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Microstructure, tensile and electrical properties of gold-coated silver bonding wire

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ABSTRACT

Au-coated Ag wire offers an oxidation-resistant layer and added benefits compared with pure Ag wires. It can remain unchanged without any deterioration for long storage periods under ambient atmospheric conditions and features superior bond strength. The surface characterization, electrical properties at high temperature, and electrical tensile properties of both pure Ag and Au-coated Ag wires are investigated for reliability assessment. The experiment confirmed that an Au layer on the surface of Ag wire can increase oxidation resistance and tensile strength. The experiment utilized a new test method, electrical tensile test, to confirm the performance of wires. The fractured surface from ductile to brittle fracture mode of the Au-coated Ag wire was caused by electromigration. Moreover, electrical test data can be considered as a reference in IC and LED packaging industries.

1. Introduction

The price of Au has increased steeply in recent years and therefore many packaging industries are switching from utilizing Au–Cu. Cu wire has many advantages over Au wire [1,2], such as better thermal and electrical properties. The mechanical properties of Cu cause reliability and durability problems in bonding systems [3,4]; thus, Cu wire cannot completely replace Au wire.

Ag wire offers the best electrical and thermal conductivity, and can be used in Au wire bonders of the same type. Nevertheless, there still exist many new challenges for Ag wire. Ag wire offers the best electrical and thermal conductivity, and can be used in Au wire bonders of the same type. Nevertheless, there still exist many new challenges for Ag wire. For instance, Ag tends to corrode in humid environments [5], Ag wire bonding has to be performed under a shielding gas in FAB formation [6] and greatly increase the fabrication cost. Therefore, Au-plated Ag wire is a new method to overcome these above difficulties, which can also employ Au pads to enhance bonding strength. Considering the correlation between the reliability of Ag wire and the temperature and electrical factors in the application. In the present investigation, the microstructure, electrical and mechanical properties of the Au-coated Ag wire was examined. Further, the fusing current test at room/high temperature and the tensile properties of the current effect is investigated.

2. Experimental details

The diameter and purity of the Ag wires was 20 μm and 4 N Ag, respectively, while the gold coating thickness was about 100 nm. The Au-coated Ag wire is referred to as ACA wire, with the core of ACA wire being pure Ag. Ag and ACA wires morphology analyses were conducted with the FIB-SEM.

The experimental schematic shown in Fig. 1a was used to determine the fusing current of fine wires. Wire bonder was used to perform the electronic flame off (EFO) and bonding processes and the shielding gas was not used in ACA wire. The first and second bonding of free air ball (FAB) was conducted on 800 nm aluminum pads for the fusing current test [7]. An effective wire length was determined to be 10 mm, and for which the DC voltage was increased 0.01 V per 2.5 s from 0 V until the wire fusing. The test temperatures were 25 °C and 85 °C.

To understand the effects of annealing and electrical current on the microstructure of the ACA wire, the thermal stability of wire was examined by imposing the static annealing treatment for 30 min at 200–500 °C in a vacuum environment. To know the effect of current on ACA wire, 90% of critical fusing current density (CFCD) was chosen for the current test and the experimental durations were 1 h, 5 h and 10 h respectively. Micro-hardness test (vickers hardness) was used to determine the hardness of wire [8].

An electrical tensile testing, called the ET test, was used to evaluate the fine wire (Fig. 1b). The electrical tensile properties were exploited to simulate the effect of electron current on the fine wire; moreover, the influence of tensile strength on the fracture

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behavior under current loading was investigated. In this study, 90% of the critical fusion current density (CFCD) was chosen for the ET test. The microscale system strain rate was $5 \times 10^{-3}\ s^{-1}$ and the test length was 50 mm.

3. Results and discussion

3.1. Subsurface and surface characteristics

Fig. 2a offers a SEM image of the Ag wire, which shows no defect and some wear marks parallel to the drawing direction. Fig. 2b presents the surface image of the ACA wire, in which continuous Au coating can be observed. The subsurface image of ACA is given in Fig. 2c, which indicates that the Au layer thickness of about 100 nm.

3.2. Annealed microstructures and hardness of ACA wires

The microstructures with different annealing temperature were shown in Fig. 3. The equiaxed grain microstructures of ACA wire was as shown in Fig. 3a. The fine grains was formed the recrystallized grains while wire annealing at temperature from 200 to 300 °C (Fig. 3b and c). Furthermore, upon annealing at 400 °C (Fig. 3d), annealing temperature had a great effect on the grain size. There were significantly increase of annealing twins and the grain size was approximately 80% of wire diameter. Finally, when the annealing temperature was 500 °C (Fig. 3e), approximately 90–95% of the grains formed recrystallization. The wire grains grew substantially which showed similar to single-crystal structure. In addition, microhardness variations of different annealing temperatures were shown in Fig. 4. Increasing the annealing temperature reduced hardness of wire sharply owing to increasing the

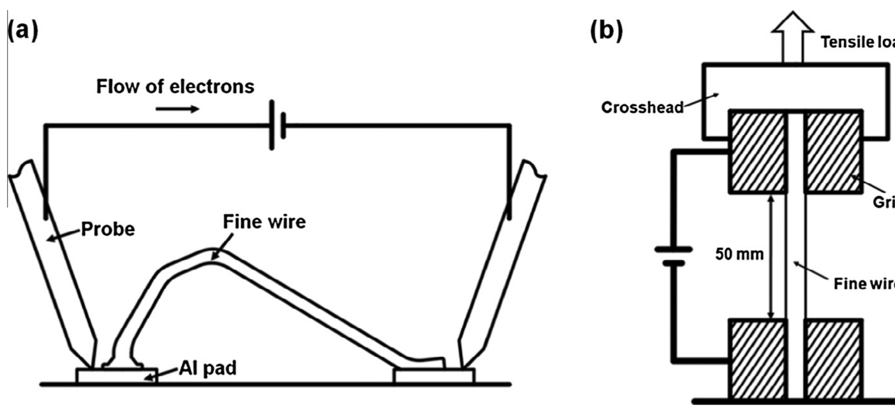

Fig. 1. Schematic diagram of the equipments. (a) Measurement system for fusing current test of fine wire; (b) mechanism for tensile test on wire in current loading.

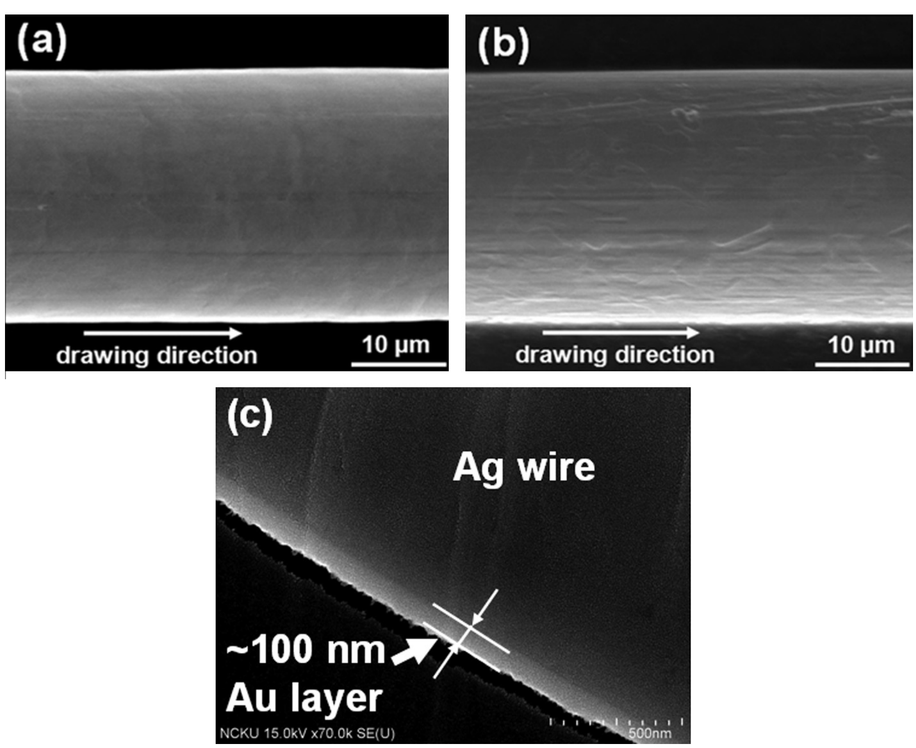

Fig. 2. Surface characterizations of the fine wire. (a) Ag; (b) ACA and (c) cross-section of ACA wire.