

# Air Film Based Contactless Planar Positioning System with Sub-micron Precision

J. Wesselingh, J.W. Spronck, R.A.J. van Ostayen, J. van Eijk

*Delft University of Technology, 3mE – PME – Mechatronic System Design*

[j.wesselingh@tudelft.nl](mailto:j.wesselingh@tudelft.nl)

## Abstract

This paper discusses a 6 DoF positioning system that utilizes a thin air film to directly position flat substrates with sub-micrometer precision. Such a positioning system can be applied in the production of electronic devices, such as integrated circuits, flat panel displays and solar cells. All these devices are manufactured on a flat base substrate, e.g. a silicon wafer or glass plate. Precision positioning stages are used during exposure, inspection, alignment, etc. We present a planar positioning system where only the product mass is driven and without mechanical contact. This system has two main advantages: a moving mass of 2 to 3 orders of magnitude smaller, since the carrier stage is eliminated and the absence of mechanical contact reduces the chance of contamination or damage.

## 1 Working principle of combined motor and bearing function

Several actuation methods for contactless substrate positioning have been researched, for instance by using electrostatic or magnetic forces [1] or air jets [2]. Our principle of actuation utilizes viscous shear from air flow for improved proportional position control and can be explained as follows (refer to Figure 1 and also [3]). Compressed air flows from an inlet under the substrate, through a pocket towards an outlet, where the pressure is below ambient. At the product surface, the air creates a viscous shear, providing a lateral force for the motor function. To reduce undesired backflow between adjacent actuators, a small dam is introduced between them. The lateral force per actuator is only dependent on dimensions and pressure:

$$F_A = \frac{1}{2}(h-t)(p_2 - p_3)b$$



The system originally used edge detection with low cost reflectance based optical sensors to position the substrate in closed loop control. Noise from these sensors limited the performance to a positioning bandwidth of 10 Hz and a servo error of 20  $\mu\text{m}$  p-p. To improve this performance a new sensor solution was devised.

### 3 Improved planar position sensing using optical encoders

To improve sensor noise levels, a commercially available sensor system was implemented. Three Renishaw Tonic encoders are used to measure all three planar degrees of freedom with a resolution of 10 nm. The required encoder scales are manufactured directly on the wafer by means of laser engraving by Lasertec B.V. The encoder lines are applied in areas of 15x15 mm for sufficient planar stroke. The resulting system with additional metrology is depicted in figure 3.

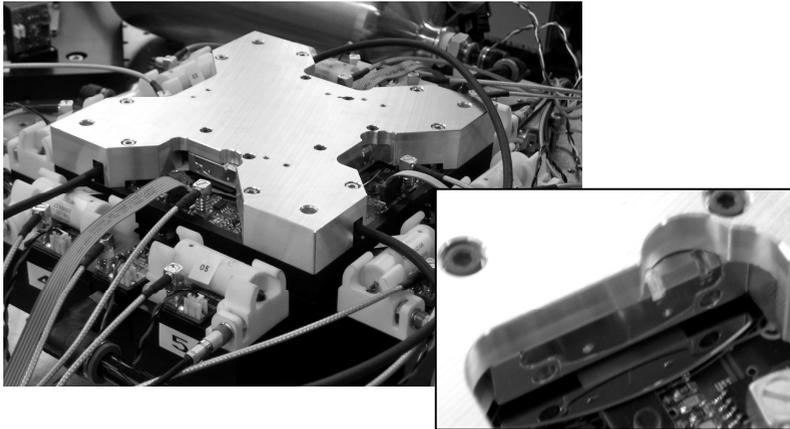


Figure 3: Photo of the experimental setup with added metrology and optical encoder with grid (insert).

### 4 Results and discussion

With the improved sensing the open-loop positioning bandwidth for  $x$ -direction is improved significantly from 10 Hz to 40 Hz, see figure 4(a). The system uses conventional PID-controllers with static decoupling of the degrees of freedom. With the new controller settings (40 Hz 0-dB frequency,  $\tau_i = 0.032$ ,  $\tau_d = 0.020$ ), a servo error of 100 nm p-p can be achieved, as can be seen in figure 4(b). Floor vibrations that excite the metrology frame are a large contributor to this error, while the wafer is essentially standing still. The system was thus placed on an active vibration isolation

table to achieve this result. The system also nears its resolution of 10 nm. Further improvements can be made by increasing the control bandwidth to improve low frequency disturbance rejection. For this, additional derivative action is required which will benefit from an increased sensor resolution.

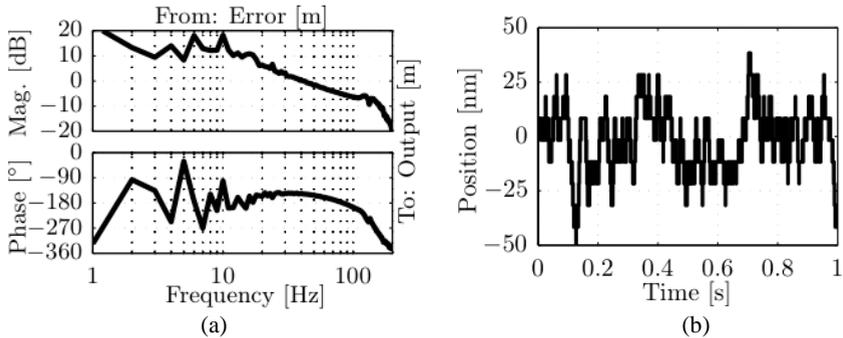


Figure 4: Open-loop frequency response of the measured system (a), servo error at standstill (b).

## 5 Conclusions

This paper discusses improvements in sensing to a contactless planar position system, which uses airflow to provide a motor and bearing function for flat substrates. An experimental setup with linear encoders for planar sensing has been designed and realized. The system achieves a positioning bandwidth of 40 Hz and a servo error of 100 nm p-p, a significant improvement compared to the previous result of 10 Hz and 20 μm p-p

## Acknowledgement

The Dutch research foundation IOP Precisietechnologie is funding this research.

## References

- [1] E. van West, et al. *Manipulation of Thin Objects Using Levitation Techniques, Tilt Control and Haptics*. IEEE Trans. Autom. Science and Eng., Vol. 7, No. 3, 2010
- [2] A. Delettre et al. *A New Contactless Conveyor System for Handling Clean and Delicate Products Using Induced Air Flows*, Proc. of the IEEE Int. Conf. on Intelligent Robots and Systems, 2010
- [3] J. Wesselingh, et al. *Contactless 6 DoF planar positioning system utilizing an active air film*. Proceedings of the 10<sup>th</sup> international conference of the EUSPEN, 2010