CSTIC 2025 POSTER

LOW-FREQUENCY NOISE MEASUREMENTS FOR ELECTROMIGRATION CHARACTERIZATION OF CU INTERCONNECT UNDER METAL BARRIER PUNCH THROUGH PROCESS OPTIMIZATION

Chenxiao Xu[1,2], Xue Li[1,2], Luhao Zhou[2], Dawei Gao[1,2], Yunlong Li[1,2,3]*

[1] College of integrated circuits, Zhejiang University, Hangzhou, China
[2] Zhejiang ICsprout Semiconductor Co., Ltd, Hangzhou, China
[3] State Key Laboratory of Silicon and Advanced Semiconductor Materials, Zhejiang University, Hangzhou, China
*Corresponding Author's Email: bta@zju.edu.cn

ABSTRACT

By applying low-frequency noise (LFN) measurements, the EM reliability of Cu wires with various bottom profiles under different optimization circumstances were discussed. As a result, this study finds out that under metal barrier PT Process optimization, the metal lines with better cross section profiles tend to have better early EM characteristic.

INTRODUCTION

As a method that has been employed for defect detection in Al interconnects for EM evaluation, there are both theories and practices indicating that LFN measurements can also be applied to characterize EM of Cu interconnects. After performing a fast Fourier transform (FFT) on original noise data, power spectral density (PSD) in the low frequency range can serve as an indicator for the initiation of voids and defects, revealing the risk of early EM failure.

METHODOLOGY

The study was conducted at different temperatures in three groups with different bottom profiles, via specific test structure, as shown in Figure 1.

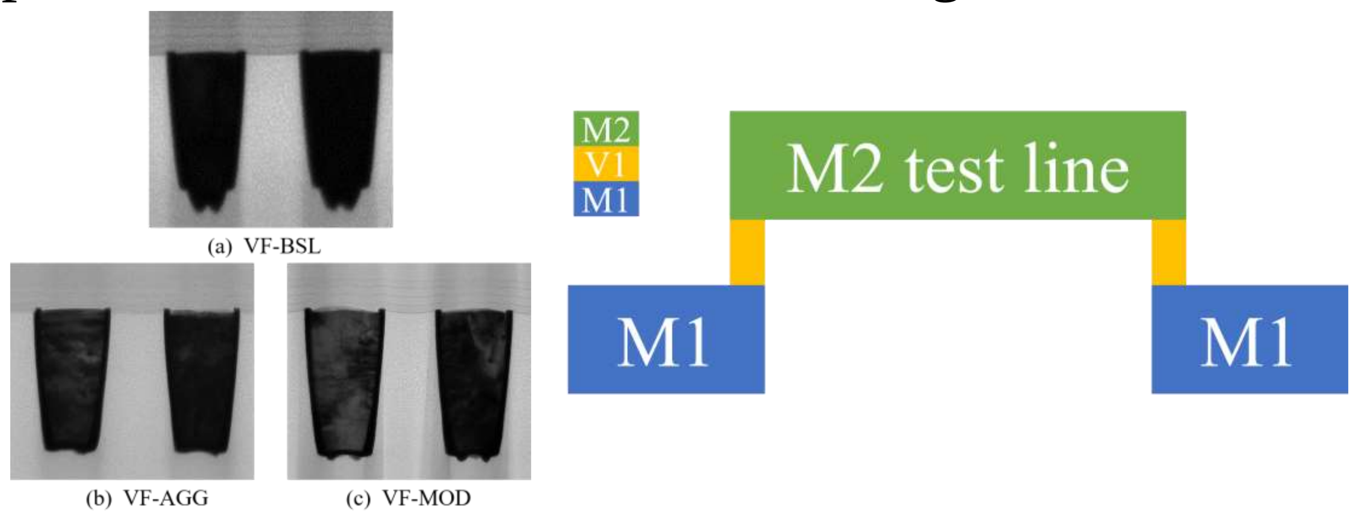

Figure 1: Cross-section profiles of experimental groups and schematic of EM test structure

By applying low constant DC to the test structure, minuscule current noise from the metal line can be obtained, which generates due to the interaction of electrons with the interconnect's sidewalls, defects and phonons etc. After analyzing the noise by means of FFT, the PSD of the noise fluctuations can then be derived, typically exhibiting a PSD proportional to $1/f^m$, with $0 < m < 2$ in the low frequency range.

RESULTS & DISCUSSION

Typical LFN analysis procedures can be conducted and shown in Figure 2.

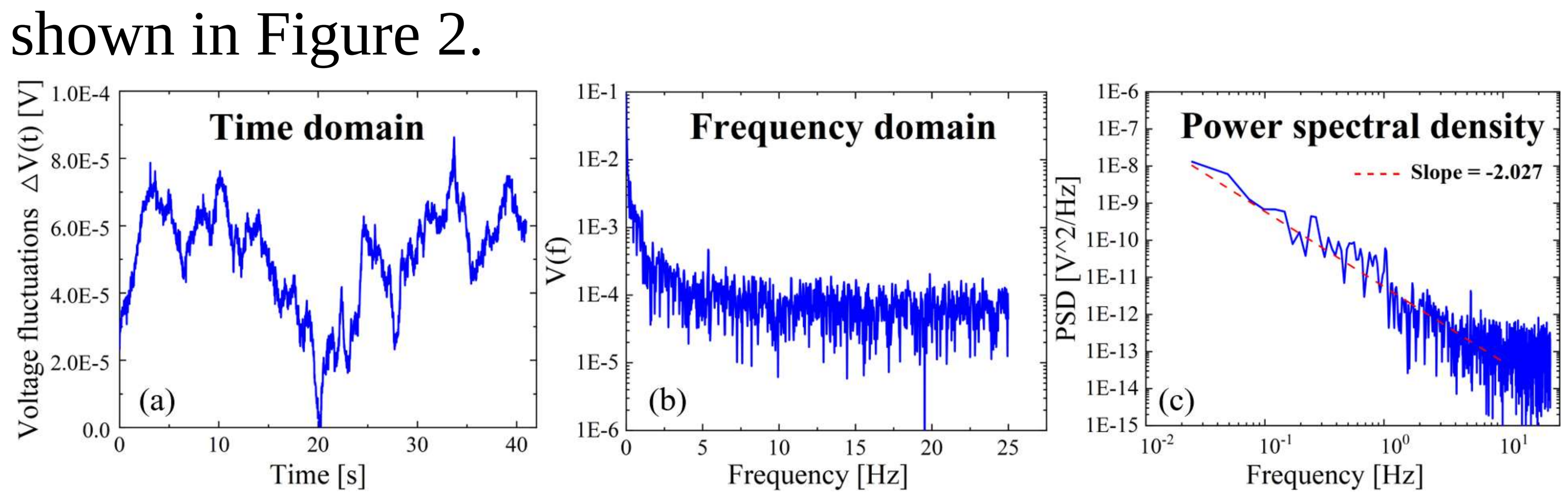

Figure 2: Typical LFN measurement in (a) time domain, (b) frequency domain and (c) PSD

The PSD of LFN under high temperatures tend to have larger slopes and order of magnitude, due to more collisions and scattering between electrons and metal atoms, more massive thermal excitations and accelerated atomic motions, indicating higher risk of EM, as shown in Figure 3.

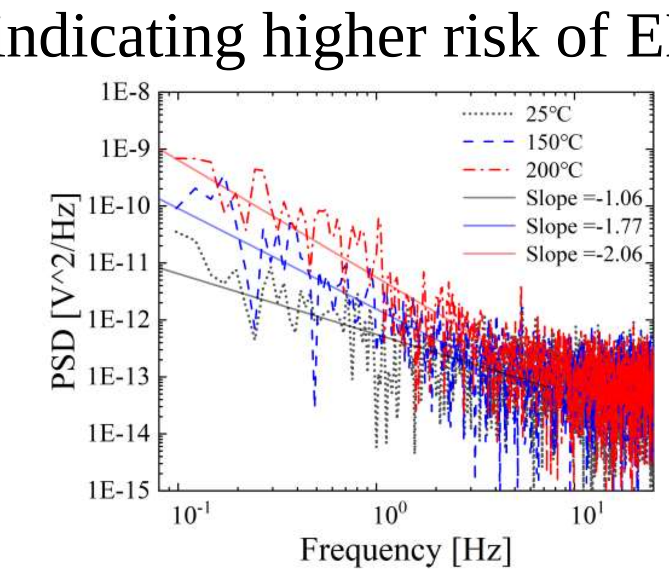

Figure 3: PSD of LFN at different temperatures.

TABLE 1. Median values of slopes in PSD of LFN between different groups at different temperatures

	VF-BSL	*VF-AGG*	*VF-MOD*
25°C	-1.49	-0.93	-0.87
150°C	-2.18	-1.68	-1.80
200°C	-2.24	-2.03	-1.92

Compare the EM characteristics via LFN measurement in qualitative experiments, and the results are listed in Table 1. Groups with better cross-section profiles have smaller absolute slopes in the PSD of LFN, revealing less risk of EM failure. This may be attributed to better cross-section profiles reducing the collision and scattering between electrons and the bottom of metal wires, decelerating the generation of voids and defects, and thereby reducing the risk of EM.

SUMMARY

In this study, LFN measurement are applied to investigate the early indication of EM failure. The results demonstrate that under metal barrier PT process optimization, the metal lines with better cross-section profiles tend to have better performance in the PSD of LFN representing better EM characteristics, due to less collision and scattering between electrons and bottom metals as well as fewer generation of voids.