Alternative Energy Systems in Electronically Point of View

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Abstract— **The output of the most electrical alternative energy sources like solar and wind energy systems has to be adjusted in frequency, form and level to match the electrical specifications of the end customer. The core of such conversion process is power electronics circuits implemented and integrated in the alternative energy system.**
In this paper, the most important reliability concerns of power electronics devices will be discussed. Future trends in packaging and interconnection technologies of power devices will be shortly presented.

Keywords: **Reliability; Failure mechanisms; Life-time**

I. INTRODUCTION

The output of the most electrical alternative energy sources like solar and wind energy systems has to be adjusted in frequency, form and level to match the electrical specifications of the end customer. The core of such conversion process is power electronics circuits implemented and integrated in the alternative energy system.
The output voltage of a photovoltaic system for example has to be converted from DC (direct current) form into AC (alternating current) form. This conversion is achieved by inverters built by power electronics switches like diodes and IGBTs (Insulated Gate Bipolar Transistors). Fig.1 shows a simplified topology of photovoltaic system with the required **Inverter.**

As a further example, the output voltage of a synchronous generator used in wind energy system has to pass two conversion processes. Firstly, the output voltage of the alternator has to be rectified to overcome the problem of the variable frequency of this voltage . Secondly, the rectified voltage has to be inverted to fit the electrical specifications of the loads. These both conversion processes are without power electronics circuits unrealizable.

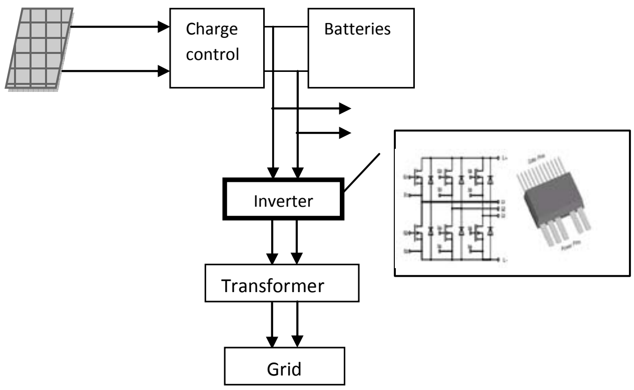

Figure1. Simplified topology of photovoltaic system

II. PACKAGING AND INTERCONNECTION TECHNOLOGIES OF POWER ELECTRONICS DEVICES

Power electronics switches like dides, IGBTs and thyristors used in middle to high power applications are housed in power modules. In this packaging variant, chips are mounted Chips are mounted on an electrical isolating substrate, mostly on with copper layers cladded ceramic (DCB), which allows the integration of several chips to build a defined function block. Fig.2 illustrates an overview of internal structure of power modules.

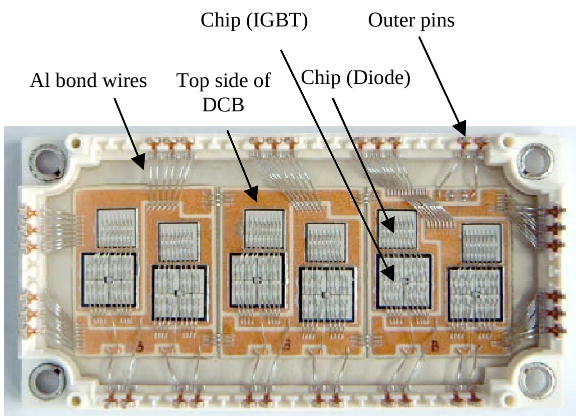

Figure2. Internal structure of modern power module

Top side connections of chips are established by aluminium bond wires. Subsequently, subassembly is soldered onto a 2-3 mm thick copper or approx. 2mm to 5mm thick aluminium-silicon carbide (AlSiC) base plate. For mechanical protection a silicon gel overlay is obtained and a plastic case is adhered to the base plate.

III. MAIN FAILURE MECHANISMS OF POWER MODULES

As shown in Fig.2, a power device is a multilayered structure consisting of materials with differential thermal expansion coefficient (CTE). Therefore, the most observed failure mechanisms affecting power devices are package-related and triggered or accelerated by thermo-mechanical stress.

Table 1 summarizes the CTE of materials typically used in power devices [1].

Table I: CTE of selected materials used in power devices

Material	**CTE[10^{-6} /K]**
Al	22
Si	3
Solder(SnAg3,5)	5,7
Al_2O_3-Substrate	8,3
AIN- Substrate	5,7
Cu	17,6

A) Bond-Wire Lift-Off

When considering Table 1, it is obvious that the aluminium and silicon exhibit the largest mismatch in CTE. Thus, the greatest thermomechanical stress during power and thermal cycling where the device is habitually heated up and cooled down, is observed at the connection zone between bond wire and the upper side of the silicon chip.

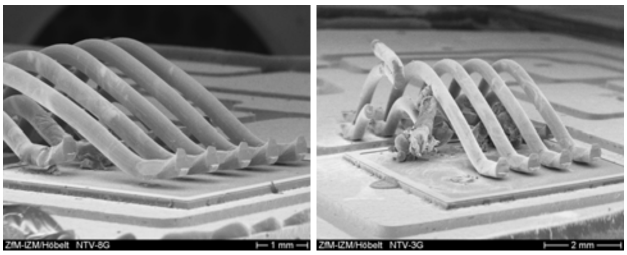

Figure3. Bond wire lift-off (left); bond wire melting (right)

Bond wire lift-off is a self accelerating effect and leads finally to the total failure of the devices. When wire lift-off occurs, the current density in the surviving wires increased significantly leading finally to their melting.

B) Solder Layer Degradation

Lead-free and lead-based solder alloys used in power devices exhibit a CTE which is heavily mismatched with that of silicon and DCB. Therefore, solder layers represents a critical interface in power assemblies, especially in the case of power modules with copper base plate. Degradation of solder joints can be categorized into:

a) Voids formation **b)** Solder fatigue

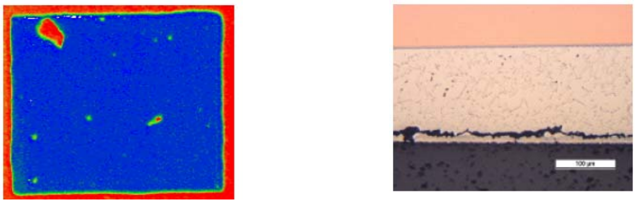

Figure4. Solder layer degradation

Voids and cracks in solder layers deteriorate the dissipation of the generated heat in the chip and leads to increased thermal resistance of the assembly.

C) Electrical and mechanical aging of DCB

Because of its excellent thermal, electrical and mechanical properties, DCB substrates are the standard circuit boards for power modules. It contains two copper foils with a thickness between 0,125 *mm* and 0,7*mm* cladded to ceramic substrate (Al_2O_3 or AlN). The main aging mechanisms affecting DCB substrates are:

a) Cracks and void formation **b)** Delamination of copper metallization

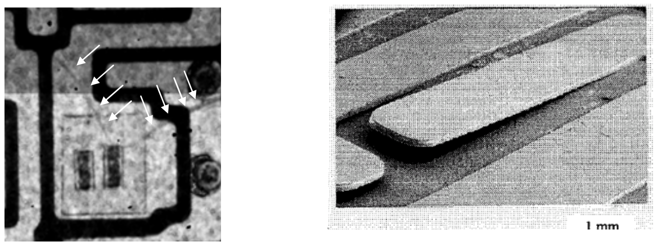

Figure5. a) Cracks on DCB b) Delamination of copper metalization

The existence of cracks and voids, leads to localized breakdown of the insulation. This phenomena is designated as partial discharge (PD) of the DCB substrates and is one of the main disadvantages of standard DCB substrates which also limits its application in high voltage ranges [2]. Delamination of copper metallization deteriorates the heat spreading effect of the DCB substrates and results in increase of the thermal resistance of the power device.

IV. ADVANCEMENTS IN INTERCONNECTION TECHNOLOGIES

Despite their reliability concerns, Aluminum bond wires are still the most used top-side connection technology of power devices and it is not expected that they would be replaced by other interconnection solution in the next future. However, intensive efforts of reliability engineers have been invested in increasing the reliability of bond wires.

For example, Intensive tests and calculations have been performed to determine the optimal dimensional parameter, chemical composition, and electrical stress profile of bond wires. It was shown that current capability of bond wires decreases overproportionally with increasing wire length where it increases underproportionally with increasing wire cross sectional area [3]. Based on these and other cognitions provided by these studies, the most suitable number of wires, loop height, wire diameter and composition for specific application could be determined.

Furthermore, Coating of bond wires with glued polymeric layer was observed to moderate the crack propagation within the wire bonds and slows the reconstruction of the aluminium metallization leading to improved power cycling lifetime of the bond wires [4] and [5]. The coating process is usually accomplished by painting multiple polymeric layers with graded hardness onto the wires immediately after the bonding process[6].

After the significant improvements achieved in the reliability of Al bond wires, the efforts of design engineers are now more and more focused on developing alternative interconnection solutions. One of these promising alternative is the in the following presented **L**ow **T**emperature **J**oining **T**echnique (LTJT).

The LTJ technique is based on sintering of sub-micro silver flakes at temperatures above 220°C and a pressure of about 40 MPa during one minute in air. The surfaces of the parts to be joined have to obtain an oxide-free metal finish such as gold or silver . The layering sequence of LTJT process is shown in Fig.6.

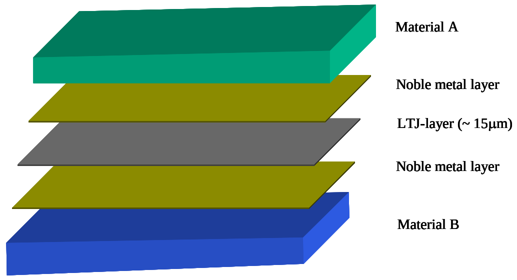

Figure6. Principle of LTJT

Power devices based on LTJT show power cycling reliability approx. four times higher than state-of-the-art of soldered standard modules.

V. SUMMARY

Life-time of power electronics circuits used in alternative energy systems is limited by the standard interconnection technologies of the power devices by which these circuits are realized. Important improvements in wire bonding and solder technologies could be achieved in the last years reflecting into increased power cycling capability of state-of-the-art of power devices compared to that expected from standard modules before ten years. However, standard soft solders are still reliability risk and there are experimental evidences that this technique will not be able to be reliable solution for the future applications of power devices especially in alternative energy systems in hot regions.

Low **T**emperature **J**oining **T**echnique (LTJT) promises to be suitable for future module set-up. Already the replacement of only chip-to-substrate solder joint (one-sided LTJT) yields significant power cycling capability.

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