Materials challenges for terawatt-scale Photovoltaics

Peter Rigby
Content

- Defining the challenge / trends in the PV industry
- Materials availability and supply chain optimisation
- PV industry strategies to meet the challenge
- EU involvement and commitment in meeting the materials challenge
- Summary and conclusions
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PV is only one of a panoply of 21st century growth industries taken for granted but which also require careful consideration and forward thinking with respect to materials availability. For example:

- Batteries
- Electric motors, generators => EV, wind turbines, Micro electronics, displays & audio visual
- Catalysts containing precious and scarce metals
- Etc

The “Materials Challenge” is multi faceted and relates to:

- Materials availability (geological, technological & geo-political constraints)
- Cost
- Performance

The different facets need to be identified, quantified, categorised and a mitigating strategy developed
Defining the challenge – PV trends

### WORLD-WIDE CUMULATIVE PV INSTALLED CAPACITY AND PRODUCTION TO 2050 USING THE REFERENCE, ACCELERATED AND PARADIGM SHIFT SCENARIOS

<table>
<thead>
<tr>
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<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
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*source: Greenpeace/EPIA Solar Generation VI, 2010.*
Defining the challenge – PV trends

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Defining the challenge – PV trends

Paradigm Scenario - Forecast world PV production

World PV production - GWp/year

Defining the challenge – PV technology evolution

PV has the advantage of having several interchangeable technologies each using different materials systems

Materials challenges for terawatt-scale Photovoltaics - Peter Rigby
Defining the challenge – PV technology evolution
### Defining the challenge – materials needs

<table>
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<th>Metal</th>
<th>PV production 2020</th>
<th>Specific metal requirement in 2020</th>
<th>Paradigm scenario total demand in 2020 for PV</th>
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<td>c-Si</td>
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Source: Umicore
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Simplified flow schematic for metals

Mining Ores → Extraction (Base metal smelters) → Refining → Intermediate Products → Device Mfr → Device Installation

Tailings / Slags (Buffer) → Production scrap stockpile (Buffer)

"Urban" Mining → EOL dismantling → EOL collection

Prod’nScrap Collection / logistics

"Lost" in parent metal → "Lost" Non-collected Devices
Materials supply – the “metals tree”


Materials challenges for terawatt-scale Photovoltaics - Peter Rigby
• Increased demand can only be met by primary production if demand for major metal rises accordingly.

• This will place an absolute cap on total material availability in terms of total reserves and production capacity.

...hence supply is finite

Extraction and refining are complex processes and require planning and investment. Increased demand will lead to temporary price peaks during the lead time necessary to install new capacity.

China’s rare-earth policy hurts optics makers

14 Oct 2010

*Export restrictions have sent the price of cerium oxide through the roof, and highlighted the industry’s vulnerability to Chinese imports.*

Following export restrictions imposed on rare-earth minerals by China in the summer, the *soaring price of cerium oxide* – a key material used as a polishing slurry for high-precision optics – is causing havoc in the optics supply chain.

According to industry sources, one company has already been forced to shut down as it awaits supplies of the material, while others may introduce a cerium surcharge if the situation does not change. Suppliers of cerium-based products are unable to guarantee prices beyond more than a few days.

One supplier has told a customer: “Due to the volatility of material availability, and changes in raw material pricing almost every day, if we cannot ship the order within the next five days the material is subject to price changes prior to actual shipment.” The price hike is also set to hit the cost of glasses and crystals doped with rare-earth elements – although the increase is taking longer to filter through this part of the optics supply chain.

**Price hike**

Robert Castellano, an industry analyst at *The Information Network*, told *optics.org*: “The market price of cerium oxide has increased to approximately $50 per kilogram in September 2010 from $15 per kg in April 2010 and $9 per kg in September 2009.”

That sudden price-hike has since been reflected directly in

![Cerium metal](image)
## Defining the challenge – materials needs

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<th>Metal</th>
<th>PV production 2020</th>
<th>Specific metal requirement in 2020</th>
<th>Paradigm scenario total demand in 2020 for PV</th>
<th>Estimated annual worldwide primary production 2010</th>
<th>Recycled material 2010</th>
<th>Total production 2010</th>
<th>2020 PV demand vs 2010 total production</th>
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Source: Umicore
Sources – Need to better understand the resources
Extraction yields and primary refining – need to optimise
Production / scrap recycling – optimise material yields in device production and production waste recycling circuits
End of Life recycling – requires effective collection logistics, recycling loops and meaningful targets for metals recovery
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Defining the challenge – PV competitiveness

€/KWh

![Graph showing PV generation cost at lowest price, utility peak power, and utility bulk power over years 1990 to 2040.]

- PV GENERATION COST AT LOWEST PRICE
- UTILITY PEAK POWER
- UTILITY BULK POWER

* h/a: Hours of sun per annum. 900 h/a corresponds to northern countries of Europe, 1,800 h/a corresponds to southern countries of Europe.

Source: EPRA.
Defining the challenge – PV cost reduction
Defining the challenge – Reducing specific material needs

Source EPIA
Trends in the PV industry – Historical improvements to efficiency
Trends in the PV industry – Efficiency improvements

Expected evolution of TFPV technology lab record efficiencies

Source PV Technology Platform
Efficiency evolution of CZTS is fast compared to other TFPV technologies.
Substitution - Indium?

Technically very challenging, but many research groups are working on the subject.
It is reasonable to believe that some low end applications may be substituted, although this has not been factored into the demand study.

Gross Consumption 2020 ~ 2.600 MT

- CIGS layer: 30%
- ITO in PV: 11%
- ITO in FPD: 51%
- Other applications: 7%

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EU policies and activities with respect to materials and resource efficiency
EU Policies with respect to materials and resource efficiency

**RMI** – first communication report on 2008 / second communication in February 2011 to highlight key issues

**EIP for raw materials** is in preparation under the auspices of DG Enterprise. Its scope will cover:
- Implementation of research topics e.g. mining, processing, recycling, substitution….
- Pilot plants and financing e.g. deep sea mining, landfill mining, recycling

A road map is being prepared by ETP SMR

**Innovation action partnerships** – EU / US / Japan

Examples of activities:
- EU + US DOE workshop in October 2011 on access to critical materials
- Joint research
- Recycling
- Illegal waste shipments
- Trade issues

**Other actions:**
- Generally raising awareness of illegal shipments of waste through the media
- Recycling - linking WEEE to the RMI
- Resource efficiency – re-use, recycling, substitution
EU Policies with respect to materials and resource efficiency

SET Plan – Materials research roadmap

To be presented in November at SET Plan conference. Fully aligned with the PVTP SRA2

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<tr>
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<th>T0+3</th>
<th>T0+5</th>
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<tr>
<td><strong>Develop predictive behavioural materials model</strong></td>
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<tr>
<td>R&amp;D for improved performance materials, processes and PV devices (cells/module) - thinner layers, wide band gap</td>
<td>R&amp;D on anti-reflective/anti-soiling/abrasion resistant coatings, enhanced light trapping/guidance, spectral conversion and new materials, lens design and production processes for optical concentrators</td>
<td>&amp; quantum structures</td>
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<td>Optimised Materials usage</td>
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<td>Light management</td>
<td>R&amp;D on improved anti-reflective/anti-soiling/abrasion resistant coatings, enhanced light trapping/guidance, spectral conversion and new materials, lens design and production processes for optical concentrators</td>
<td>R&amp;D on alternative material systems for TFPV</td>
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<tr>
<td>High throughput, low cost film / layer deposition / thin film (epitaxial) growth</td>
<td>R&amp;D on:</td>
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<tr>
<td>Novel materials</td>
<td>- improved vacuum based processes</td>
<td>- new materials for (transparent and non-transparent) conductors for magnetics&lt;br&gt;- CPV trackers: low cost materials</td>
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<tr>
<td>Materials for system related devices</td>
<td>- non-vacuum solution processing for thin films&lt;br&gt;- epitaxial growth (e.g. thin crystalline silicon layers)&lt;br&gt;- alternative processes to replace current front and back metallisation of crystalline silicon cells</td>
<td>- novel particle synthesis techniques.&lt;br&gt;- layer cost &lt;0.05€/Wp (module cost 0.5€/Wp) - 10% of efficiency improvement</td>
<td></td>
</tr>
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<td>Supporting Research &amp; Educational infrastructure</td>
<td>Pilot scale manufacturing line for thin, high strength low cost PV glass</td>
<td>Pilot scale manufacturing lines of specific solar grade materials&lt;br&gt;- non-vacuum processing materials&lt;br&gt;- plasmonic effect (nano particle synthesis techniques)</td>
<td>Pilot scale manufacturing lines for PV devices incorporating improved performance materials&lt;br&gt;- low silver/silver-free metallisation&lt;br&gt;- encapsulants, optical glues&lt;br&gt;- containing TCOs&lt;br&gt;- low silver/silver free metallisation&lt;br&gt;- pilot scale manufacturing lines of specific solar grade materials&lt;br&gt;- improved vacuum based processes&lt;br&gt;- non-vacuum solution processing for thin films&lt;br&gt;- epitaxial growth (of e.g. thin crystalline silicon layers)</td>
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Summary and conclusions

Anticipated strong growth in PV will be accompanied by stress in the supply chain for specialty (scarce) metals

The “stress” is manageable by a number of strategies:

- Improving the extraction rates and primary refining of metals
- Improving knowledge of reserves
- Optimising the in-process waste management and recycling
- Effective End of Life recycling schemes with meaningful targets
- Using less material by:
  - making more efficient devices
  - making thinner layers
  - increasing materials yield in production
- Maintaining parallel PV technologies using different materials systems and developing new substitute materials systems
Back up
Gross Consumption of Indium *

Includes change in inventory requirements, Based on annual PV production of 160 GWp

Source: Umicore

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