LCA Case Studies

LCA of Electronic Products

An environmental assessment of Gallium Arsenide Monolithic Microwave Integrated Circuit System-In-a-Package (SIP) Switch Product

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Abstract

Intention, Goal, Scope, Background. A new paradigm called System-In-a-Package (SIP) is expected to represent the wave of future microsystem packaging and integration. No environmental assessment has been made of manufacturing processes for SIP and the purpose of this paper is to assess the upstream environmental impact of the process used by Chalmers to manufacture an electronic product using the SIP technology.

Objectives. This paper aims at an environmental assessment of a gallium arsenide (GaAs) Monolithic Microwave Integrated Circuit (MMIC) Switch Product based on a so-called SIP concept on a Liquid Crystalline Polymer (LCP) substrate. This study focuses on the identification of environmentally substantial upstream processes from cradle-to-gate for this product.

Methods. This work is based on a life cycle inventory model that has been developed earlier by the authors, and this model is now applied to the system including the straight-line manufacturing processes in the facilities of the Microtechnology Centre (MC2) at Chalmers University of Technology and the manufacturing processes of raw materials in the upstream processes. A main scenario was built in the LCA software EcoLab corresponding to the linear process in MC2 and other manufacturing processes were identified in the upstream which were used to develop the upstream process tree.

Results and Discussion. The spin coating of photoresist material has the highest environmental impact within the system boundaries and the uncertainty of the results is estimated to be small. The exposure and development as well as deposition stages also give impacts, both for the copper and resistant material deposition. In the manufacturing processes inside MC2, the electricity consumption clearly dominates. The results predominantly reflect energy use, whereas toxicological aspects could not be reliably assessed due to lack of data and reliable methods, and therefore need separate attention. Nevertheless, a toxicology assessment has been made with the Toxic Potential Indicator (TPI), which, compared to a telephone, showed a relatively large value for the switch. The toxic potential of the switch is higher per mass unit than a digital telephone.

Conclusions. The previously developed LCA data collection model worked well for the SIP product. The electricity consumption for the deposition machine and the solvent consumption in spin coating are the two most important hot spots. For greenhouse warming potential the acetone consumption in the spin coating steps is the most significant contributor, and the copper consumption in the copper deposition step dominates for abiotic resource depletion.

Recommendations and Outlook. It is recommended that the machines in the MC2 process lab used to manufacture the SIP product are studied for a longer period of time as it would make the electricity consumption figures more accurate. More electronic packaging concepts, such as System-on-a-chip (SOC) and multi-chip modules (MCM), should be evaluated and compared to SIP.

Keywords: Eco-indicator; electronic products; environmental assessments; gallium arsenide; LCI methodology; life cycle assessment (LCA); life cycle inventory (LCI); liquid crystalline polymer (LCP); monolithic microwave integrated circuit switch; system-in-a-package (SIP); upstream processes

Introduction

A new paradigm called System-In-a-Package (SIP) is expected to represent the wave of future microsystem packaging and integration. SIP is a single component, multi-functional, multi-chip package providing all the needed system functions. In the 21st century, the new challenge is not how many transistors can be built onto a single chip, but how to integrate these together predictably, harmoniously and cost effectively. Designers hope to merge memory with logic, mixed signals with digital signals, and to integrate passive components with active circuits, but this complexity will increase the cost of the manufacturing process as the options include integrated circuits and passive components packaged together in a functional module. It is a new development and provides an extension of today's system packaging and integration, driven by the emerging low cost, low parasitic packaging technologies, particularly for portable, low power consumption and high performance products. A similar manufacturing process described in this work, the Integrated Manufactured Board, is environmentally benign as the production of residuals is small [1–6]. Chalmers University of Technology has also made some research work in this area and is currently manufacturing modules that use a planar structure [7–9].
No environmental assessment has been made of similar manufacturing processes and the purpose of this paper is to assess the environmental impact for the process used by Chalmers to manufacture an electronic product using the SIP technology. The environmental assessment is partly made using a previously developed data collection model for the life cycle inventory of electronic products [10].

1 LCA Methodology of Electronic Products

A model for collection of life cycle inventory (LCI) data occurring in the upstream processes has been developed and the LCA software EcoLab has been used. [11,12]. The 45 LCI modules in Fig. 1 were mapped against the SIP product parts list and only five modules could be found. The LCP substrate corresponds to the plastic mechanics module (group 19) within the mechanical components, the resistance material to resistors (group 32) within the passive components, the gallium arsenide (GaAs) bare die to the Standard IC (group 24), the copper laminate to metallic mechanics (group 20) and the conductive adhesive to composite mechanics (group 21).


For a further explanation on the data collection model for LCI of electronic products, see [10]. A material content declaration of the switch is shown in Table 1.

![Diagram of LCI data collection model and schematic life cycle of an electronic product applied to the SIP GaAs MMIC Switch Product based on the LCP substrate](image)

Table 1: The approximate material content declaration of the GaAs switch

<table>
<thead>
<tr>
<th>Name of the part</th>
<th>Mass [g]</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCP Substrate</td>
<td>0.158</td>
<td>LCP 50%, Glass fibre 50%</td>
</tr>
<tr>
<td>Conductive adhesive</td>
<td>0.25</td>
<td>Silver 80%, Diglycyl ether of bisphenol A 14%, 1-cyanoethyl-2-ethyl-4-methylimidazole 4%</td>
</tr>
<tr>
<td>GaAs bare die</td>
<td>0.00042</td>
<td>Gallium 50%, Arsenic 50%</td>
</tr>
<tr>
<td>Deposited resistance material</td>
<td>0.041</td>
<td>Nickel 60%, Chromium 40%</td>
</tr>
<tr>
<td>Copper laminate</td>
<td>0.281</td>
<td>Copper 100%</td>
</tr>
<tr>
<td>Deposited copper</td>
<td>0.0446</td>
<td>Copper 100%</td>
</tr>
</tbody>
</table>