What’s in your electronic product, where does it come from, and why should a product safety engineer be concerned?

Rick Row
September 28, 2010
IEEE Product Safety Engineering Society
Santa Clara Valley Chapter
Agenda

• Why care what minerals are in your supply chain?
  – More elements, & U.S. relies on imports for many of them
  – CSR, EHS & other issues at mining & material processing end of supply chain threaten resilience of your company
  – Increasing accountability of manufacturers

• Case studies of issues & accountability
  – Conflict minerals from the Heart of Darkness
  – China’s grip on rare earths
  – Lithium: Might keeping your Tesla in batteries become a problem?

• Recommendations for action; & discussion

Please ask quick questions throughout and hold rest for discussion at end
How many elements on the Periodic Table are, and will be, used by the electronics industry?

For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.
Number of elements used in computer chips continues to grow

Materials in a cell phone

- **ABS-PC, 29%**
- **Ceramics, 16%**
- **Cu & its compounds, 15%**
- **Other plastics, 8%**
- **Epoxy, 9%**
- **Silicon plastics, 10%**
- **Flame retardants, 1%**
- **Others, 4%**
- **Ag & its compounds, 1%**
- **Zn & its compounds, 1%**
- **Ni & its compounds, 1%**
- **Fe, 3%**

**Others <1%**
- Sn
- Pb
- Ta
- Co
- Al
- W
- Au
- Pd
- Sb
- Mn
- Li compounds
- Cr$_2$O$_3$
- LC
- RuO$_2$
- Be
- P
- Mo
- ITO
## Minerals in a typical computer system

<table>
<thead>
<tr>
<th>Computer Component</th>
<th>Element or Compound Used</th>
<th>Mineral Source of Element</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRT monitor, phosphorescent coating, transition metal</td>
<td>Zn, S</td>
<td>Sulfur, hemimorphite, zincite, smithsonite, franklinite</td>
</tr>
<tr>
<td></td>
<td>Ag</td>
<td>Silver, pyrargyrite, cerargyrite</td>
</tr>
<tr>
<td></td>
<td>Cl</td>
<td>Halite</td>
</tr>
<tr>
<td></td>
<td>Al</td>
<td>Bauxite</td>
</tr>
<tr>
<td></td>
<td>Cu</td>
<td>Chalcopyrite, boronite, enargite, cuprite, malachite, azurite, chrysocolla, chalcocite</td>
</tr>
<tr>
<td></td>
<td>Au</td>
<td>Gold</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>Euxenite</td>
</tr>
<tr>
<td></td>
<td>Eu</td>
<td>Euxenite</td>
</tr>
<tr>
<td></td>
<td>K, F, Mg, Mn</td>
<td>Alunite, orthoclase, nephelite, leucite, apophyllite; Fluorite, cryolite, vesuvianite, lepidolite, dolomite, magnesite, espinite, spinel, olivine, pyrope, biotite, talc, pyroxenes</td>
</tr>
<tr>
<td></td>
<td>Cd</td>
<td>Greenockite</td>
</tr>
<tr>
<td></td>
<td>As</td>
<td>Realgar, orpiment, niccolite, cobalite, arsenopyrite, tetrahedrite</td>
</tr>
<tr>
<td></td>
<td>Gd, Tb</td>
<td>Monazite, bastnasite, cerite, gadolinite, monazite, xenotime, euxenite</td>
</tr>
<tr>
<td>CRT monitor glass</td>
<td>Pb</td>
<td>Galena, cerussite, anglesite, pyromorphite</td>
</tr>
<tr>
<td></td>
<td>Si</td>
<td>Quartz</td>
</tr>
<tr>
<td>Plastic case, keyboard</td>
<td>Ca</td>
<td>Calcite, gypsum, apatite, aragonite</td>
</tr>
<tr>
<td></td>
<td>Ti</td>
<td>Rutile, ilmenite, titanite</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>Apetite, pyromorphite, wavellite</td>
</tr>
<tr>
<td>Liquid crystal display (LCD) monitors</td>
<td>Pb</td>
<td>Galena, cerussite, anglesite, pyromorphite</td>
</tr>
<tr>
<td></td>
<td>Si</td>
<td>Quartz</td>
</tr>
<tr>
<td></td>
<td>Fe</td>
<td>Hematite</td>
</tr>
<tr>
<td></td>
<td>Sn</td>
<td>Cassiterite</td>
</tr>
<tr>
<td></td>
<td>In</td>
<td>Sphalerite (commonly found with zinc)</td>
</tr>
<tr>
<td>Metal case</td>
<td>Fe</td>
<td>Magnetite, limonite</td>
</tr>
<tr>
<td>Flat-screen plasma display monitors</td>
<td>Si</td>
<td>Quartz</td>
</tr>
<tr>
<td></td>
<td>Pb</td>
<td>Galena, cerussite, anglesite, pyromorphite</td>
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<td>Printed circuit boards, computer chips</td>
<td>Si</td>
<td>Quartz</td>
</tr>
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<td></td>
<td>Cu</td>
<td>Chalcopyrite, boronite, enargite, cuprite, malachite, azurite, chrysocolla, chalcocite</td>
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</tr>
<tr>
<td></td>
<td>Al</td>
<td>Bauxite</td>
</tr>
</tbody>
</table>
A hybrid car exemplifies a mix of green tech & electronics.
Also on tonight at SLAC and will be available on DVD from SLAC library.
Answer: There’s few non-transuranic elements that the electronics industry won’t be using.
Answer: There’s few non-transuranic elements that the electronics industry won’t be using.
U.S. is heavily dependent on other countries for raw materials—yet little systematic analysis of potential materials supply issues.

2006 U.S. Net Import Reliance for Selected Nonfuel Mineral Materials

Source: USGS
From a study of criticality to U.S. of 12 specific elements plus rare earths

EU’s view of criticality of materials

These 14 are regarded as critical

These 14 are regarded as critical

Including these three “conflict minerals”

“Conflict minerals” & “DRC conflict free minerals”

Defined in §1502 of the Dodd-Frank Wall Street Reform & Consumer Protection Act (i.e., Financial Reform Bill or H.R. 4173) — July 21, 2010

“Conflict minerals” (§1502(e)(4))
- Coltan, cassiterite, gold, wolframite, or their derivatives
- Any other minerals/derivatives determined by Secretary of State to finance conflict in DRC or adjoining countries

“DRC conflict free minerals” (§1502(b))
- Product that do not contain minerals that directly or indirectly finance or benefit armed groups in the DRC or adjoining countries

Coltan -> Tantalum (Ta) & niobium (Nb) (columbium)
Cassiterite -> Tin (Sn)
Gold (Au)
Wolframite -> Tungsten (W)
What does §1502 require?

- **Section 1502**
  - July 21, 2010
  - Public comment
  - SEC to enact rules & regs by 4/17/2011
  - Public companies

- **Sec. of State**
  - to design plan to guide commercial entities
  - within 180 days

- **Annual Disclosure to this fact**
  - May label product "DRC conflict free"

- **Did conflict minerals originate in DRC or adjoining countries?**
  - Yes
    - **Conflict minerals necessary to functionality or production of products?**
    - Yes
      - **Additional Annual Report to SEC, plus on company web site**
      - "to exercise due diligence on the source & chain of custody of such minerals"
      - * Independent private sector audit
      - * Description of manufactured products that are not DRC conflict-free
      - * Country origins of "conflict minerals"
      - * Specific efforts used to determine mine and/or location of origin

  - No
    - **May label product "DRC conflict free"**

- **Conflict minerals necessary to functionality or production of products?**
  - No
    - **Cannot use label but NOT required to change source of supply**
      - **DRC conflict-free?**
      - Yes
      - No
Why will §1502 be significant for the electronics industry?

- Industry does use conflict minerals
- Tracking sources of conflict minerals difficult
  - Competitive information; illegal transactions involved; most sources not subject to U.S. jurisdiction; complex supply chains
- Difficult to assess what must be done as key terms are undefined & little practical guidance
  - “Necessary to the functionality or production”
- There is a real underlying social issue, and much public interest in industry’s response

And a lot of people have locked in on a specific “solution” & don’t seem to doubt its efficacy in resolving a complex problem with deep historic roots.

Watch videos on http://www.raisehopeforcongo.org/
A TV story & follow-on social-media buzz show their power in building public interest in a tragic situation.
“Tantalum is arguably the most significant metal on the list for the electronics sector”
Zoe McMahon, Supply Chain Social & Environmental Responsibility Manager, HP, 11Nov09

<table>
<thead>
<tr>
<th>Country</th>
<th>Reserves (tons, in 2010)</th>
<th>Production (tons, in 2009)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>40,000 (38.1%)</td>
<td>560 (48.3%)</td>
</tr>
<tr>
<td>Brazil</td>
<td>65,000 (61.9%)</td>
<td>180 (15.5%)</td>
</tr>
<tr>
<td>Canada</td>
<td>NA</td>
<td>40 (3.4%)</td>
</tr>
<tr>
<td>DRC</td>
<td>NA</td>
<td>100 (8.6%)</td>
</tr>
<tr>
<td>Rwanda</td>
<td>NA</td>
<td>100 (8.6%)</td>
</tr>
<tr>
<td>TOTALS</td>
<td>105,000</td>
<td>1,160</td>
</tr>
</tbody>
</table>
Electronics Industry Actions

• Electronics Industry Citizenship Coalition (EICC) & Global eSustainability Initiative (GeSI) already working
  – Education & stakeholder engagement
  – Engaged Resolve, a non-profit
    – *Tracing a Path Forward: A Study of the Challenges of the Supply Chain for Target Metals Used in Electronics*, April 2010

• IPC, other industry associations, some companies lobbied on bill
  – Also will provide comment to SEC
  – Following & influencing action by supply chain
    • International Tin Research Institute (ITRI) announced Phase II of its Tin Supply Chain Initiative (iTSCI)
Coming up on October 8

The Movement to Ban Conflict Metals: How It Will Affect You — and All Links in the Supply Chain

Dear Colleagues,

Sourcing “conflict metals” from the Democratic Republic of the Congo has become a grave social issue. Now financial reform regarding conflict metals — tin, gold, tantalum and tungsten — has just been signed into law, and reporting will be an SEC requirement for all publicly traded companies. IPC has been following this issue for last two years and will be providing guidance to the SEC.

We are convinced that this new SEC requirement will have a significant impact on the entire electronics industry supply chain — whether your organization is publicly traded or not! You can run but you can’t hide: end users of your products are concerned about this social issue, and will require documentation.

To help you learn more, IPC offers a one-hour presentation, The Movement to Ban Conflict Metals: It Can and Will Impact the Electronics Industry. We encourage you and your staff to stay up-to-date on this important topic: register to participate in the live webinar session on October 8.

Best regards,

Anthony Hilvers
Vice President of Industry Programs
IPC — Association Connecting Electronics Industries®

Register at: www.ipc.org/conflict-metals-registration
And further electronics industry & supply chain responses on conflict minerals to watch for

• EICC and GeSI developing a Smelter Verification Program (SVP) to audit smelters on the origin of their materials.
  – Aim to enable responsible sourcing
  – To cover smelters worldwide, so will cover minerals originating in the DRC
  – Being launching this fall.

• EICC to release a summary statement on website of first audits using SVP, & plan to make summary information available after first round of audits early 2011
  – Initial audits will focus on tantalum suppliers
  – To start tin audits early 2011.

• ITRI (a non-profit representing tin industry) developed a program to 'bag and tag' minerals from the mine to the processors.
  – Provides input to smelters on the origin of materials that SVP will use
  – Now on hold as President of Congo halted mining in 3 eastern provinces where program being trialed
**Rare earths**: reliable supply of great concern outside China

“...disruptions in the availability of **rare earths** would have a major negative impact on our quality of life.”
Committee on Critical Mineral Impacts on the U.S. Economy, 2008

Rest of world (outside China) will face rare earths shortage if new mines outside China are not opened.
Prices have been rising fast

<table>
<thead>
<tr>
<th></th>
<th>3-Year Average</th>
<th>March 2010</th>
<th>June 2010</th>
<th>Sept. 2010</th>
<th>% change March-Sept. 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Oxides</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lanthanum oxide</td>
<td>$2.75</td>
<td>$3.00</td>
<td>$3.69</td>
<td>$16.78</td>
<td>459.33%</td>
</tr>
<tr>
<td>Cerium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxide (glass applications)</td>
<td>1.83</td>
<td>1.86</td>
<td>2.94</td>
<td>16.33</td>
<td>777.96%</td>
</tr>
<tr>
<td>Oxide (water filters)</td>
<td>6.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>XSORBX®</td>
<td>4.50</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Europium oxide</td>
<td>200.94</td>
<td>215.00</td>
<td>258.00</td>
<td>268.38</td>
<td>24.83%</td>
</tr>
<tr>
<td><strong>Metals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lanthanum</td>
<td>$4.55</td>
<td>$6.00</td>
<td>$6.00</td>
<td>$18.14</td>
<td>202.33%</td>
</tr>
<tr>
<td>Praseodymium</td>
<td>14.60</td>
<td>17.27</td>
<td>19.52</td>
<td>29.26</td>
<td>69.43%</td>
</tr>
<tr>
<td>Neodymium</td>
<td>14.73</td>
<td>17.27</td>
<td>19.52</td>
<td>29.71</td>
<td>72.03%</td>
</tr>
<tr>
<td><strong>Alloy products</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NdFeB alloy</td>
<td>$16.00</td>
<td>$19.52</td>
<td>$25.00?</td>
<td></td>
<td>56.28%</td>
</tr>
<tr>
<td>SmCo alloy</td>
<td>23.00</td>
<td>24.61</td>
<td>31.50?</td>
<td></td>
<td>36.96%</td>
</tr>
</tbody>
</table>
Essential to electronics & green tech

“Rare earths are absolutely indispensable. (Green technologies) will not work without rare earths.” Mark Smith, Chief Executive Officer of Molycorp Minerals

Gearless wind turbine—0.2 t NdFeB magnets/MW
Basic rare earth commercial & technical facts

• Global rare earth oxides market is tiny (around $1.3 bn in 2008)
  – But near essential in small amounts for electronics, magnets, etc.
  – Price inelastic
  – REO price has negligible impact on final product price—availability is the issue
  – Limited recycling
• Forecast demand growth 8 to 11% per year (by Roskill); China’s faster (25% pa from 2004 to 2007)
• HREEs rarer in economic quantities; more valuable than more common LREEs
• Capital intensive (>US$40/kg annual capacity)
• Long start-up; limited expertise outside China
• Not found as free metals in the earth’s crust, rather as a mixed ‘cocktail’ of minerals that need to be separated.
  – Rare earths are chemically similar so they are difficult to separate
  – Each orebody is different; so the process route is project specific
  – The ratio of rare earths in any new mine may not be what the market wants, thus will drive prices in both directions
• Rare earths have unique chemical, magnetic and luminescent properties
China increasingly focused on maximizing its use of its rare earth resources

“There is oil in the Middle East; there is rare earth in China”

Deng Xiaoping, 1992

• During 1990s and early 2000s, significant over-production & low prices led to most non-Chinese rare earth producers shutting down their operations.
  • China subsidized costs over past 20 years, plus ignored environmental, health issues, wasted resources in mining rare earths, & licensed many small, inefficient operations
• Since 2004, China provides 90%+ of worldwide production of rare earths
  – By ~ 2013, Chinese demand -> production, so exports could be cut off
  – China declared its “heavy” rare earths resource finite (~15 years)
• Stricter Government control of mining, production & export
  • Export quotas (falling annually) & export taxes (15% to 25%) on rare earth ores; domestic consumption is a priority
  • Tightening up on illegal mining, and smuggling (⅓ of total exports in 2008)
  • Increasing observation of environmental legislation
  • Govt guidelines to enhance consolidation by M&As (cut firms from 90 to 20 by 2015)
• Chinese spending heavily on R&D on rare earths usages
  • Gained control of U.S. & Japanese permanent magnet technology
  • Wants to control supply chain from mines to end uses
• Indications China willing to use rare earths as a political weapon
China has officially denied this story, but its existence is troubling.
Rest of world now scrambling to cover for their “foolishness”

• Jack Lifton: “although the panic over Chinese “hoarding” is misplaced, the U.S.’ dissolution of its domestic rare earth metals production has been equally “foolish.” ... We’ve shut down an industry that’s strategic and critical, and all in the name of low cost.”

• GAO estimates up to 15 years to rebuild U.S. supply chain

• Prices have risen quickly and availability of some rare earths is tight

• China does not have a monopoly on rare earth deposits
  – However:
    "It's very, very dangerous for people to be committing hundreds of millions of dollars to projects that will take another five years or more to see the light of day. With today's prices, a lot of stuff makes sense ... but I also think prices at this level are unsustainable.“

Constantine Karayannopoulos, chief executive of Neo Material Technologies (NEM.TO), Sept. 15, 2010
New mines outside China likely to go ahead first:

- Mt. Weld in Western Australia and Mountain Pass in U.S. are most advanced in development
- Each approx. 20,000 tons REO/year

Will governments or end users be willing to put up equity to reduce risk of continued Chinese domination of rare earths market?
EHS aspects of the rare earths

- Rare earths generally moderately to highly toxic. Symptoms include writhing, ataxia, labored respiration, walking on the toes with arched back and sedation.
- Lanthanum: flammable, can react with water to offgas H₂
- Cerium: ignites spontaneously in air at 150–180°F
- Praseodymium: chemical, physical & toxicological properties have not be thoroughly investigated; moderately to highly toxic
- Neodymium: flammable dust; chemical, physical & toxicological properties have not been thoroughly investigated
- Neodymium-iron-boron magnets extremely powerful
  - Can shatter if fly together, wear protective glasses around them
Lithium—next critical element or overblown media attention?

- Can Bolivia become the next Saudi Arabia of the electric car era?
- Future demand for lithium in batteries?
  - Depends on rate of expansion of lithium-ion battery demand in plug-in hybrid & electric vehicles
  - Substitutes are possible
  - R&D has been funds limited; non-lithium chemistries breakthroughs still possible
Bolivia’s dream to dominate the electric car market is just that, for now

- Too much competition
- Not attractive to mining companies (e.g., hostile to foreign investment, poor infrastructure, little industrial base, extreme income disparity)
- But maybe international aid now to Bolivia would pay off in long term

<table>
<thead>
<tr>
<th>Country</th>
<th>Mine production 2008</th>
<th>Mine production 2009e</th>
<th>Reserves²</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>W</td>
<td>W</td>
<td>38,000</td>
</tr>
<tr>
<td>Argentina</td>
<td>3,170</td>
<td>2,200</td>
<td>800,000</td>
</tr>
<tr>
<td>Australia</td>
<td>6,280</td>
<td>4,400</td>
<td>580,000</td>
</tr>
<tr>
<td>Brazil</td>
<td>160</td>
<td>110</td>
<td>190,000</td>
</tr>
<tr>
<td>Canada</td>
<td>690</td>
<td>480</td>
<td>180,000</td>
</tr>
<tr>
<td>Chile</td>
<td>10,600</td>
<td>7,400</td>
<td>7,500,000</td>
</tr>
<tr>
<td>China</td>
<td>3,290</td>
<td>2,300</td>
<td>540,000</td>
</tr>
<tr>
<td>Portugal</td>
<td>700</td>
<td>490</td>
<td>NA</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>500</td>
<td>350</td>
<td>23,000</td>
</tr>
<tr>
<td>World total (rounded)</td>
<td>25,400</td>
<td>18,000</td>
<td>9,900,000</td>
</tr>
</tbody>
</table>

The identified lithium resources total 2.5 million tons in the United States and approximately 23 million tons in other countries. Among the other countries, identified lithium resources for Bolivia and Chile total 9 million tons and in excess of 7.5 million tons, respectively. Argentina and China each contain approximately 2.5 million tons of identified lithium resources.

Source: USGS
Better materials management pays off over the long term

Source: Nokia
Recycling can reduce dependence on foreign suppliers

- The expansion in the number of elements used in electronics will put additional demands on recyclers
- The U.S. has not assigned a high priority to the recovery to secondary materials cf European Union, Japan, South Korea, etc.
Product safety engineers can play a key role in maintaining business performance as social values evolve & pressure on natural resources builds.
Recommendations

• Lobby federal government to do its job
  – China’s stranglehold is our failure
    • Free market won’t pay a premium for national security of supply; will the U.S. government to keep critical know-how and mineral production in the country?
    • Review & consider support for federal legislation (e.g., RESTART Act)
  – Gov’t agencies better suited to help reduce violence in Congo than this attempt to embargo difficult-to-identify “conflict minerals” in U.S.
    • IPC, other industry associations, and a number of affected companies lobbied to reduce burden of “conflict minerals” requirement
    • Propose & support alternative actions more likely to succeed & less burdensome
  – Help less developed countries like Bolivia to avoid resources curse

• Partner with government, other industries and civic organizations to jointly maintain industry criticality matrices & to trace raw materials

• Take DfE and recycling seriously
  – Reduce primary demand; design with substitution in mind, when possible

• Stimulate EHS R&D for technology metals
  – Knowledge (e.g., toxicological) is scarce
  – Manufacturing with nano materials scenario?
References


• USGS Minerals Information Team publications
  – Most significant complier in U.S. of information on nonfuel minerals
  – But no current U.S. federal source of all needed info to track criticality of minerals annually

• Dudley Kingsnorth’s presentation on Rare Earths to SME Annual Meeting 2010

• Rare earth market consultants: Jack Lifton, Roskill Information Services, Dudley Kingsnorth, RareMetalBlog

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