CRM Vision Workshop

Printed Circuit Boards
### Scope

List of critical raw materials at EU level (in alphabetical order):

<table>
<thead>
<tr>
<th>Antimony</th>
<th>Indium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beryllium</td>
<td>Magnesium</td>
</tr>
<tr>
<td>Cobalt</td>
<td>Niobium</td>
</tr>
<tr>
<td>Fluorspar</td>
<td>PGMs (Platinum Group Metals)$^1$</td>
</tr>
<tr>
<td>Gallium</td>
<td>Rare earths$^2$</td>
</tr>
<tr>
<td>Germanium</td>
<td>Tantalum</td>
</tr>
<tr>
<td>Graphite</td>
<td>Tungsten</td>
</tr>
</tbody>
</table>

$^1$ The Platinum Group Metals (PGMs) regroups platinum, palladium, iridium, rhodium, ruthenium and osmium.

$^2$ Rare earths include yttrium, scandium, and the so-called lanthanides (lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutetium)
### Scope – Printed Circuit Boards and Electronic components

<table>
<thead>
<tr>
<th>Printed circuit boards (with components)</th>
<th>CRM content</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Printed circuit board</strong> (bare without components)</td>
<td>Pd - not very common generally Ni/Cu and Au are used</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Components</th>
<th>Ta, Pd, Nb</th>
</tr>
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<tbody>
<tr>
<td>Capacitors</td>
<td>Ta, Pd, Nb</td>
</tr>
<tr>
<td>Resistors</td>
<td>Ta, Ru</td>
</tr>
<tr>
<td>Semiconductors</td>
<td>Ga, Ge, In, Sb, Ta</td>
</tr>
<tr>
<td>Transistors</td>
<td>Ga, Ge</td>
</tr>
</tbody>
</table>

**Electronic and integrated circuits**

<table>
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<th>Capacitors</th>
<th>Ta, Pd, Nb</th>
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<tr>
<td>Transistors</td>
<td>Ga, Ge</td>
</tr>
<tr>
<td>Connectors</td>
<td>Pd Ru, Be</td>
</tr>
</tbody>
</table>
Top PCB producers in 2012 and PCB production by region

Top 10 PCB producers in 2012, and their share of global output:

- Singapore: 0.8%
- Philippines: 0.8%
- Vietnam: 0.8%
- Germany: 1.8%
- Thailand: 2.2%
- USA: 4.6%
- Taiwan: 13.2%
- South Korea: 13.4%
- Japan: 14.7%
- China: 42.8%

World PCB production by region, 2012:

- Asia/Pacific: 90.1%
- North America: 5%
- Europe: 4.5%
- Middle East & Africa: 0.2%
- Other Americas: 0.2%

Total: $59.98 billion
End markets for PCBs in Western Europe 2011

End markets for PCBs, Western Europe 2011

- Instrumentation/Medical: 10%
- Industrial electronics: 23%
- Military/Aerospace: 7%
- Consumer electronics: 9%
- Computers: 14%
- Communications: 17%
- Business retail: 1%
- Automotive: 14%
- Other: 5%

End markets for PCBs in Western Europe 2011
**Electronics production forecast 2021**

**ELECTRONICS PRODUCTION**  
**2009 - 2021**

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2011</th>
<th>2013</th>
<th>2015</th>
<th>2021</th>
<th>CAAGR '09-'15</th>
<th>CAAGR '15-'21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computers and Office</td>
<td>$396</td>
<td>$433</td>
<td>$474</td>
<td>$500</td>
<td>$617</td>
<td>4.0%</td>
<td>3.6%</td>
</tr>
<tr>
<td>Communications Infrastructure Equipment</td>
<td>$157</td>
<td>$174</td>
<td>$192</td>
<td>$213</td>
<td>$281</td>
<td>5.2%</td>
<td>4.7%</td>
</tr>
<tr>
<td>Consumer and Portable Electronics</td>
<td>$298</td>
<td>$319</td>
<td>$341</td>
<td>$400</td>
<td>$479</td>
<td>5.0%</td>
<td>3.1%</td>
</tr>
<tr>
<td>Automotive Electronics</td>
<td>$105</td>
<td>$129</td>
<td>$158</td>
<td>$161</td>
<td>$237</td>
<td>7.4%</td>
<td>6.6%</td>
</tr>
<tr>
<td>Medical Electronics</td>
<td>$77</td>
<td>$85</td>
<td>$93</td>
<td>$103</td>
<td>$134</td>
<td>5.0%</td>
<td>4.5%</td>
</tr>
<tr>
<td>Military and Aerospace Electronics</td>
<td>$118</td>
<td>$129</td>
<td>$140</td>
<td>$151</td>
<td>$189</td>
<td>4.2%</td>
<td>3.8%</td>
</tr>
<tr>
<td>Total Electronics Production</td>
<td>$1,242</td>
<td>$1,382</td>
<td>$1,541</td>
<td>$1,679</td>
<td>$2,171</td>
<td>5.2%</td>
<td>4.4%</td>
</tr>
</tbody>
</table>

Source: [INEMI 2013 Roadmap](https://www.inemi.org)
PCB production forecast 2016

Source: BPA 2012
Global PCB market value will increase from $56.6 billion in 2011 to $68.5 billion in 2016, China's share of production will increase from 45% to 51%.
Forecast industrial electronics semiconductors 2018
Price development of Pd, Ru and Pt
Gallium Arsenide market forecast 2017

Source: GaAs Wafer Market & Applications
Palladium consumption in multilayered ceramic capacitors

Source: Paumanok Publications, Inc
Flexible, organic and printed electronics – expected impacts

Source: IDTechEx 2014
Printed electronics forecast

The global PCB manufacturing market is expected to increase its market size from around $62.3bn in 2013 to around $74.31bn in 2018.

Source: NanoMarket

What is substitution?

Substance for Substance

Process for Process

Service for Product

New Technology for Substance
Landscape / drivers

- Trends in electronics
  - Ubiquitous electronics
  - Green electronics
  - Flexibility, recyclability
- Green image
- Pressure from NGOs and public
- Legislation and regulation
  - Restrictions of toxic materials
  - REACH
  - Platinoide legislation
  - Green public procurement guideline
- Price is an important driver if it becomes extra high -> performance
- New business in EU
- Standardization
- Mining

Restraining issues:
- Long time to be able to substitute
- New CRMs
- Safety issues
- No pressure for substitution from the end users
- Energy vs. material efficiency

- Recyclability,
- Environmental protection,
- Safety
Policy initiatives

• Policies to support recycling to ensure the availability of (the recycled) CRM
• Strategies made in collaboration with industries and other stakeholders
• Environmental protection policies
• No single country is able to change the situation, must be done European wide in collaboration – in collaboration even worldwide
• Awareness and transparency; what raw materials the products include
• Responsibility: from EPR to IPR
• Design the materials for recycling and recycling organized
Market initiatives

- Research exists; to bring the results to market needs more support
- Financial support is needed for industry to develop substitution solutions
- Large scale R & D covering the whole value chain; Closed loop business models
- Reuse is developing
- Stockpiling of CRMs
- Devices with new functionalities
Research initiatives

- H2020: funding mechanism should support better industry participation – less byrocracy, bigger projects
- Funding is too strictly limited to specific topics, integration on systems level is needed
- Specific research targets (e.g. material by material substitution) can only be funded nationally, bigger efforts on EU or global level

- Cleansky 2;
- Green Elec- easier recyclability
- Graphene research
- Substitution of Indium

- Plating manufacturing: from subtractive to additive manufacturing
## Research initiatives

<table>
<thead>
<tr>
<th>SUBSTANCE FOR SUBSTANCE</th>
<th>PROCESS FOR PROCESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Cobalt replacement</td>
<td></td>
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<table>
<thead>
<tr>
<th>SERVICE FOR PRODUCT</th>
<th>NEW TECHNOLOGY FOR SUBSTANCE</th>
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<tr>
<td></td>
<td>• Plating manufacturing: from subtractive to additive manufacturing</td>
</tr>
<tr>
<td></td>
<td>• Augmented reality</td>
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</table>
PCB – forwards to Vision 2030

Currently about 90% of the production in Asia/Pacific Market and product expectations:
- Embedded components e.g. in carbon fibre
- Flexible electronics
- In home monitoring
- Safety & Security
- Manufacturing 3.0
- PCB higher temperature resistant
- Privacy related technology

Key drivers for substitution
- Where recycling & reuse are not the option – e.g., miniaturisation and embedded in different materials
- Performance main driver but varies based on specifics of the application e.g. GaN ‘wrong way substitution’
- Availability of CRM

R&D funding to address gaps – types of ways to fund substitution

Collaboration