SHORT COMMUNICATION

Repair of microelectronic circuits using Joule heating induced local electrodeposition

H. KAWAMOTO

Manufacturing Engineering Laboratory, Corporate Research Laboratories, Fuji Xerox Co., Ltd, 2274, Hongo, Ebina-shi, Kanagawa 243-04, Japan

Received 19 May 1993; revised 1 November 1993

1. Introduction

A unique self-induced repair (SIR) process utilizing thermal potential induced by Joule heating was reported by Chen [1] and the present author [2] for repair of constrictions or incipient breaks in microelectronic circuits. Since the method utilizes the thermal battery effect in a copper/copper sulphate system, it is restricted to the repair of copper electrodes. However, the process is expected to be applicable to the repair of microelectronic lines made of other metals, for example, nickel lines for the repair of an ionographic printhead [3]. Two approaches are possible to realize this application. One is to investigate a suitable electrolyte for a non-copper metal, as 1.0 M $CuSO_4$ and 0.5 M H_2SO_4 for copper [2]. This approach is generally disadvantageous, because an electrolyte having high and negative (lower potential at the hotter region) thermal potential and a high conductivity does not always exist for any kind of metal. Another is the successive layer method, i.e. in the first place, uniformly plating a thin copper film on a non-copper line, then performing SIR of copper on the preplated line, finally finishing plating the same metal with the original line. In the present study the feasibility of the latter method is studied and the utility of the method is demonstrated through numerical calculation and experiments.

2. Experimental details

Figure 1 shows a schematic drawing of the experimental setup. A nickel wire, initially 0.127 mm in diameter and 15 mm in length, was connected to L-shaped nickel terminals and immersed in an electrolyte solution containing 1.0 M $CuSO_4$ and 0.5 M H_2SO_4, because this electrolyte composition gives a maximum self-induced deposition rate [2]. The wire was uniformly preplated with copper of 0.5 μm thickness using the regular electroplating method, and then self-induced deposition was performed by the procedure reported in [2]. A copper plate with a lead was immersed in an electrolyte solution. This plate served as a regular anode in the pre-electroplating operation, and then in the SIR process it was connected to one end of the nickel terminals to serve as an anode of the thermal battery. The temperature of the solution was kept constant at 25° C, and the a.c. 50 Hz Joule heating current was set at 2.0 A, because the maximum temperature of the wire was numerically predicted to be 100° C under this operating condition. The operation without boiling of the solution ensures uniform deposition [2].

3. Results and discussion

Figure 2 shows the results of the experiments and the calculation. The following points may be made.

(i) It is demonstrated that the Joule heating induced deposition was realized for the nickel wire pre-plated by copper.

(ii) The qualitative characteristics of the deposition dynamics were the same as those reported in [2]. That is: (a) due to the small thermal time constant of the fine wire, 0.1 s in the present case, compared to the operating time, the lead heated up almost immediately when a.c. current was applied; (b) copper deposited on the heated portion (cathode) of the wire and dissolved from the colder portion (anode), the copper plate, due to the thermal potential; (c) the Joule loss decreased with increase in the cross section of the heated part of the wire. This resulted in a decrease in the rate of temperature rise; (d) the deposition rate decreased gradually as deposition increased, and then; (e) as the temperature over the wire became uniform, the deposition was self-terminating.

(iii) The experimental results agreed well with the calculation in respect to the dynamic resistance change during the operation and the deposition thickness after the 30 min, operation. The calculation method reported in [2] was modified so that physical properties of the line, density, specific heat, thermal

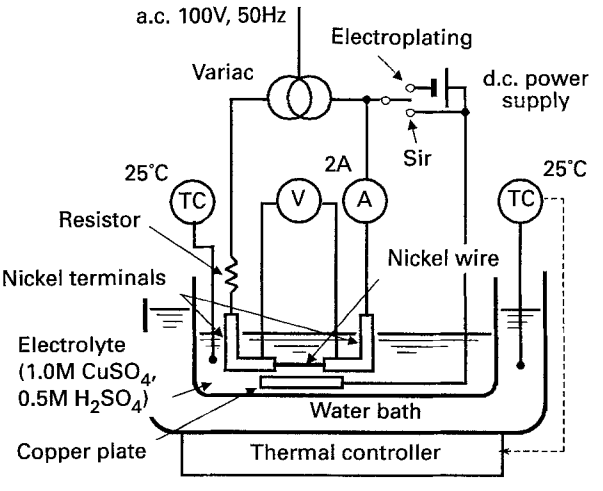

Fig. 1. Experimental setup.

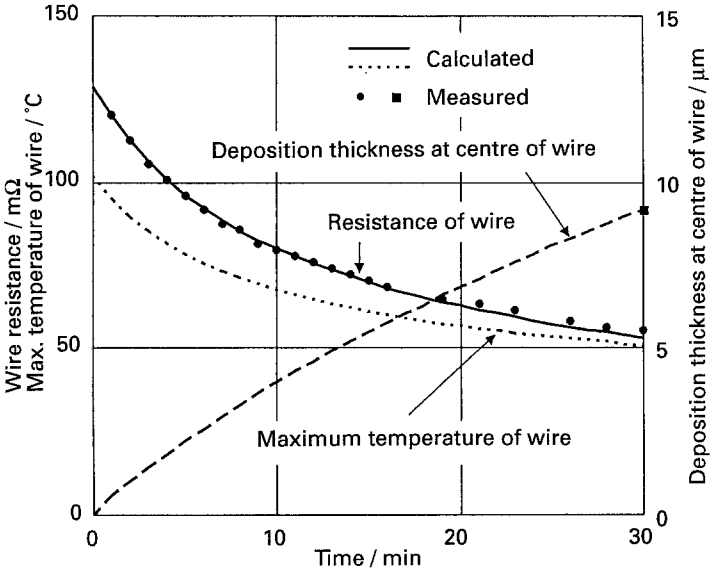

Fig. 2. Dynamics of Joule heating induced electrodeposition. The measured resistance of the wire during the operation was calibrated to compensate the current pass in the electrolyte.

conductivity, and electronic conductivity, were calculated as weighted values of nickel and copper.

The present method is expected to be utilized for the fine patterning of microelectronic electrodes made of non-copper metals.

References

[1] C. J. Chen, *J. Electrochem. Soc.* **138** (1991) 969.
[2] H. Kawamoto, *J. Appl. Electrochem.* **22** (1992) 1113.
[3] T. Tanaka, private communication.