Superlattices and Microstructures 45 (2009) 249–255

Contents lists available at ScienceDirect

Superlattices and Microstructures

journal homepage: www.elsevier.com/locate/superlattices

Scanning electron and laser beams induced current (SELBIC) method for observing failures in GaAs high electron mobility transistors

Haruki Sueyoshi [a,*], Shin-ichi Takasu [b], Woon Choi [a], Hajime Tomokage [a]

[a] Department of Electronics Engineering and Computer Science, Fukuoka University, 8-19-1 Nanakuma, Jonan-ku, Fukuoka 814-0180, Japan

[b] Advanced Technology Division, JEOL Ltd., 1-2 Musashino 3-chome, Akishima, Tokyo 196-8558, Japan

ARTICLE INFO

Article history:
Available online 11 February 2009

Keywords:
Electron and laser beams
Scanning method
Failure analysis

ABSTRACT

The electrical imaging observation of failures in GaAs high electron mobility transistors (HEMTs) is performed using scanning electron and laser beams induced current (SELBIC) method. An electron beam and infrared (IR) laser beam with a wavelength of 1064 nm irradiate coaxially from each side of a HEMT sample. When HEMT sample#1 and #2 are scanned from the back surface using a laser beam, a high contrast spot in the current image of sample#1 was observed between the gate and source regions. Since the *I*–*V* characteristic between the gate and source shows an increase in leakage current, the high contrast spot in the current image is suggested to be an electrically active failure. The current image is compared with the image under electron beam irradiation. It is ascertained by a cross sectioning technique with focused ion beam (FIB). The current spot is due to a crack causing a local short circuit in an insulating layer.

1. Introduction

Failure analysis of electronic devices is vital, because of the demands for high reliability, high yield, and short turn-around time (TAT). Recent features of electronic devices are higher compactness, higher speed, and higher performance, based on the advanced LSI and packaging technologies. Several

* Corresponding author. Tel.: +81 92 871 6631.
E-mail address: td066501@cis.fukuoka-u.ac.jp (H. Sueyoshi).

doi:10.1016/j.spmi.2008.11.017

chips make a system on the printed circuit board (PCB), but for further miniaturization, one system has been made on one chip such as system on a chip (SoC) by millions of small sized transistors with fine patterns. In addition, three-dimensional packaging technologies such as stacked die package and package on package (PoP) have been developed for advanced electronic devices. Therefore, microscopical characterization is needed for failure analysis, but the complicated structure makes the failure detection difficult [1]. In the case of the flip-chip bonded package, it is also difficult to observe the inter connection failure from the backside of the chip, although defects such as voids and Si nodules in the chip and poor interconnection degrade not only the performance of the electronic devices, but also high-speed signal transmission.

In failure analysis, an electron beam has been used widely for observing defects in semiconductor devices. The electron beam induced current (EBIC) method has been applied to the defects analysis by the recombination due to the presence of defects in the depletion layer of p-n junction [2–4]. However, in the case of a flip-chip bonded package, EBIC method cannot observe the flip-chip interconnection, because the range of the electron beam is short compared to the chip thickness. The optical beam induced current (OBIC) and optical beam induced resistance change (OBIRCH) method have been proposed for the failure analysis of semiconductor package [5–9]. The current change in the excited free carriers by presence or absence of failure can be detected in the OBIC method. When the infrared beam irradiates as IR (infrared)-OBIC and IR-OBIRCH methods, the beam can penetrate the semiconductor substrate. Then the change in current or resistance in an active area of the chip and interconnection region is observed non-destructively. The single contact optical beam induced current (SCOBIC) has also been developed for electrical observation of many transistors with internal junctions [10,11].

In this paper, we report the current imaging observation of GaAs high electron mobility transistors (HEMTs) using scanning electron and the laser beams induced current (SELBIC) method. In a vacuum, IR laser beam with wavelength of 1064 nm irradiates and scans from the backside of GaAs substrate, and then the change in induced current of HEMTs is observed under non-biased condition. The current spot between gate and source electrodes is observed on the sample with a high leakage current. Moreover, the electron beam irradiates to the sample during IR-laser scanning. The additional current image due to electron beam irradiation is observed near the current spot. It is ascertained by a cross-sectioning technique with focused ion beam (FIB). The current spot corresponds to the crack in the insulating layer.

2. Experimental procedure

Fig. 1 shows the block diagram of SELBIC system which consists of the main console, control rack, and operation console. In the main console, the cold cathode field emission gun and laser sources with two wavelengths of 1064 nm (YAG laser) and 1400 nm (laser diode) are installed coaxially across the vacuum chamber. Two laser beams can irradiate to the specimen from backside through the quartz window in the still-air or vacuum. In contrast, the electron beam can irradiate from top side in vacuum of 9.6×10^{-5} [Pa]. The specimen is set on the sample stage in the vacuum chamber, and tungsten probes are connected to the sample electrodes in order to measure the induced current. In the control rack, there are three scanning controllers for electron beam, laser beams, and simultaneous beams scanning. In the SELBIC system, the electron beam observation and optical beam observation is performed separately using each scanning controller. In addition, electron beam and laser beam are scanned in the same area at the same time using the synchronous scanning controller. The electron beam and laser beam can also irradiate to given spots. The output of the current amplifier and optical image are compared on the same display.

Table 1 shows the relation between beam irradiation and observation mode, which the SELBIC method can perform. When the electron beam is scanned, SEM and EBIC observations are available. When the optical beam is scanned, on the other hand, the IR-OBIC and IR-OBIRCH measurements are available for the backside observation, and the optical microscopy (OM) is performed under the fixed beam. SELBIC method deals with electron beam and laser beam simultaneously in the same area. The beams can be scanned or fixed during current measurements. Therefore, there are three observation modes, as shown in Table 1. We refer to the method as SELBIC method.