LCA of microwave absorbers obtained from copper slags

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DISMI
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PROJECT LIFE10 ENV/IT/419

Partners involved:
• Industries: Ceramica Fondovalle S.p.A. and Micro Energy S.r.l.
• University of Trento
• University of Modena and Reggio Emilia

General goal:
Energy free valorisation of copper metallurgical waste
Objectives

✓ Diminution of the environmental load

✓ Strengthen the slags market through its valorisation

Producing new materials as:
- heating elements
- semiconducting glazes (residential applications)
- MW absorbers

Vs traditional materials: less energy, less raw materials

1 ton Cu → ton Cu slags

Concrete additive, anti-freeze layer in road construction, mineral abrasive...
MW ABSORBERS

Bulk with copper slags (CS)

Tile with copper slags (CS)

Silicone carbide (SiC) tile

Powder (65-70wt%)
Waste glass (15-20wt%)
Other oxides (10wt%)

Powder (60wt%)
Clays (40wt%)

SiC: 78%
Bond: 20%
Iron oxide: 0.9%
Other oxides: 1.1%
Flow Chart  Primary Production of copper (IPCC-BREF)

Flow Chart Bulk with CS

- Economic allocation 0.853%
  - Copper slags
  - Other raw materials
  - Electric energy
  - Thermal energy
  - Transports
  - Pallet
  - Cardboard
  - Protective film

- Storage and characterization of raw materials
  - Grinding of slags
  - Charging of raw materials
  - Mixing of raw materials
  - Melting
  - Casing
  - Sorting and packaging
  - Final distribution

- Recycling of scraps
- Air emissions
- Wood recycling
- Cardboard recycling
- Protective film recycling

- End of life management
Flow Chart of tile with CS

1. Extraction of clay raw materials and transport to the factory
2. Slip production
3. Atomisation
4. Weighing and dry mixing
5. Laying atomized and pressing
6. Firing in a hybrid kiln
7. Cutting and drilling (on request)
8. Sorting and packaging
9. Final distribution
10. End-of-life management

- Diesel
- Electricity consumption

- Airborne emissions
- Wastewater treatment
- Recycling of atomized waste
- Recycling of scraps of fired tiles
- Recycling of scraps of cutting
- Wood Recycling
- Cardboard recycling
- Protective film recycling

Raw materials preparation
Green
Firing
Machining
Distribution
Flow Chart of SiC tile

- Extraction of clay raw materials and transport to the factory
- Collection and transport of copper slag
- Slip production
- Milling to the desired size
- Atomisation
- Weighing and dry mixing
- Laying atomized and pressing
- Firing in a hybrid kiln
- Cutting and drilling (on request)
- Sorting and packaging
- Final distribution
- End-of-life management

- Raw materials preparation
  - Airborne emissions
  - Wastewater treatment

- Green
  - Recycling of atomized waste
  - Airborne emissions
  - Recycling of scraps of fired tiles

- Firing
  - Airborne emissions
  - Recycling of scraps of cutting

- Machining
  - Wood recycling
  - Cardboard recycling
  - Protective film recycling

- Distribution
  - Protective film recycl
## Microwave absorbers

<table>
<thead>
<tr>
<th>Type</th>
<th>Size</th>
<th>Weight</th>
<th>Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk with CS</td>
<td>325x325x10mm</td>
<td>2.28 kg</td>
<td>Microenergy Srl</td>
</tr>
<tr>
<td>Tile with CS</td>
<td>325x325x10mm</td>
<td>3 kg</td>
<td>Saint-Gobain Ceramics</td>
</tr>
<tr>
<td>SiC tile</td>
<td>325x325x10mm</td>
<td>2.01 kg</td>
<td></td>
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</tbody>
</table>
**Microwave absorbers**

- **Bulk with CS**
  - Absorbers
  - → release the absorbed heat, speeding up heating
  - → contribute to the capture of microwave emissions

- **Tile with CS**

- **SiC tile**

**Dir. 2013/35/UE**

Exposure Limit Value, ELV: 50 Wm\(^{-2}\)

\(6 \text{ GHz} \leq f \leq 300 \text{ GHz}\)
1. LCA of the bulk with $CS$

2. LCA of the tile with $CS$

3. LCA of the SiC tile

4. LCA comparative analysis of all 3 materials
**Goal and scope** 1) Assessment of the environmental impacts caused by the production of the bulk and the ceramic tile containing copper slags applied on industrial microwave. 2) Comparative analysis carried out between the innovative products and one commonly used in the target market (SiC tile).

**Studied system** a bulk and a ceramic tile both obtained using copper slags, compared to the traditional tile contained SiC.

**Function of the system** to attenuate microwave emissions in accordance with the provisions of the legislation (Dir. 2013/35/UE).

**Functional unit** mass of material produced, which represents one tile (325x325mm) required for the lifespan of one industrial microwave oven.

**System boundaries** all the stages of the product’s life from-cradle-to-grave.

**Data quality** Primary data, literature data, database (Ecoinvent, Unimore-LWG)

**Software** SimaPro 8.0.2

**Valution method** Impact 2002+
Assumptions

Economic allocation
Copper slags are not considered as waste (K. Harn Wei 2013)

<table>
<thead>
<tr>
<th></th>
<th>Mass production</th>
<th>Price</th>
<th>Allocation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>1 ton</td>
<td>5305 €/ton*</td>
<td>99,147%</td>
</tr>
<tr>
<td>Slags</td>
<td>1,63 ton</td>
<td>28 €/ton**</td>
<td>0,853%</td>
</tr>
</tbody>
</table>

Efficacy and duration
Same performance for the three materials examined

*London Metal Exchange (09-18-2013)
**Peute Baustoff GmbH, subsidiary of Aurubis AG (Hamburg)
Analysis of Bulk with CS

Preparation + Mixing of raw materials

- Carcinogens
- Non-carcinogens
- Respiratory organic
- Respiratory inorganics

- Ozone layer depletion
- Ionizing radiation
- Global warming

- Aquatic ecotoxicity
- Terrestrial ecotoxicity
- Terrestrial acid/nutri

- Land occupation
- Mineral extraction
- Non renewable energy
Analysis of Bulk with **CS**

- **Functional Unit:** 2,28kg
- **Total Damage:** 1,38E-3Pt
- **Major process contribution:**
  - 50% **Melting**
  - 42% **Preparation raw materials**

- **Major impacts on:**
  - 32% **Non renewable energy**
  - 29% **Respiratory inorganics**
  - 26% **Global Warming**

- 36% **Respiratory inorganics**  \( PM \ 2,5 \)
- 19% **Non renewable energy**  \( Oil \)
- 17% **Global Warming**  \( CO_2 \)
- 15% **Terrestrial ecotoxicity**  \( Zinc \)

**Natural gas**  \( PM \ 2,5 \)

**Melting process**
Analysis of Tile with CS

| Slip production | Pressing Drying Firing |

- Carcinogens
- Non-carcinogens
- Respiratory organic
- Respiratory inorganics
- Ozone layer depletion
- Ionizing radiation
- Global warming
- Aquatic ecotoxicity
- Terrestrial ecotoxicity
- Terrestrial acid/nutri
- Land occupation
- Mineral extraction
- Non renewable energy
Analysis of Tile with CS

- Functional Unit: 3kg
- Total Damage: 8,53E-4Pt
- Major process contribution:
  - 40% Slip production
  - 28% Pressing-Drying-Firing
- Major impacts on:
  - 31% Respiratory inorganics → $PM\,2.5$
  - 27% Non renewable energy → Natural gas
  - 24% Global Warming → $CO_2$
  - Slip production
    - Firing
Comparison between Bulk with CS, Tile with CS and SiC tile

- Bulk with CS
- Tile with CS
- SiC tile

- Carcinogens
- Ozone layer depletion
- Aquatic ecotoxicity
- Land occupation

- Non-carcinogens
- Ionizing radiation
- Terrestrial ecotoxicity
- Mineral extraction

- Respiratory organic
- Global warming
- Terrestrial acid/nutri
- Non renewable energy

- Respiratory inorganics
Comparison between Bulk with CS, Tile with CS and SiC tile

- Functional Unit: the necessary mass for one MW oven
- Total Damage Bulk with CS: 1,38E-3 Pt → 54% lower than SiC tile
- Total Damage Tile with CS: 8,53E-4 Pt → 72% lower than SiC tile
- Total Damage SiC Tile: 3,01E-3 Pt
- Major process contribution:
  - 83% Slip production → 94% SiC production
SiC production

Composition of 1kg of SiC (Ecoinvent database)

RoW, Rest of the World
RER, European production
Recycled RoW and RER
Sensitivity analysis: Tile with CS and tile with only recycled SiC

Bulk with CS

Tile with recycled SiC

- Carcinogens
- Non-carcinogens
- Respiratory organic
- Respiratory inorganics
- Ozone layer depletion
- Ionizing radiation
- Global warming
- Aquatic ecotoxicity
- Terrestrial ecotoxicity
- Terrestrial acid/nutri
- Land occupation
- Mineral extraction
- Non renewable energy
Sensitivity analysis: Tile with CS and tile with only recycled SiC

- Functional Unit: the necessary mass for one MW oven

- Total Damage Bulk with CS: 1,38E-3 Pt

- Total Damage recycled SiC Tile: 9,17E-4 Pt

→ 28% higher than recycled SiC tile!
CONCLUSIONS

Among the all MW absorbers analysed, the innovative material produced by Microenergy S.r.l shows the best environmental performance.

**Valorisation of waste material**

- 90% of waste raw materials have been used to produce the final bulk samples
- 60% of waste material have been used in the production of copper slags tile
Possible improvements

- Preferring national supply
- Opt for a transport with lower environmental impact

Copper slags

Assumptions of efficacy and duration

- Model a correlation factor
- Assess the release of heat

More study on toxicity
On environment and human health

- Assess an eventual release of slag components
Thank you for your attention