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Nondestructive Measurement of LSI Electroplating Current Distribution Using Magnetic Sensors

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1. Introduction

Copper electroplating is generally applied on the fabrication of Large-Scale Integration (LSI) besides other methods because of its excellent via/trench filling ability, good adhesion and lower process temperature and cost. Then, in the electroplating process, estimating a growth rate of electroplating in real-time is essential because it is difficult to electroplate the LSI wafer uniformly [1].

In this paper, applying inverse analysis methods, a new nondestructive method to monitor a growth rate of electroplating from the magnetic flux density outside the electroplating device measured by magnetic sensors is developed. It is able to estimate a growth rate of electroplating from the current density on the LSI wafer surface because the rate mainly depends on the current density. We focused on the magnetic flux density that is induced by the current density in the electroplating device. By measuring the magnetic flux density outside the electroplating device and applying the inverse analysis method, the current density on the LSI wafer surface could be estimated. In order to verify the effectivity of the present method, the numerical simulations under several electroplating conditions are performed. The results show that this method could be applicable to practical problems.

2. Outline of the present method

Figures 1 and 2 show the geometry of the LSI electroplating device. In Fig.2, j is the current density on the wafer surface, and B is the magnetic flux density induced by the current density in the LSI electroplating device. The electric potential in the electroplating device obeys the Laplace equation and the magnetic flux density B is given from Biot-Savart law. Then the observation equation between the discrete-valued vector of the plating current density distribution $\{j\}$ and the data vector of the magnetic flux density $\{B\}$ is given as follows.

$$\{B\} = [W]\{j\} \tag{1}$$

where $[W]$ is the matrix derived from the shape of the device and locations of magnetic sensors. By the instability in solution of eq.(1), slight errors of $\{B\}$ (for example, measurement errors) give estimated values of $\{j\}$ large errors. To regularize the estimated values, we apply Tikhonov regularization.

$$||[W]\{j\} - \{B\}||^2 + \alpha\, ||\{j\}||^2 \to \text{min.} \tag{2}$$

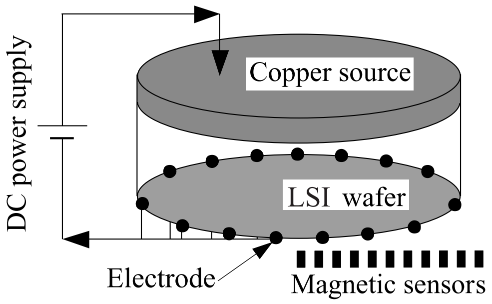

Figure 1: The LSI electroplating device

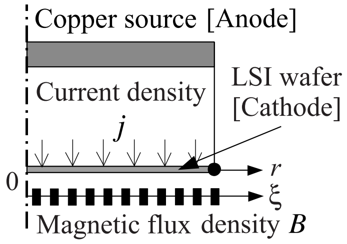

Figure 2: Cross-sectional view of the LSI electroplating device

where α is Tikhonov regularization parameter. We select the value of α by L-curve method [2].

3. Results of the numerical simulation by the present method

It shows the calculated results when the diameter of the silicon wafer is 300 mm as follows. Fig.3 shows the phantom data of the magnetic flux density under the electroplating device induced by the plating current. They are generated by the direct calculation and trancated less than 0.1 μT for taking account of effects by measurement errors. Fig.4 shows the results of the current density distribution on the LSI wafer surface calculated using the phantom data (ref. Fig.3). Then r and ξ are the distance from the center of the electroplating device (ref. Fig.2). For comparison, the results obtained that the estimated distributions are similar to the exact distribution even if the phantom data include some errors. The results show that this method could be applicable to practical problems.

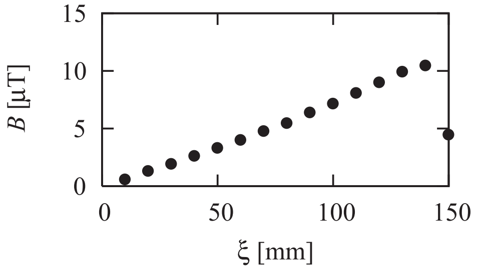

Figure 3: The magnetic flux density distribution (Phantom data)

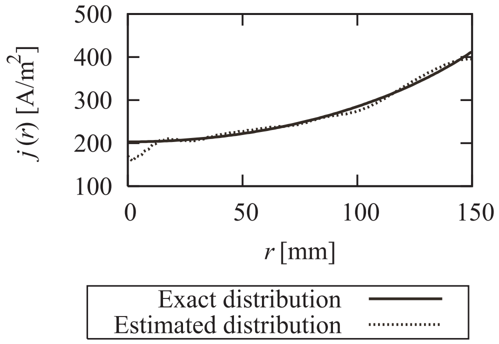

Figure 4: The current density distribution on the LSI wafer surface

References

[1] Aoki,S., Amaya,K., Abe,K. and Miyasaka,M. “Optimization of Electroplating on Silicon Wafer”. *Transactions of the JSME, Series A*, Vol. **68**, No. **666**, 133–138, 2002.

[2] P.C.Hansen. “Analysis of Discrete Ill-Posed Problems by Means of the L-Curve”. *SIAM Review*, Vol. **34**, No. **4**, 561–580, 1992.