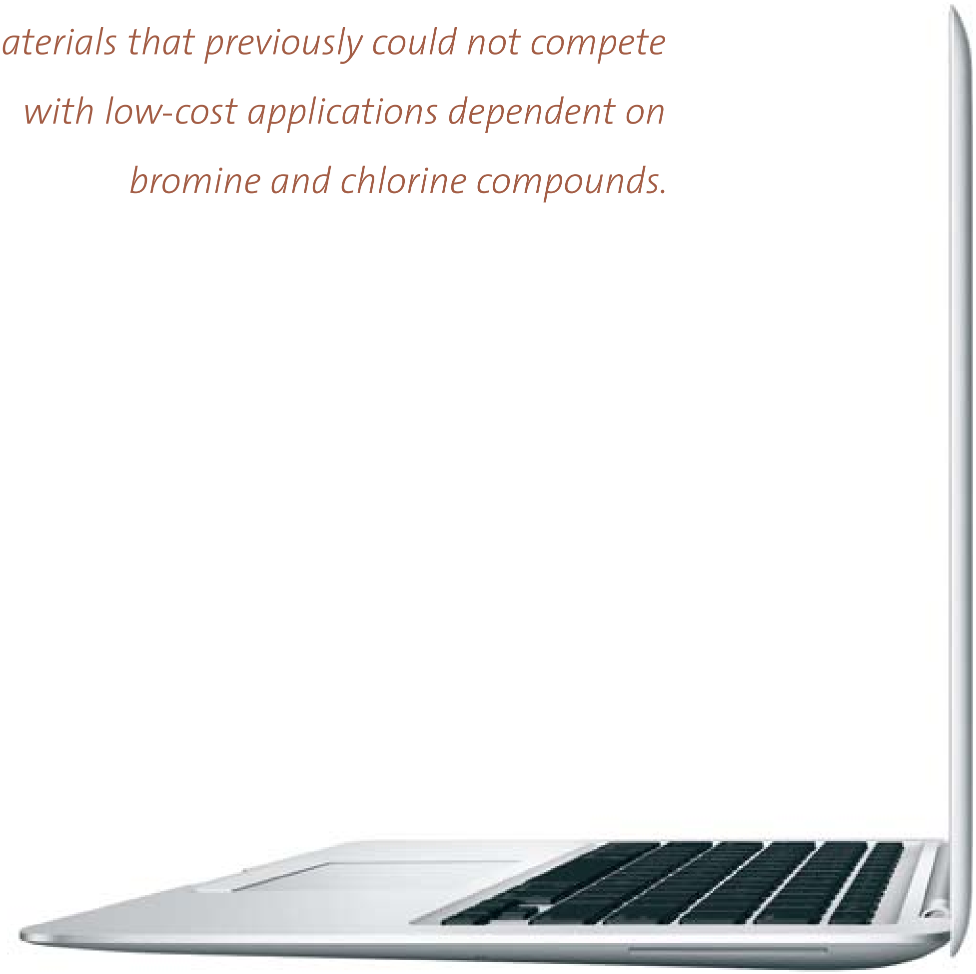

Electronics manufacturers, standards bodies, and legislators have begun to take notice of the human health and environmental concerns associated with the use of brominated and chlorinated compounds in electronic products. An array of conflicting definitions and policies have emerged to address these 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.

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