A Study of Advance Acid Decapsulation of Copper Wire-bonded Packages

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ABSTRACT

In this project, we investigated chemical decapsulation methods of copper-wire-bonded packages to prevent or minimize corrosion of the copper wire and internal integrated circuit (IC) components. The decapsulation process utilizes a mixed acid solution of nitric and sulfuric acids to remove the epoxy molding compound, exposing the semiconductor chip, copper wires, and bonding materials for failure analysis (FA). We systematically varied the acid mixture ratios to reduce surface damage caused by corrosion, particularly that induced by nitric acid. Following decapsulation, scanning electron microscope (SEM) was used to observe and evaluate the surfaces of the copper wire and bonding area. The optimal acid ratio resulted in significantly improved surface quality, as evidenced by SEM imaging, compared to conventional methods. Additionally, we explored an integrated decapsulation method that incorporates cathodic protection to further mitigate nitric acid corrosion.

INTRODUCTION

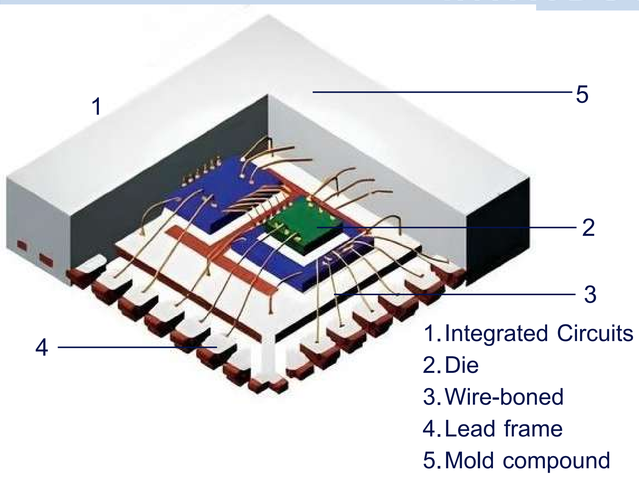


Fig. 1 Structure of an integrated circuit (IC)

Integrated Circuits (ICs) are semiconductor devices that integrate multiple electronic components onto a single silicon chip and are protected by an epoxy molding compound to ensure mechanical and environmental stability. The internal structure includes the die and bonding wires, which are critical to device performance. ICs failures such as open/short circuits, cracking, or corrosion may occur, requiring failure analysis (FA) to determine the root cause. A key step in FA is decapsulation, particularly chemical decapsulation, which uses acids to remove the epoxy resin and expose the internal structure for inspection.

A removal epoxy resin based on chemical decapsulation by mixing of acids

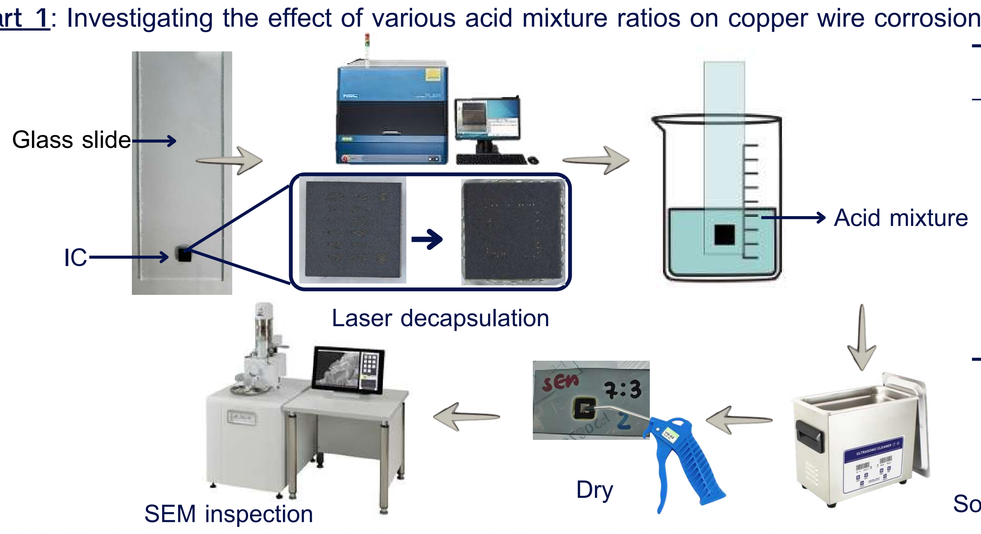
$$H_2SO_4 + HNO_3 \longrightarrow HSO_4^- + NO_2^+ + H_2O \qquad (1)$$

Attract to the copper wire surface

Decompose the mold compound (epoxy resin) through nitration reaction

EXPERIMENT

Part 1: Investigating the effect of various acid mixture ratios on copper wire corrosion



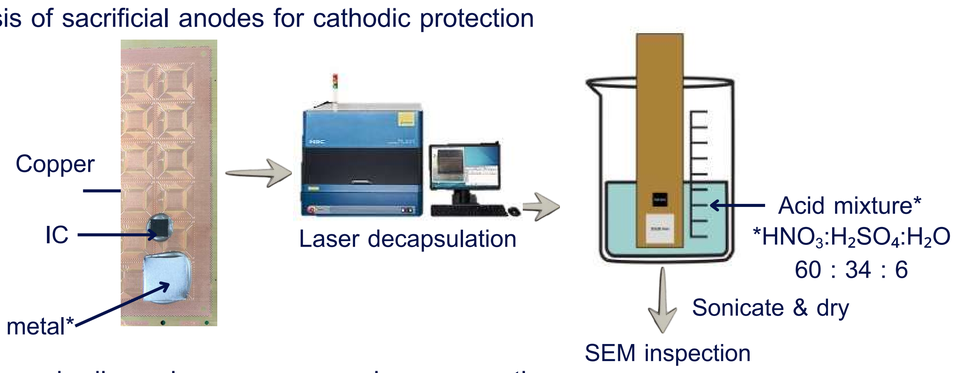
HNO_3 :	H_2SO_4:H_2O
60	40 : 0
60	38 : 2
60	36 : 4
60	34 : 6
60	32 : 8

Part 2: Evaluation of an integrated decapsulation method utilizing chemical removal and cathodic protection

2.1 Comparative analysis of sacrificial anodes for cathodic protection

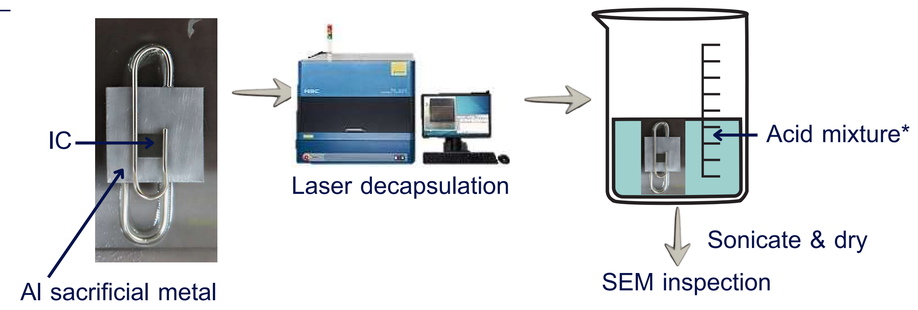
*Sacrificial metal

- Magnesium
- Aluminum
- Zinc
- Nickel



2.2 Effect of aluminum anode dimensions on copper wire preservation

Al size (mm x mm)
4x4
8x8
16x16
32x32
64x64
128x128



RESULTS AND DISCUSSION

Part 1: Investigating the effect of various acid mixture ratios (HNO_3:H_2SO_4:H_2O) on copper wire corrosion

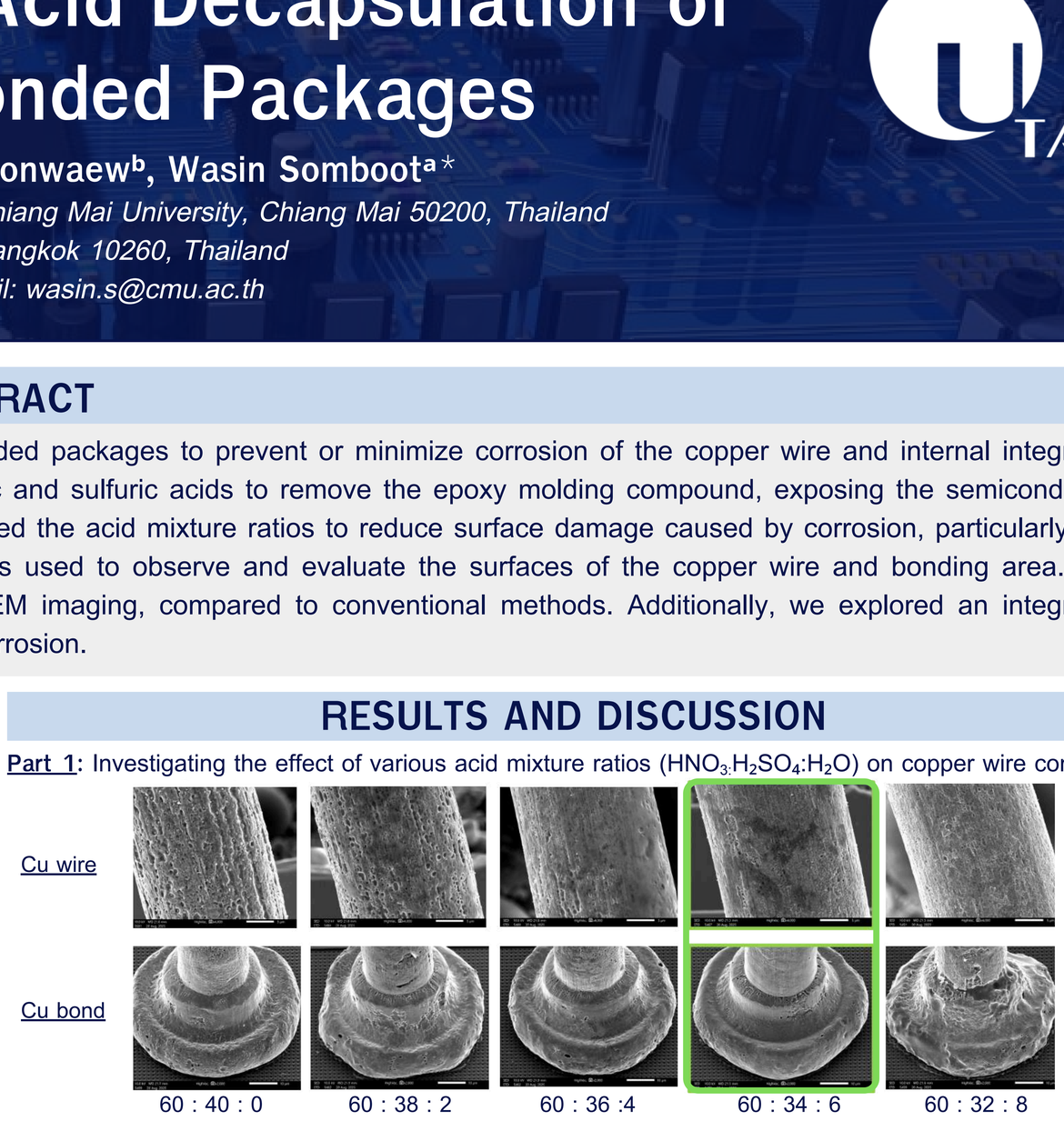


Fig. 2 SEM images of Cu wire surfaces following decapsulation with various acid mixture ratios (HNO_3: H_2SO_4 : H_2O) to investigate the effects on surface morphology and corrosion.

Part 2: Evaluation of an integrated decapsulation method utilizing chemical removal and cathodic protection

2.1 Comparative analysis of sacrificial anodes for cathodic protection

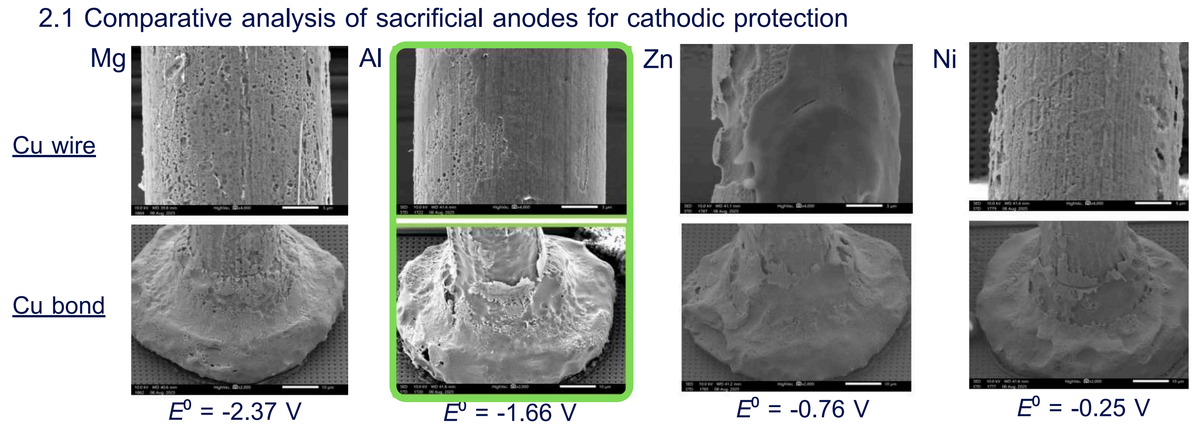


Fig. 3 SEM images of Cu wire surfaces following decapsulation utilizing various sacrificial anode metals (Mg, Al, Ni, and Zn).

2.2 Effect of aluminum anode dimensions on copper wire preservation

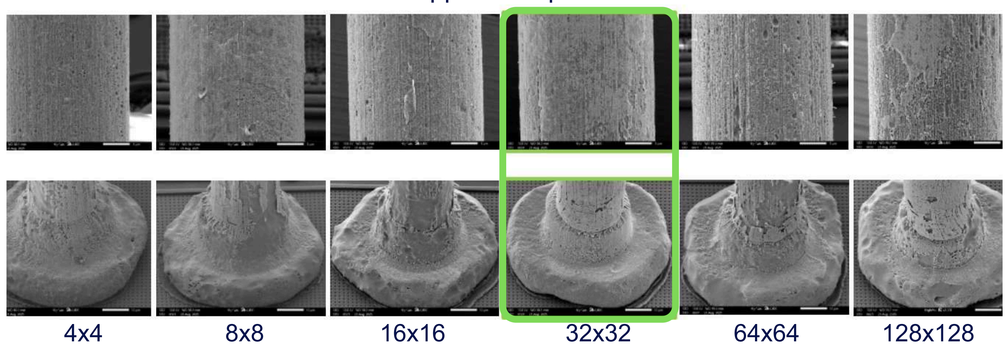
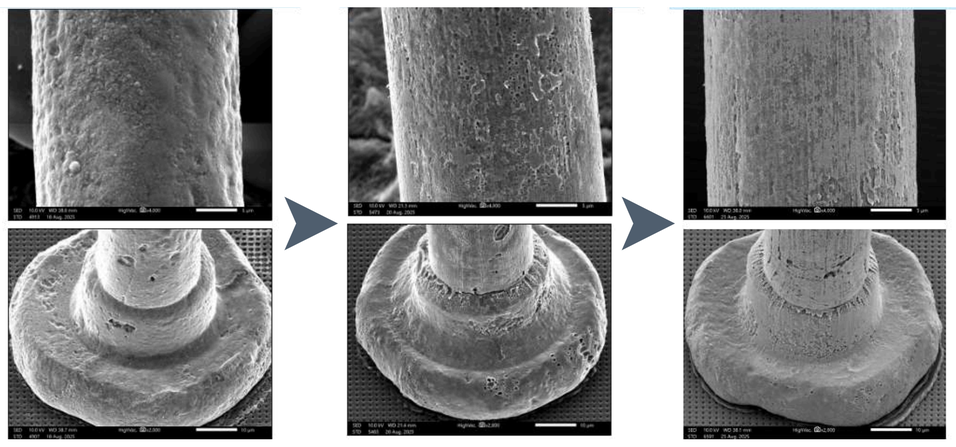


Fig. 4 SEM images of Cu wire surfaces following decapsulation utilizing Al as a sacrificial anode with varying anode dimensions. The images illustrate the effect of Al sheet size on the degree of cathodic protection provided to the copper wire.

CONCLUSIONS



1. Successfully improved the mixed-acid method to minimize nitric acid corrosion of copper wires and bonding areas by optimizing acid ratios and surface adsorption.
2. Developed an advanced method combining chemical etching with an aluminum (Al) sacrificial anode, demonstrating superior corrosion resistance compared to mixed-acid methods.

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