A High Precision System for Aligned Metal Printing on Wafers Using ECPR – ElectroChemical Pattern Replication

P. Möller [1]
[1]*Replisaurus Technologies AB, Sweden*
patrik.moller@replisaurus.com

Abstract

This paper describes the principle of a new wafer metallization method capable of printing patterned metal layers on 200 and 300mm wafers. It discloses a novel system architecture for a high precision tool designed to perform aligned metal printing using the method. Continuous print cycling confirm an actual alignment performance for the system better than the targeted level of 250nm, measured using 200mm wafers.

Introduction

The new metallization approach called ElectroChemical Pattern Replication (ECPR), combines the precision and resolution of advanced lithography with the efficiency of electrochemical deposition by integrating the entire metallization sequence for top metal layers used in IC applications into one single electrochemical metal printing step. [1,2,3] ECPR offers a unique combination of resolution, dimensional accuracy, high deposition rates and low cost per layer, bridging the gap between front- and back-end metallization. In order to make full use of the high resolution patterning capabilities, printing of multiple layers with well-controlled layer-to-layer registration is required for most applications.

ECPR – The principle for patterned electrochemical metal printing

In the ECPR process, a template (master electrode), consisting of an electrically conducting electrode layer and a patterned layer of electrically insulating material is used. The master is firstly pre-filled with an anode material, such as copper, in the cavities of the insulating structures, as shown in Fig 1a & b. During the print-step the master is put in contact with a seed layer coated substrate with an electrolyte applied between the two surfaces (figure 1a). When put in contact, excessive electrolyte is forced away from the master electrode and substrate interface. Local electrochemical micro cells, filled with electrolyte, are formed in the cavities defined by the pattern of the master electrode (figure 1b).

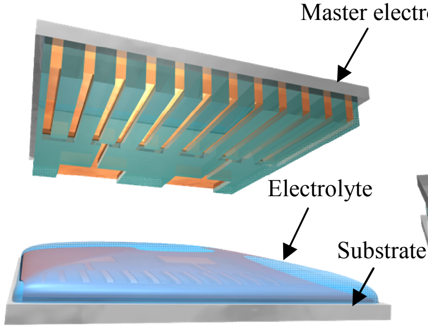

Figure 1a. Master with anode material and substrate with seed layer and electrolyte on

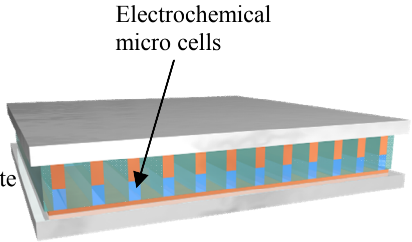

Figure 1b. Master and substrate in contact.

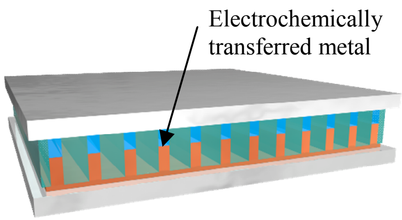

Figure 1c. Electrochemical metal transfer.

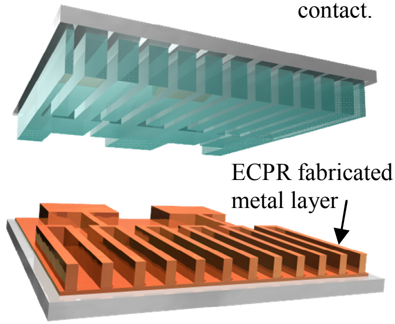

Figure 1d. Separation, followed by seed etch. (seed etch not shown)

Next an external potential is applied, over the master electrode and substrate surfaces, and electrochemical material transfer takes place inside each local micro cell. Metal is dissolved into ions from the pre-filled anode material in the master and transported through the electrolyte in each micro cell and deposited as metal on the cathodic seed layer (figure 1c). After separation, an inverse metal replica of the master electrode pattern has been produced on the substrate (figure 1d), which will go through seed layer etch thereafter (not shown). Subsequently the master is pre-filled again, and the steps are repeated over and over for producing new replicas from the master.

System architecture for aligned ECPR print tools

ECPR printing involves aligning two opaque wafer substrates to each other before bringing them into contact while a thin film electrolyte is applied between. The following constrains have been guiding the design of an alignment system for ECPR:

	Feature	**Target specification**
A.	Alignment accuracy	< 250nm @ 3s, 200/300mm wafers
B.	Print force on chambers	Supporting > 10 000N
C.	Alignment cycle time	<10s
D.	Module footprint	< 1500 x 1000mm for 300mm modules
E.	Cost	Compatible with CoO levels for top IC layers

In the conceptual design phase several schemes for aligning and bringing the two wafers in contact were analysed, including fundamentally new methods and commonly known schemes from wafer scanners, wafer bonders and mask aligners. The analysis resulted in a conceptual design for a novel intersubstrate alignment architecture based on the following key components, also shown in Figure 2:

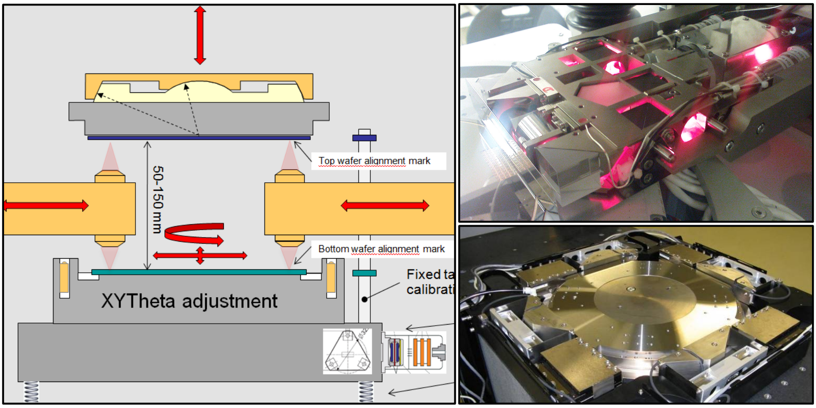

Figure 2a - System architecture, **2b** – low profile vision system, **2c** – XYT stage

- A vibration isolation system
- Two high resolution inter-substrate measurement systems comprising low-profile microscope and X-Y stages to position the microscopes over the wafers.
- A high precision high Z-force compatible air bearing XYT wafer stage
- A high stiffness Z-stage actuating the top chuck of the process chamber
- A linear and angular drift monitoring system
- An ECPR process chamber
- A levelling mechanism to ensure co-planarity between chucks.

An error and cycle time budget was created to determine allowed error- and cycle time components for the respective subsystems, targeting a total alignment error <250nm @3s. In order to meet the error budget a low profile optical measurement system based on a intersubstrate microscope with 37mm vertical focal plane distance and a 4-motor closed loop XY-Theta wafer stage was developed. (Figure 2b, 2c).

Alignment results

The vision system was designed to acquire the position of alignment keys on two separated wafers in intersubstrate mode as well as overlay measurements using alignment keys superimposed in one printed layer. The following alignment results have been achieved by using transparent calibration wafers to first find the correction factors for the tool, then by continuous aligned wafer print cycling measuring alignment errors between the two wafers in superimposed position after each transfer. Measurements confirm < 150nm align errors during 35 consecutive cycles, measured on wafer center line, left and right side, 15mm from the edge on 200mm wafers.

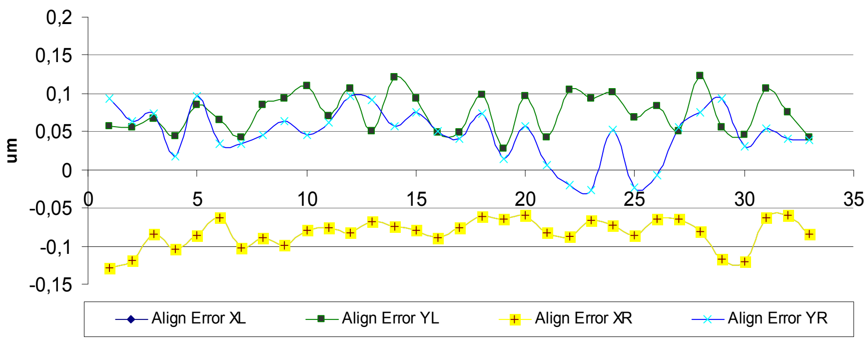

Figure 3. Measured alignment errors, left (XL,YL) & right (XR,YR) on glass wafers

Summary

A new alignment system for ECPR metal printing capable of aligning 200mm wafers with <0,150um alignment error over 35 consecutive print cycles has been demonstrated. Longer term alignment performance and system drift was not studied within the scope of this study, such data is being gathered and will be reported elsewhere.

References

[1] Moller P., Fredenberg M., Wiwen-Nilsson P., in AESF SURFIN / Interfinish 2004, proceedings (2004).

[2] Fredenberg M., Möller P., Recent Progress in the Development of ECPR (ElectroChemical Pattern Replication) - Metal Printing for Microelectronics, ECS 208 Fall Meeting, Los Angeles, October 19, 2005.

[3] Möller P., Fredenberg M., Dainese M., Aronsson C., Metal Printing of Copper Interconnects Down to 500 nm using ECPR – ElectroChemical Pattern Replication, Micro- and Nano Engineering 2005, Microelectronic Engineering 83 (2006) 1410–1413.