PhD proposal M/F

Exploring self-healing solutions
for Aluminum source layers in Power Devices

Ref JCB_PhD_2019CEMES

Industrial Partner: MITSUBISHI ELECTRIC R&D CENTRE EUROPE

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Type of contrat: 3 years contract, from September 2019

Reference: JCB_PhD_2019CEMES

Research topic: Reliability of power devices

Subject proposed by: Julio BRANDELERO, Mitsubishi Electric R&D Centre Europe, Rennes

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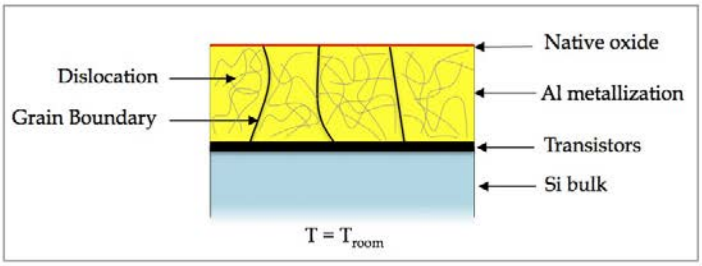
And Marc LEGROS, CEMES-CNRS, Toulouse

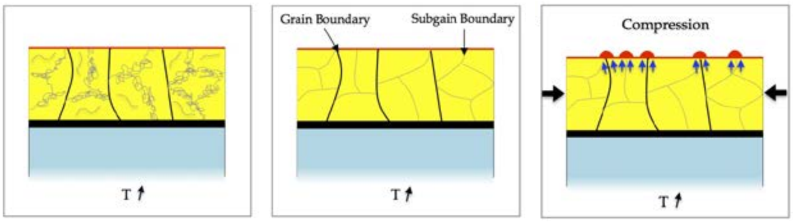
Context:

Power electronics applications have expanded in many fields such as domotics or energy conversion, but their reliability is mostly critical in the transportation field and off-shore applications. Anticipating or even preventing their failure is a key technical issue.

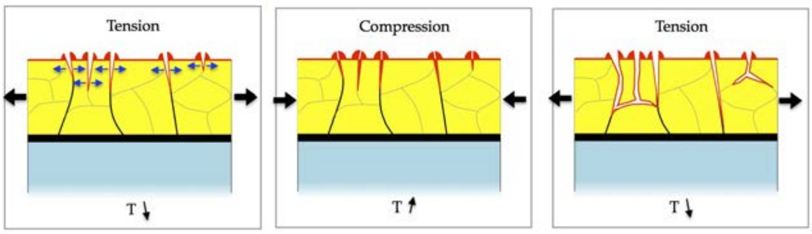
In recent years, several weak spots have been identified in the structure of modern Silicon-based power MOSFETs and IGBTs, and some solutions have been found to increase their resistance to disruption (solder, packaging…). However, the aging of the top metal source, mainly made of Aluminum or Aluminum alloy has persisted as an intrinsic phenomenon, which degrades the electrical performance of the device over time. The deterioration of the Al layer occurs through mechanisms that involve grain boundary diffusion, crack formation and surface oxidation, also driven by stresses arising from thermal mismatch between the metal and the silicon, as described in Fig. 1. Similar oxidizing cracks develop between the metallization and the wire bondings, leading to local failure of the device [2].



a)



b) c) d)



e) f) g)

Figure 1. *Gao's model extended to Al layers undergoing tension and compression stresses during thermal cycles [2]. (a-c) The dislocation density decreases by recombination in sub grain boundaries and absorption at GB interfaces. (d-g) Al diffusion along grain boundaries, and subsequent oxidation causing crack propagation through the Al layer. ref. [1]*

Objectives:

The study will focus on the aluminum layer of the power device that interfaces the silicon die and the electrical circuit.

The objective of this thesis is to find technical ways to slow down the mechanisms that cause the deterioration of the Aluminum layer, either by increasing the metallic contact between the wire bondings and the metal in the initial state and/or to restore this electrical contact during operation.

Thesis conditions and development:

Thesis starts:

From September 2019

Presence:

Mainly at the CEMES in Toulouse (85% time).

Regular visits are planned to Mitsubishi Electric R&D Centre Europe, Rennes.

Planning & reporting:

The work program is divided as follows:

- T1: Increase the metallic contact
- T2: Restore the electrical connection
- R: Thesis writing

Monthly reports (1 page) and quarterly meetings (alternately in Toulouse and Rennes)

Education and experience required:

- Engineer's degree or Master's degree with a focus in Materials Science
- Simulation and programming softwares (COMSOL Multiphysics, Python)
- Competence in materials characterization tools (TEM, FIB)
- Strong general scientific knowledge and multidisciplinary opening (materials science, electrical, mechanical, thermal, chemical, mathematical)
- Power electronics skills would be a plus
- Communication and writing skills in English
- Motivation and dynamism to work in a research environment
- Ability to work in a multicultural and international environment

Send your CV and motivation letter in a pdf format by mail (by specifying in object: your name and the reference JCB_PhD_2019CEMES):

jobs@fr.merce.mee.com

References:

1. D. Martineau, C. Levade, M. Legros, P. Dupuy, and T. Mazeaud. "Universal mechanisms of Al metallization ageing in power MOSFET devices." In: Microelectronics Reliability 54.11 (2014), pp. 2432–2439.

2. R. Ruffilli *et al.*, Mechanisms of power module source metal degradation during electro-thermal aging. *Microelectronics Reliability* (2017).