A Parallelism Alignment Mechanism for Nanoimprint Lithograph with Large Imprinting Force

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Abstract

This paper proposes a force-bypassed parallelism alignment mechanism to address the negative effect of the imprinting force in Nanoimprint Lithograph (NIL). It enables the imprinting force bypass the delicate compliant members, thus ensuing the active and passive parallelism alignment able to be carried out properly even under a large imprinting force. A prototype of the parallelism alignment mechanism has been developed and tested. Experimental results show that superior alignment accuracy still can be achieved under an imprinting force up to 1KN.

1 Introduction

Nanoimprint Lithograph (NIL) utilizes the imprinting force to transfer circuit patterns from a template to a substrate. Its two critical specifications i.e. overlay accuracy and pattern transfer fidelity, depend on performance of the parallelism alignment system.

Parallelism alignment in NIL needs to perform out-of-plane (θx and θy) motions, which brings the template and substrate surface into parallel contact while minimizing the lateral motion during the imprinting process. This is typically implemented through adopting an active alignment to eliminate large wedge errors firstly and then a passive alignment to compensate the residual errors [1]. The active alignment is done by a motorized precision stage, while the passive one done by virtue of the deformation of a compliant mechanism under imprinting force. Imprinting forces may vary from a few Newtons to several hundred Newtons in different tasks. A large imprinting force will deteriorate the alignment performance if the compliant mechanisms directly undertake such a force.

To compensate the wedge error with a relative higher sensitivity, most of off-the-shelf complaint mechanisms [2] used for NIL parallelism alignment are arranged within the force loop of compression. This configuration is acceptable only for cases with small imprint forces. For cases with large imprint forces, such a design may result in the compliant mechanism a significant deformation in unwanted directions, consequently decreasing the overlay accuracy between the template and the substrate. This paper will address this issue through presenting an imprinting force bypassed parallelism alignment mechanism.

2 Descriptions of parallelism alignment mechanism structure

Figure 1 is an assembly view of the NIL press head developed in SIMTech. It includes a template unit and a parallelism alignment unit. The template unit comprises a template, a heating block, isolate plates and three force sensors, etc. The alignment unit carries the template unit to perform required parallelism alignment.

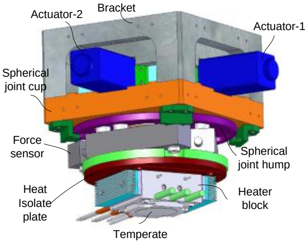


Figure 1: NIL press head

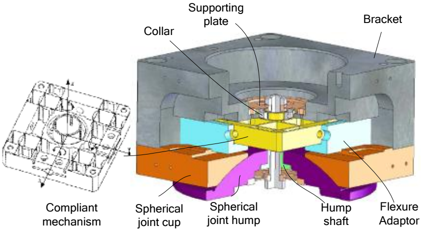


Figure 2: Structure of parallelism alignment unit

Shown in Figure 2 is the structure of the parallelism alignment unit, which comprises a special spheroidal joint, a compliant mechanism, and two actuators. The spheroidal joint is a reverse ball-and-socket joint, consisting of a ball-shaped hump and a thin socket part. The hump can rotate about the center of the template surface. Unlike common ball-and-socket joints, the shaft here is fixed on the top of the hump and goes through the top opening of the socket. The compliant mechanism is anchored on the top of the socket (or cup). Its platform (central portion) is firmly connected with the hump shaft. The stiffness of the platform after considering actuators connection is shown in Table 1. Obviously, the platform allows the hump θx and θy tilting motions, but limits the hump θz motion due to the high stiffness value.

Table 1: Stiffness of compliant mechanism platform

Translational Stiffness (N/µm)			Angular Stiffness (N•m/deg)		
Kx	*Ky*	*Kz*	$K_{\theta x}$	$K_{\theta y}$	$K_{\theta z}$
25.5	25.5	4.7	22.0	22.0	395.5

3 Function analysis of parallelism alignment mechanism

A schematic of working principle of the parallelism alignment unit is shown in Figure 3, in which the non-uniform press forces distributing on the template is compounded as a linear imprinting force F and a small torque M at the template centre. It can be seen that imprinting force F goes through the template block, spherical joint hump, spherical joint cup and bracket, finally, reaching to the machine frame. In other words, the compliant mechanism does not bear the imprinting force F, but only undertake the small torque M during compression. This feature means the large imprinting force will not affect the behaviors of the compliant mechanism.

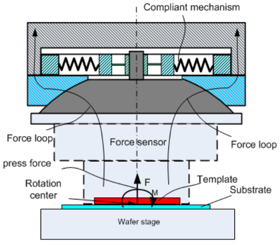


Figure 3: Working schematic

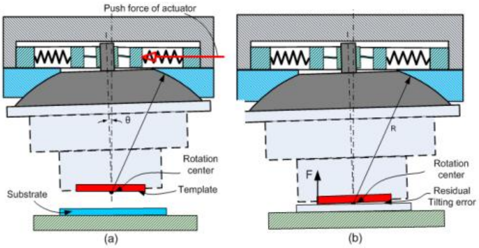
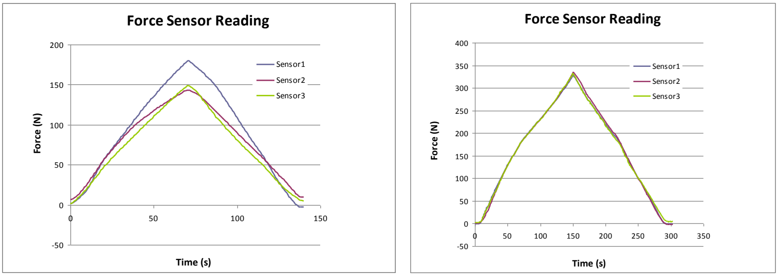


Figure 4: Active/passive alignment in one setup

With the force-bypassed feature, the press head allows both active alignment and passive alignment tasks in one setup. Before the template is brought to contact with the substrate, an active alignment task is conducted to eliminate the coarse tilting errors (Figure 4 (a)). Two actuators drive the complaint mechanism to carry the hump to perform tilting motions about the template surface center until the required parallel accuracy is reached. After the template contacts with the substrate, a passive alignment is applied to eliminate the residual error of the active alignment. As shown in Figure 4 (b), under a non-parallel contact, the press force on the template will offset from the rotation center. This offset will result in the template block self-rotating about the template center to eliminate the non-parallelism.

4 Experimental results

Press force uniformity is an important indicator of the press head parallelism. Three force sensors uniformly installed on the template unit are used to measure and monitor the press force distribution. The total press force of about 1KN is gradually applied on the template and then release to zero. Figure 5 (a) shows the distribution of the press force before alignment. The maximum variation of the press force over the template is over 20 percent. Figure 5 (b) shows the press force distribution after alignment. It can be found that the variation of press force is less than 5 percent. Under such force uniformity, the parallelism error over the template area (Φ50mm) can be less than 20 nm.



(a) (b)

Figure 5: Force sensor reading (a) before alignment; (b) after alignment

5 Conclusions

Large imprinting force may affect the alignment accuracy in NIL. Using the "smart" mechanism design presented in the paper will reduce the negative effect of the imprint force.

References:

[1] Byung Jin Choi, Sidlgata V. Sreenivasan, Stephen C. Johnson, "High precision orientation alignment and gap control stages for imprint lithography process", US patent No: 6873 087B1, Mar 29, 2005.

[2] Jae Jong Lee Kee-Bong Choi and Gee-Hong Kim "Design and analysis of the single-step nanoimprinting lithography equipment for sub-100 nm linewidth" Current Applied Physics Volume 6, Issue 6, October 2006, pp. 1007-1011