Using deformable surface for thin substrate transport and positioning system: Initial design and preliminary results

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Abstract

A new concept for a contact-less wafer handling and positioning system, which uses a deformable surface, has been developed at Delft University of Technology [1]. This research is a continuation of the research on contact-less wafer handling and positioning systems [2, 3]. The new concept [1] does not suffer the disadvantage of the bandwidth-limiting proportional pneumatic valves from [3]. In this paper, firstly the measurements on the statically tilted air bearing experiment are compared with an improved FEM model [1] that takes into account the deformation of the thin substrate and the nonlinear property of the inlet restriction. Secondly, an initial design for a three DoF positioning system is proposed. This design allows for all the surface parts to tilt the same angle simultaneously by a simple mechanical action: The relative displacement of two parallel plates.

1. Introduction

In high-tech industries, there is often a need to transport and position fragile substrates. For instance, a semiconductor wafer needs to be aligned precisely in the lithography process, or a solar cell sheet needs to be transported between different fabricating processes. With the aim to increase production throughput, larger substrates will be used in the future. As a consequence they will be more susceptible to contamination, damage or even breakage. Furthermore, the coupled increase in the size of carrying stages introduces a large amount of additional mass, which costs much more energy from the precision motion control point of view. There is a demand to develop a system that is able to handle and/or transport fragile substrates directly without product carriers and without causing damage.

2. Contact-less actuation using a thin air film

A thin substrate can be positioned without any mechanical contact by an array of air-based actuators (Figure 1) [1-3]. When a positive pressure p_{in} and vacuum pressure p_{out} are applied respectively at the inlets and outlets, the resulting average pressure in the air film is able to levitate the substrate with a high bearing stiffness. On the other hand, the large difference between the resulting pressure p^+ and p^- forces an air flow along the surface in the pocket, resulting in a planar force on the substrate. The force generated by one actuator, which has a geometry described in Figure 1, is given by:

$$F_X = b\frac{(t-h)}{2}(p^+ - p^-) \tag{1}$$

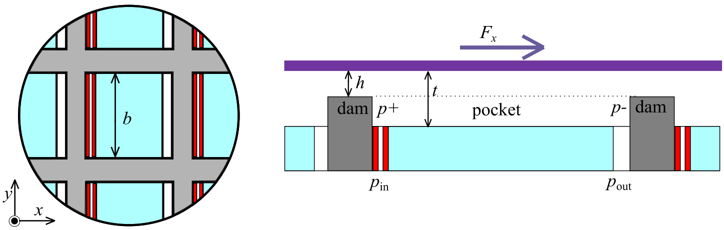

Figure 1: Actuator array for contact-less wafer handling and positioning.

3. Deformable surface concept

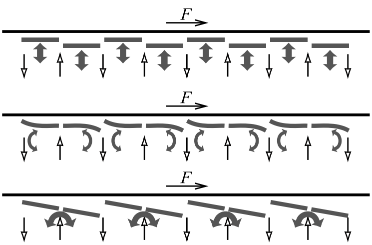

Figure 2: Different configurations.

From Equation 1, the force can be controlled by varying either the pressure difference $(p^+ - p^-)$ or the depth of the pocket $(t - h)$. In the original pressure variation concept [2, 3], proportional valves have been employed to control the pressure and thus the force. However, these valves limit the bandwidth, when applied with position feedback control, since they are placed relatively far from the actuators. Controlling the force by using a deformable surface is a new concept that does not suffer this disadvantage [1]. As shown in Figure 2, a deformable surface can be configured in different ways. After comparing these configurations regarding the trade-off between performance and complexity, the tilting configuration has been chosen for further investigation.

4.1 Experimental setup

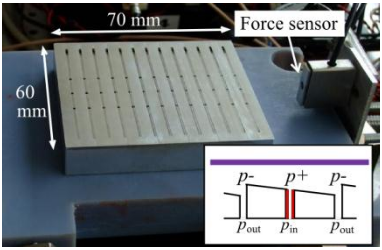

Figure 3: Tilted air bearing setup.

A system with an array of seven tilting actuators (length: 10 mm, step height: 25 μm) has been built (Figure 3). When positive pressure p_{in} and vacuum pressure p_{out} at the inlets and outlets are applied, the substrate is carried on a thin film of air and is pushed against the force sensor. The total mass flow of the whole system is measured.

4.2 FEM model and its experimental validation

The test setup has been modelled in an FEA model, based on Reynolds' equation for thin air films. The model includes the deformation of the wafer and measured non-linear restriction values. Figure 4 shows a better prediction when the real restriction value is implemented into the model. This restriction is not a constant, it depends non-linearly on the pressure drop between two ends of the restrictor.

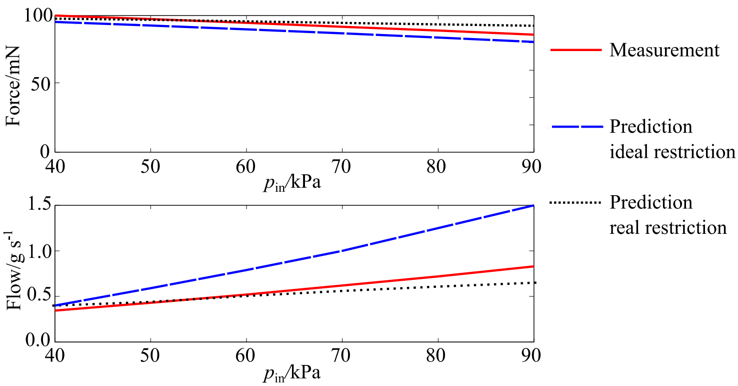

Figure 4: Performance of the tilted air bearing, p_{out} = 20kPa.

4. The preliminary test of a three DoF system

The tilting actuator concept can be realised into a three DoF actuated system as presented in Figure 5. The actuator surfaces (hexagonal shape) are connected to the base through flexible stems. These stems are mechanically connected together by an intermediate plate. The transitional and rotational motion of this plate will tilt all the actuator surfaces. A setup of this design has been built using additive manufacturing techniques. This demo shows that by using the deformable surface concept, the force (and/or torque) can be generated and controlled in different directions on the floating substrate.

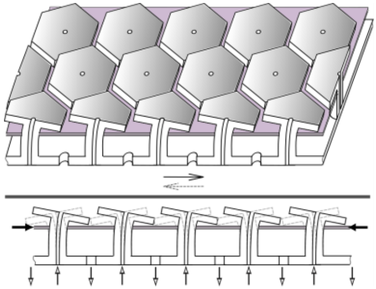

Figure 5: The three DoF mechanism.

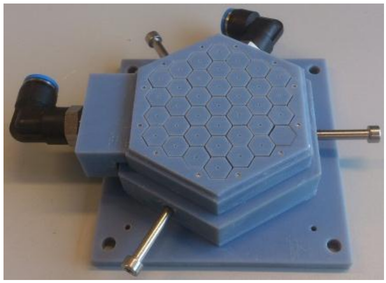

Figure 6: The three DoF setup.

5. Discussion and conclusion

The static behaviour of the tilting surface contact-less actuation system is predicted accurately by the developed model. The tilting concept has been experimentally proven to be simple and promising for contact-less positioning and transport systems. In further research the dynamic behaviour is going to be investigated.

References:

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