POSITION CONTROL IN LITHOGRAPHIC EQUIPMENT

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INTRODUCTION

In IC manufacturing, lithographic scanners expose a circuit pattern onto a semiconductor wafer by means of an optical system. The stage scanning position accuracy must be in the single nanometer range to support imaging and overlay requirements. In the past 10 years, stage acceleration, position error and settling time have all improved 5-8 fold. This paper describes the progress in control technology that stood at the basis of these improvements, and hints towards future techniques.

200 MM WAFER SCANNER

A long-stroke / short-stroke horizontal actuator system, the first operating in slave mode, drives the stage, its position being measured with interferometers. The wafer is on-line focused by means of a level sensor and a cam-shaft actuator system. Only minor coupling is present between the horizontal and vertical controllers. Feedforward of setpoint acceleration and of measured disturbances, like lens acceleration, enable a high accuracy.

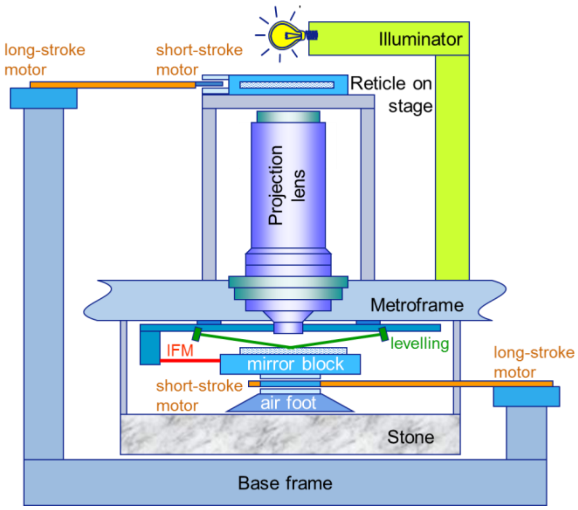

FIGURE 1: 200 mm lithographic scanner layout

300 MM DUAL-STAGE SCANNER

For 300 mm wafers, scanners are equipped with a second wafer stage, which measures the wafer surface height map and aligns the wafer in the horizontal plane, in parallel with the first wafer stage exposing the wafer [1]. Stage short stroke control is fully 6-DOF integrated. Later tools implement a water layer between lens and wafer (immersion lithography), leading to added noise and position-dependent stage behavior.

The controller design follows the following steps.

Decoupling and compensation

To allow the use of 6 independent SISO controllers, this step linearizes the stage behavior and reduces its position dependency.

Feedback controller design

The feedback controllers are designed to achieve optimum disturbance rejection. A higher control bandwidth is generally favorable, but is limited by stage dynamics and motor/sensor layout [2].

Feedforward controller design

Setpoint feedforward takes care of the main acceleration force, with a 99.9% required accuracy. The feedforward filter needs to better and better match the plant's process inverse [3]. Off-line obtained wafer height map data allows feedforwards in all 6 DOF's.

300 MM DUAL-STAGE PLANAR SCANNER

Improved accuracy and throughput were obtained by using a 6-DOF planar actuator, and a planar encoder system replacing the interferometers.

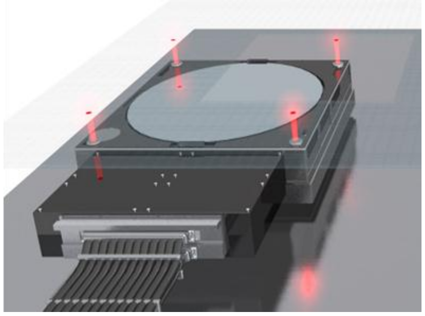

FIGURE 2: Planar stage with encoder measurement system

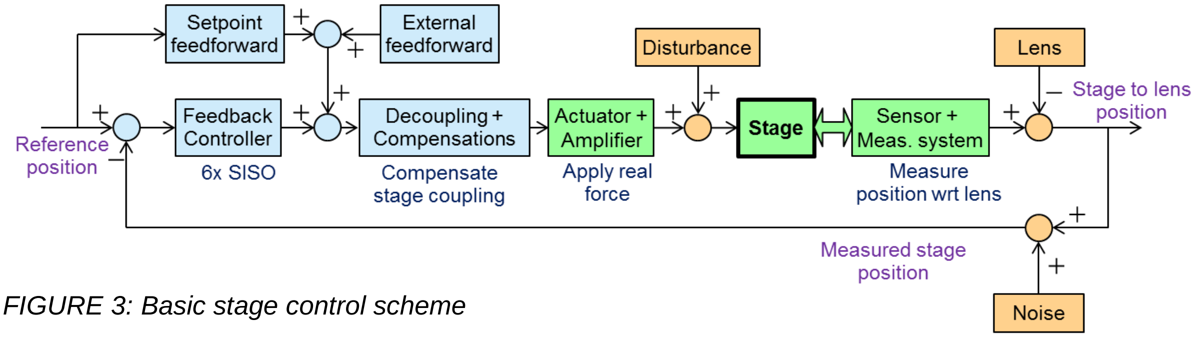

FIGURE 3: Basic stage control scheme

New control techniques include dive torque control, torsion mode control and ILC for edge leveling.

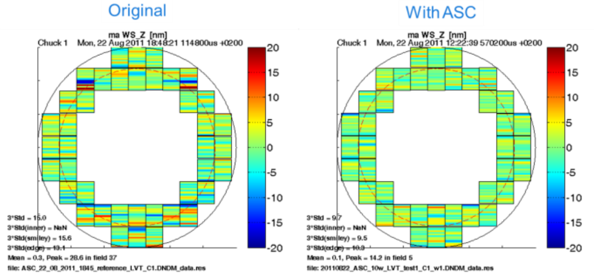

FIGURE 4: MA-z improvement by ILC: peak values reduced from 28 nm to 14 nm.

FUTURE DEVELOPMENTS

Increased stage dimensions for 450 mm wafers lead to reduced eigenfrequencies and require active mode shape control both at resonances and quasi-statically.

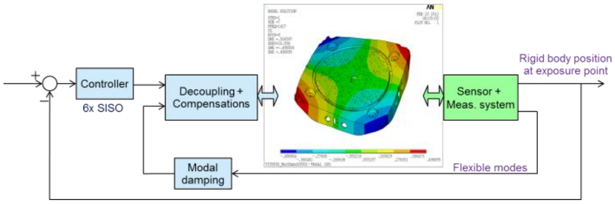

FIGURE 5: over-actuation and oversensing allows mode damping, deformation compensation, and bandwidth improvement

CONCLUSIONS

Control techniques have evolved significantly over time, enabling the stage scanning accuracy required for today's chip manufacturing.

REFERENCES

[1] B. Sluijk et al., "Performance results of a new generation of 300 mm lithography systems," in Proc. of SPIE, vol. 4346, Santa Clara, 2001, pp. 445 – 557

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[3] M. Boerlage, M. Steinbuch, P. Lambrechts, and M. van de Wal, "Model-based feedforward for motion systems," in Proc. IEEE Conf. Control Applications 2, Istanbul, Turkey, 2003, pp. 1158–1163.