國立交通大學

機械工程學系

碩士論文

覆晶自我校準機構之設計與實現

Design and Implementation of Flip-Chip Self-Aligned Mechanism

研 究 生：尤冠今
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A thesis
Submitted to Department of Mechanical Engineering
College of Engineering
National Chiao Tung University
in partial Fulfillment of the Requirements
for the Degree of
Master
In
Mechanical Engineering

August 2009

Hsinchu, Taiwan, Republic of China

中華民國九十八年八月

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摘要

在覆晶製程之中，當晶片結合時晶片面與基板面彼此相對的歪斜可能會造成在晶片面下的凸塊與基板上的襯墊僅有部分的接觸，此部分接觸可能會導致凸塊與襯墊僅有部份的接合或是造成凸塊過度壓擠而發生破裂，影響覆晶封裝的品質。

本研究主要是在設計與實現覆晶機構中平面結合時的自我校準機構，此自我校準機構的設計與實現，讓鑲在晶片上的凸塊與基板上的襯墊就可以均勻的貼合，提升覆晶製程的良率。在自我校準機構的設計之中，使用球面氣體軸承的設計,以球面對來產生兩個轉動自由度以利於平面的對準，利用氣體潤滑的方式，讓基板面移動配合晶片面來達成共平面的狀態。

Design and Implementation of Flip-Chip Self-Aligned Mechanism

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Abstract

In bonding process of flip chip, when there is an angle between the chip and the substrate, bonding can only be achieved at one corner or broken bumps to affect package quality of flip chip.

The main purpose of this thesis is design a self-alignment system for flip chip devices. It is application of flip chip by self-alignment system to solve an angle between the chip and the substrate. Pads and bumps can contact uniformly and improve package quality of flip chip. In the design of self-alignment, it used the spherical air bearing. The spherical surface can be provided two degree of freedoms to achieve coplanarity. It's used be a little force that moves substrate to match chip by air lubrication.

誌謝

首先該感謝的是成維華教授，感謝老師在學生兩年的碩士生涯中的指導，孜孜不倦的教導求學問的態度與研究的方式，讓學生在這兩年收穫良多，再次的感謝老師的付出與指導。

感謝實驗室嘉豐學長、秉霖學長和向斌學長、舶強、文彬、洋豪和奕旻學長、學磊、星雲和富源學長給予業界上、生活上以及學業上的意見、指導以及照顧。

感謝同學們文祥、志隆、安鎮和之浩，讓我在求學的生活之中增添了許多的樂趣。以及感謝學弟們的幫助。

這一路上受到幫助的實在太多，需要感謝的人無法一一提名道謝，謝謝這一路有你們的幫忙，我才能夠順利完成學業。

這兩年來的日子，點點滴滴不但豐富了我的學識，也豐富了我的視野，最後感謝我的家人願意支持我就學直到研究所畢業，我想沒有家人的支持，沒有今天的我，深深的感謝我的父母。

尤冠今僅於 2009.08

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Chapter 1 Introduction

1.1.Motive and objectives

In bonding process of flip chip needs more precise driving system to improve the bumps and the pads contact. Because there are a lot of bumps and pads and high packaging density, bonding of flip chip needs more complex structure to produce the chip and the substrate coplanar. Flip chip bonding process usually needs pressure and heating to contact pads and bumps, in addition to, the self-alignment system can be achieved the substrate with the chip coplanar. To make flip chip bonding is uniform contact substrates.

When there is an angle between the substrate and the chip, bonding can only be achieved one corner or broken bumps and it affect package quality of flip chip, as show in Figure 1.1. The main purpose of this thesis is to design the self-alignment system for flip chip devices. Self-alignment system solve an angle between the chip and the substrate and let them achieve coplanar. It provide uniform surface to transmit pressure and heat, let chip and substrate contact easily and promote successfully for flip chip bonding.

1.2.Development of flip chip

There are at least three popular methods for interconnecting the chip(s) on the substrate: face-up wire bonding, face-up tape-automated bonding, and flip chip. Comparing with the popular face-up wire bonding technology and face-up tape-automated bonding technology, flip chip technology provides shorter possible leads, lower inductance, higher frequency, better noise control, higher density, greater input/output (I/O), smaller device footprints, and low profile. Flip chip technology is defined as mounting the chip to a substrate with any kind sof interconnect materials and methods, as long as the chip surface (active area) is facing to the substrate. The flip chip was introduced by IBM in the early 1960s, which became the logical foundation of the IBM System/360 computer line. The so-called C4, controlled-collapse chip connection technology utilizes solder bumps deposited on wettable metal terminals on the chip and a matching footprint of solder wettable terminals on the substrate. The solder-bumped flip chip is aligned to the substrate, and all solder joints are made simultaneously by reflowing the solder. There are some methods for flip chip technology shown in Figure 1.2: solder-bumped flip chip, conductive adhesive polymer flip chip, anisotropic conductive adhesive flip chip, wire-bumping flip chip, etc. Every type of flip chip interconnects themselves by the heating temperature, pressure, precision position, and request of coplanar error between chip and substrate.[1]

Flip chip bonder requirements are usually determined on the basis of the throughput, alignment accuracy and performance requirements. Typically the alignment accuracy for self-alignment is specified as less then one-quarter of the bond pad dimensions. That is, if the chip is misaligned to substrate by less than 25 percent of the bond pad dimensions, the reflow process is capable of self-aligning the chip to the substrate. If greater reliability is needed or self-alignment is not possible, then a bonder with better accuracy is needed.

Even a rigid structure, the planarity problem still exists. For a given system, the planarity between the chip and the substrate depends on the machining and assembly variation. There may always be a small angle between these two surfaces. This planarity angle may not be important if the chip is small. As the chip size increases, this small angle could result in a large gap variation.

Deformation of bumps was used as the criteria for good bonding. Bump deformation in the range from 15–45% represented good connections. The non- or partial-bond conditions, deformation less than 15%, resulting from insufficient pressure between the bonding surfaces might cause poor mechanical or electronic connection. On the other hand, excessive deformation, over 45%, might damage chip or substrate. So, the degree of coplanarity is important to bump's deformation uniform in bonding of flip chip. [1]

1.3.Research Orientation

In this paper, four chapters summarized as follows: The chapter 1 focus on flip chip technology for the development and application, then illustrate flip chip self-alignment system and the motives and objectives. Chapter 2 is illustrated the patents and literature about bonding head of flip chip mechanism, and compared their advantages and defects and it will introduce the design of self-alignment system. System design further detail parts and analysis and integration. Chapter 3 is the improvement of force control system. Chapter 4 is operation of this flip chip mechanism and conclusion.

Chapter 2 Self-alignment Mechanism Design

2.1.Bonding Head of Flip Chip Types

The following bonding head of flip chip patents have been arranged in two forms: active form and passive form. They are classified by power resources. Two forms are introduced as follows:

2.1.1. Active Form

This mechanism used actuators to adjust surface that achieve coplanar. I'll introduce two kinds of method to adjust coplanar calibration. It is usually used more sensors and actuators to place on device.

The first patent is used autofocus system to indentify the chip and the substrate whether coplanar, then adjusts the surface by two degrees of actuators, show in Figure 2.1. [2]

The second patent is called "Methods for adjusting coplanarity calibration of A thermocompression head". Figure 2.2 show that s device supply a test chip, which have many bumps on chip, then put the test chip on the stage, and press the bumps on the chip by a thermocompression head. After compression bumps' height are measured, and use height difference of the bumps to adjust the thermocompression head, promote effective and exact. [3]

All of active form bonding head of flip chip patents depends on a lots of sensors and actuators to adjust the plant and its accuracy proportional with actuator, but the mechanism is needed more elements, in addition to structure complex and cost more expensive.

2.1.2. Passive Form

The mechanism of passive form is used pressure of contact to adjust surface that achieve coplanar. Following will introduce some kinds of methods to adjust coplanarity calibration.

The first patent is presented by Qing Tan. Because control the ultrasonic energy transmission is difficult, the yield of thermosonic bonding is low and unreliable. A small planarity angle between the bonding tool and the stage can result in a nonuniform ultrasonic energy distribution. A self-planarization concept was proposed to solve this problem. A layer of polymer was placed between the bonding tool and the chip to smooth the nonplanar contact. As shown in Figure 2.3, if a layer of polymer material is placed between the tool and the chip, the deformation of the soft material can enhance the contact between the tool and the substrate as a static force applied. But there are some problems to layer of polymer material, likes layer of polymer material how to install in device and what kinds of material can be used, etc. [4]

The second patent is design by David W. Swanson, as show in Figure 2.4. A pressure head for contact area of workpiece though relative movement in the vertical Z-direction includes a frame, a horn for contacting the workingpiece and a gimbal connected to frame. The gimbal supports the horn such that the horn can rotate about horizontal X and Y rotation axes and can translate in the Z-direction relative to the frame. A pivot rod includes a bearing surface bearing against horn such that the horn may rotate about the X-axis and for applying downward pressure to the horn. The shape and orientation of the bearing surface corresponding to the shape and orientation of the contact area of horn. David W.

Swanson presents: this mechanism in many applications with workpieces requiring very bonding tolerances, it imperative that force exerted on the horn by the workpiece required aligning the gimbaled horn with the horn by workpiece be extremely small. These is necessitated because the gimbaled horn not only rotates as it is aligned but also moves sideways thereby producing shear forces on the workpiece. If the rotational force is more than de minimis, then the shear force created in the rotation will disrupt the workpiece. Consequently, the mass of the gimbaled head needs to be minimized and the lever arm from the point of alignment force to the gimbal point or axis need to be maximized. Even the forces required to overcome the static friction of bearings in many conventional gimbaled horns or to overcome the moment and resistance to rotation crested by wires leading to the heating element and thermocouple on the gimbaled horn are too large for use in some high tolerance application. These ideas likes the mass of the gimbaled head needs to be minimized, it can be inspired about self-alignment mechanism of flip chip. [5]

Finally, the source of patent is came from Matsushita Electric Industrial Company, as show in Figure 2.5, the method of pressure bonding a bumped electronic part use: a tilting mechanism which tiltably supports a suction tool for sucking a bumped electronic part; and locking means for inhibiting a tilting operation of the tilting mechanism. The method includes: a suction step of sucking the bumped electronic part to the suction tool; a step of detecting the position of the bumped electronic part which is sucked to the suction tool, and positioning the bumped electronic part with respect to a substrate, under a state where the tilting operation is inhibited; and a pressure bonding step of pressure bonding bumps of bumped electronic part which is sucked to the suction tool, to the substrate under a state where the tilting operation is enabled, According to this arrangement, the tilting mechanism is not accidentally swung during the positioning operation, and hence the mounting accuracy is prevented from being impaired. [6]

2.1.3. Comparing

About comparing active form and passive form, exact calibration of active form mechanism is proportion to actuator, so exact calibration of active form is better than passive form, but active form mechanism needs many elements, complex, and expensive. The exact calibration of passive form mechanism is proportion to exact calibration of elements, it’s usually limited by structure, but structure of passive form mechanism is simpler, and cost cheaper than active form mechanism.

According to review of these patents and literatures, it can be obtained some conclusions about self-alignment system, like to reduce friction on rotatable surface and unify the top of the head and rotating axis's the moment of force as far as possible to amplify small resistible force that overcame rotatable friction force and rotor inertia. So I select the spherical air bearing to be my rotatable surface. The spherical surface can be supplied two degrees of move and air pressure will hold on the spherical surface to reduce the friction. We’ll introduce about air bearing and design of self-alignment system

2.2.Air Bearing

Unlike contact-roller bearings, air bearings utilize a thin film of pressurized air to provide an exceedingly low friction load-bearing interface between surfaces. The two surfaces don't touch. Being non-contact, air bearings avoid the traditional bearing-related problems of friction, wear, particulates, and lubricant handling, and offer distinct advantages in precision positioning and high-speed applications.

The fluid film of the bearing is air that flows through the bearing itself to the bearing surface. The design of the air bearing is such that, although the air constantly escapes from the bearing gap, the continual flow of pressurized air through the bearing is enough to support the working loads.

According to the methods of providing pressure, there are two kinds of air bearing as shown in Figure 2.6: aerostatic bearings, which require a feed of pressurized air for their operation, and aerodynamic bearings, which generate their own internal pressure differentials. The latter generate this pressure by action of simultaneously shearing as shown in and squeezing the environmental gas between the surfaces in relative motion, whereas the former require an external pump to produce the pressure, and this purpose is using aerostatic bearing to be a part of self-aligned mechanism.

2.3.Mechanism Design Conception

We were design and implementation of flip-chip mechanism last year, as show in Figure 2.7[7], but there is not adjusted coplanar calibration of the flip chip mechanism, so we’ll design a self-alignment system to install on this device.

Self-alignment is an important key of flip chip technology. So we will use air compressor、air bearing and spring to be the self-alignment mechanism, and the conceptual mechanism is shown in Figure 2.8. The self-alignment mechanism is installed on the force device that moves with the force control mechanism, which is a moveable platform that drives by the Z-axis positioning system. The first stage of Z-axis vertical positioning will carry the force control platform and to bonding position, the second stage by the electromagnet and a permanent magnet repulsive force increasing between the two boards and the upper board will rise upward, and the electromagnetic is a defense device ensure that the springs repulsive force would not too large, and the third stage of self-alignment will adjust coplanar calibration of the chip and the substrate to increase the production yield. On top of the flip chip mechanism will have a pressure sensor to measure the pressure between chip and substrate.

2.4.Mechanism Design Requirements

It is important to bonding of flip chip for self-alignment mechanism. So consider high precision and high stability is the primary mechanism design considerations. Usually reduce the friction is the main countermeasure. Therefore should consider the following several requests before the design:

1. When high speed position, self-alignment mechanism is locked stability.
2. When substrate is placed on lower stage, self-alignment mechanism is locked stability, too.
3. The self-alignment mechanism is locked stability, as the bumps and the pads are bonded.

4. When adjust coplanarity calibration of bonding head, the self-alignment will be floated and provided two degrees of freedom to rotate.
5. Low request for environment, and easy to operation.

Next is analyzing the adjusting coplanar calibration of flip chip.

2.5.Movement Path Analysis and Planning

We'll need to plan the movement path to adjust coplanar calibration of flip chip. The followings will illustrate the stage movement path.

1. To position the stage so that the lower chuck is centered beneath the tool on the upper chuck by control the Z-axis vehicle positioning system.
2. Rotate the lower chuck until it is approximately square to the upper chuck.
3. Slowly raise the stage until there is between 1000g~1500g of force by force control system. (The estimating of force is read by load cell)
4. Note the current pressure. This is starting point for the adjusting coplanar calibration of surface.
5. With pressure established, released the air to allowing rotator to float momentarily to force the lower chuck to conform to the upper chuck's planarity.
6. Note the force which is now applied. The force will likely drop the first few times this done.
7. If the force has dropped, slowly move the stage up until the force reads similar to the starting force.
8. Repeat steps 4 through 6 until there is no real change in force after stop supply air.

9. Once the pressure stabilizes, the self-alignment is completed and Z-axis vehicle positioning system can be lowered.

2.6.Mechanism Detail Analyze

In this section will analyze the self-alignment mechanism, and illustrate its capability and characteristic. The following is analysis:

This self-alignment mechanism system include air bearing、spring、tube、connectors, and air compressor, this design as show in Figure 2.9 and the actual mechanism as show in Figure 2.10. First, the base of the air bearing can fix the air bearing on top of the force control system as show in Figure 2.11 and Figure 2.12. It holds position mechanism and moved with force control system by controlled the Z-axis vehicle positioning system as show in Figure 2.13 and Figure 2.14. Inside of the air bearing, it’s used a spring to fix the rotator to avoid the rotator fall off, and hold on the rotator fixed. We are digging four pipes to pass the air to the rotator. As air contact the rotator, it can be creating a thin film of pressurized air. The rotator utilizes this thin film of pressurized air to become an exceedingly low friction load-bearing interface between surfaces. And air supply source must be stability, so we need choice the better air compressor that can supply stable air pressure to self-alignment mechanism. When air through the pipes, it maybe decrease pressure of compressed air. So we need to choice more than require air fluid.

Chapter 3 Improvement of Force Control System

To achieve the smallest resolution, we used electromagnet to be the output of the force control system. But it can’t be providing strength enough to bonding the chip and the substrate when there are lots bumps. So we use the motor that use to Z-axis position originally to be the first stage force control system that is a rough adjustment. And it uses the electromagnet to be the second stage force control system that is a slight adjustment. We use two stage force control to reach the smallest resolution and enlarge the force control range.

3.1 Force control system

It’s using ball bearing screw rod, DC servo motor, precision linear shafts, timing pulley and timing belt to be the 1st Force control mechanism. And let electromagnet, the iron slab attracted by electromagnet, load cell, precise shaft, oil-less bearings and springs be the 2nd force control mechanism. The first stage of Z-axis vertical positioning mechanism will lift to the bonding position and then we move up Z-axis vertical positioning mechanism to compress the spring to change the bonding force. The second stage is by controlling the magnetic force and spring force to change the bonding force. First, the springs are pre-compressed by the initial magnetic force. When we decrease the current of electromagnet slowly, at the same time the magnetic force between electromagnet and iron slab also decreases slowly. And when the magnetic force is less than spring force slowly, the iron slab that locked on the carrier platform will move up to increase the force between chip and substrate. So we can change the bonding force by current control. And in the middle of the flip chip mechanism have a load cell to measure the force between chip and substrate.

3.2 Model of Force Control Mechanism

Before we analyze the model of steering system, we define the symbols meaning of each term in fundamental equation.

Symbol	**Description**
F	Magnetomotive force
N	Coil turns of electromagnet
i	Current in the coil
Φ	Magnetic field flux
R	Magnetic reluctance
l_c	Average length of path in the square core
μ	Magnetic permeability of material
A	Area of cross section of magnetic circuit
W_e	Electrical energy
W_f	Energy supplied to the field
W_m	Energy converted to mechanical form
λ	Flux linkage
μ_0	Permeability of air
f_m	Magnetic force
i_0	Initial current of electromagnet
k_L	Spring constant of load cell
k_S	Spring constant of spring

x	Compression of spring
x_L	Compression of spring and load cell
G	Air gap of electromagnet
D	The air gap when x = 0

3.2.1 Magnetic Circuit

In the circuit, the current flow path known as the circuit. In magnetic field, the magnetic field flux of space known as the magnetic circuit. The current in the circuit in the form of loop, just like the magnetic field flux in the magnetic circuit to form a loop. Current flows in the circuit, there must be a source of electromotive force. In the flow of magnetic flux in the magnetic circuit must also be a source of magnetomotive force. On the electric and magnetic terms of the duality, we can know the similarities in Figure 3.1 and Table 3.1. And the magnetic circuit, magnetomotive force as follows

$$F = N \cdot i \tag{3-1}$$

And in the magnetic circuit, the relation of magnetomotive force with magnetic reluctance R is

$$F = \Phi \cdot R \tag{3-2}$$

Where, Φ is the magnetic field flux. From the Table 3.1 know as follows

$$R = \frac{l_c}{\mu A} \tag{3-3}$$

A is the cross-section area of the core.

3.2.2 Field energy

Consider a differential time interval dt during which an increment of electrical energy dW_e (excluding the i^2R loss) flows to the system. During this time dt, let dW_f be the energy supplied to the field (either stored or lost, or part stored and part lost) and dW_m the energy converted to mechanical form (in useful form or as loss, or part useful and part as loss). The energy balance equation can be expressed as

$$dW_e = dW_m + dW_f \tag{3-4}$$

Consider the electromechanical system of Figure 3.2. The movable part can be held static equilibrium by the spring. Let us assume that movable part is held stationary at some air gap and the current is increased from zero to a value i. Flux will be established in the magnetic system.

Obviously,

$$dW_m = 0 \tag{3-5}$$

and from equation (3-4) and (3-5),

$$dW_e = dW_f \tag{3-6}$$

If core loss is neglected, all the incremental electrical energy input is stored as incremental field energy. Now,

$$e = \frac{d\lambda}{dt} \tag{3-7}$$

$$dW_e = ei\ dt \tag{3-8}$$

From equation (3-6), (3-7), and (3-8),

$$dW_f = i\ d\lambda \tag{3-9}$$

The relationship between coil flux linkage λ and i for a particular air gap length is shown in Figure 3.3. The incremental field energy dW_f is shown as the crosshatched area in this figure. When the flux linkage is increased from zero to λ, the energy stored in the field is

$$W_f = \int_0^{\lambda} i \, d\lambda \tag{3-10}$$

3.2.3 Mechanical force in the electromagnetic system

Consider the system shown in Figure 3.2. Let the movable part move from one position (say $x = x_1$) to another position (say $x = x_2$) so that at the end of the movement the air gap decreases. The $\lambda - i$ characteristics of the system for these two positions are shown in Figure 3.4. The current ($i = v/R$) will remain the same at both positions in the steady state. Let the operating points be a when $x = x_1$ and b when $x = x_2$.(Figure 3.4)

If the movable part has moved slowly, the current has remained essentially constant during the motion. The operating point has therefore moved upward from point a to b as shown in Figure 3.4(a). During the motion,

$$dW_e = \int ei \, dt = \int_{\lambda_1}^{\lambda_2} i \, d\lambda = \text{area}\, abcd \tag{3-11}$$

$$dW_f = \text{area}\, 0bc - \text{area}\, 0ad \tag{3-12}$$

$$\begin{aligned} dW_m &= dW_e - dW_f \\ &= \text{area}\, abcd + \text{area}\, 0bc - \text{area}\, 0ad \\ &= \text{area}\, 0ab \end{aligned} \tag{3-13}$$

If the motion has occurred under constant-current conditions, the mechanical work done is represented by the shaded area (Figure 3.4(a)), which, in fact, is the increase in the coenergy.

$$dW_m = dW_f'$$

If f_m is the mechanical force causing the differential displacement dx,

$$f_m \, dx = dW_m = dW_f'$$

$$f_m = \left. \frac{\partial W_f'(i,x)}{\partial x} \right|_{i=\text{constant}} \tag{3-14}$$

Let us now consider that the movement has occurred very quickly. It may be assumed that during the flux linkage has remained essentially constant, as shown in Figure 3.4(b). It can be shown that during the motion the mechanical work done is represented by the shaded area $0ap$, which, in fact, is the decrease in the field energy. Therefore,

$$f_m \, dx = dW_m = -dW_f$$

$$f_m = -\left. \frac{\partial W_f(\lambda,x)}{\partial x} \right|_{\lambda=\text{constant}} \tag{3-15}$$

Note that for the rapid motion the electrical input is zero ($i \, d\lambda = 0$) because flux linkage has remained constant and the mechanical output energy has been supplied entirely by the field energy.

In limit when the differential displacement dx is small, the areas $0ab$ in Figure 3.4(a) and $0ap$ in Figure 3.4(b) will be essentially the same.

Therefore the force computed from Equation 3.14 and 3.15 will be the same.

3.2.4 Linear system

Consider the electromagnetic system of Figure 3.2. If the reluctance of the magnetic core path is negligible compared to that of the air gap path, the $\lambda - i$ relation becomes linear. For this idealized system

$$\lambda = L(x)i \tag{3-16}$$

Where $L(x)$ is the inductance of the coil, whose value depends on the air gap length. The field energy is

$$W_f = \int i \, d\lambda \tag{3-17}$$

From Equation 3-16 and 3-17

$$W_f = \int_0^{\lambda} \frac{\lambda}{L(x)} d\lambda = \frac{\lambda^2}{2L(x)} \tag{3-18}$$

$$= \frac{1}{2} L(x) i^2 \tag{3-19}$$

From Equation 3-15 and 3-18

$$f_m = -\frac{\partial}{\partial x}\left(\frac{\lambda^2}{2L(x)}\right)\Bigg|_{\lambda=\text{constant}}$$

$$= \frac{\lambda^2}{2L^2(x)} \frac{dL(x)}{dx}$$

$$= \frac{1}{2} i^2 \frac{dL(x)}{dx} \tag{3-20}$$

For a linear system

$$W_f = W_f' = \frac{1}{2} L(x) i^2 \tag{3-21}$$

From Equation 3-14 and 3-21

$$f_m = \frac{\partial}{\partial x}\left(\frac{1}{2}L(x)i^2\right)\bigg|_{i=\text{constant}}$$

$$= \frac{1}{2}i^2\frac{dL(x)}{dx} \tag{3-22}$$

And the inductance

$$L(x) = \frac{N^2}{R(x)} \tag{3-23}$$

and

$$R(x) = R_0 + R_G(x) = R_0 + \frac{G(x)}{\mu_0 A} = \eta\frac{G(x)}{\mu_0 A} \qquad (\eta > 1) \tag{3-24}$$

By the other way, we can rewriter the magnetic force

$$f_m = -\frac{\partial}{\partial x}\left(\frac{1}{2}\frac{N^2}{R(x)}i^2\right) \tag{3-25}$$

3.3 Bonding Force Control

Because the first step we start the electromagnet, if the motor lift up too much, the electromagnet and iron slab can be crash. In this thesis, we can find the largest lift range of motor. And we use the variable air gap to make the magnetic energy change between electromagnet and iron slab, the magnetic reluctance is also different for the variable air gap. In the force control mechanism, we have a magnetic circuit, the path includes the electromagnet, air gap and iron slab as shown in Figure 3.5. And the air gap changes from the distance of moving by motor.

3.4 Model of Force Control Mechanism

For force control mechanism, we can see its free body diagram as Figure 3.5.

We can rewriter the equation by Equation 3-3 and 3-25

$$f_m = \frac{\mu_0 A N^2 i^2}{2n\left(D-x\right)^2} \tag{3-26}$$

Where

$$\begin{cases} G = D - x & \\ G = 0 & \end{cases} \quad when \quad \begin{matrix} D > x \\ D \le x \end{matrix}$$

Where D is the air gap when x = 0, that is air gap when M_2 is moved to the neutral position of the spring.

So we can obtain the balance equation as follow.

$$k_S \times (x) = F_0 + k_L \times (x_L - x) + \frac{\mu_0 \times A \times N^2 \times i^2}{2n \times (D-x)^2} \tag{3-27}$$

F_0 is displayed value by load cell.

And when we give an initial magnetic force make springs compressed, where $x_L = x$, we can obtain the equation as follow.

$$k_S \times (x) = F_0 + \frac{\mu_0 \times A \times N^2 \times i^2}{2n \times (D-x)^2} \tag{3-28}$$

This Equation 3-28 can find out the initial value x of compression of springs.

Now Z-axis positioning mechanism lifts up the force control mechanism to bonding position, where $x_L = x$, the first stage force control is used Z-axis positioning mechanism lifts up the force control mechanism that x_L is the moving distance of Z-axis positioning mechanism. So we can find the compression of springs x. Then we will take this x to Equation 3-27, we can find out the force f_m of the electromagnet when i is the variable, and find out resolution of the force control system.

3.5 Experiment Result

In the experiment, we change the current i; and by the Equation 3-27, we can know the compression x_L of the load cell. Figure 3.6 and Figure 3.7 show the experiment result and theoretical curve by force control of electromagnet, when we control the motor under big strength. And we could control the resolution is smaller than 10g. Figure 3.8 and Figure 3.9 show the experiment result and theoretical curve by force control of electromagnet, when we control the motor under small strength. And we could control the resolution is smaller than 1g. Because when we control strength by motor, the air gap will change. If air gap is too small, the resolution will increase.

Chapter 4 Experimental design

Original plan is use CCD and chuck of current mechanism to set up on improved mechanism as shown in Figure 4.1 and Figure 4.2, but we don’t have this equipment. So we need think another way to implement flip-chip mechanism.

4.1 Mechanism design

Current mechanism is using the CCD by beam splitter to aim at the position of chip and substrate between upper chuck and lower chuck. We use another way to simplify this method. It use glass and glass chip replace upper chuck and chip, and design a new lower chuck that has holding the chip and heating as shown in Figure 4.3. We stick the glass chip on glass and hold the substrate by vacuum. Then we can use CCD to aim at chip and substrate under the glass.

4.2 Working procession

When we want to operation this flip chip, the followings will illustrate the stage movement path.

1. To start the flip chip mechanism so that Z-axis vehicle positioning system will raise to the “Home” position.
2. To start self-alignment procession, the stage will raise to “Bonding” position by Z-axis vehicle positioning system.
3. Slowly raise the stage until there is between 1000g~1500g of force by force control system. (The estimating of force is read by load cell)

4. Note the current pressure. This is starting point for the adjusting coplanar calibration of surface.
5. With pressure established, released the air to allowing rotator to float momentarily to force the lower chuck to conform to the glass's planarity.
6. Note the force which is now applied. The force will likely drop the first few times this done.
7. If the force has dropped, slowly move the stage up until the force reads similar to the starting force.
8. Repeat steps 4 through 6 until there is no real change in force after stop supply air.
9. Once the pressure stabilizes, the self-alignment is completed and Z-axis vehicle positioning system can be descended to "Chip and substrate placed" position.
10. Place chip and substrate.
11. Raise lower chuck to "Bonding" position, and use CCD to check chip and substrate weather alignment.
12. After chip and substrate alignment. Input temperature、force and time to start bonding procession.
13. Complete bonding, the stage will descend to "chip and substrate place" position, put out the chip, finish the flip chip bonding procession.

4.3 Hardware Introduction

When design a mechanism, we must know our need then we could find the matched hardware. In this mechanism most important elements of force control. The electromagnet and permanent magnet provide repulsive force to push the substrate up and contact with chip. So the following are the introduction of hardware.

4.3.1 Load Cell

Load cell in the force control mechanism is important to measure the contact force. The load cell needs accuracy and sensitive. The load cell we chose is FUTEK S-BEAM 25lb shown in Figure 4.4.

Its features and performance show as follows.

- Rated Output (RO)................2 mV/V
- Nonlinearity...........................±0.1% RO
- Hysteresis..............................±0.1% RO
- Operating Temp....................-60 to 200°F
- Excitation (Max)..................10 VDC
- Bridge Resistance.................350 Ω nom
- Safe Overload……………...…1000% of RO
- Material……………………..stainless steel
- Compensated temp…………60 to 160°F
- Weight………………………9g

4.4 Conclusion

The main purpose of this thesis is to design the self-aligned system and improve bonding force control of flip chip devices. For this purpose, we use air bearing to achieve coplanar, so we can solve issue of an angle between the substrate and the chip in flip chip bonding procession. And we change method of the force control to improve range of force control. From the experiment, we can know that use magnetic force to control bonding force is available. The resolution of force control can also meet the current requirements.

Reference

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Figures

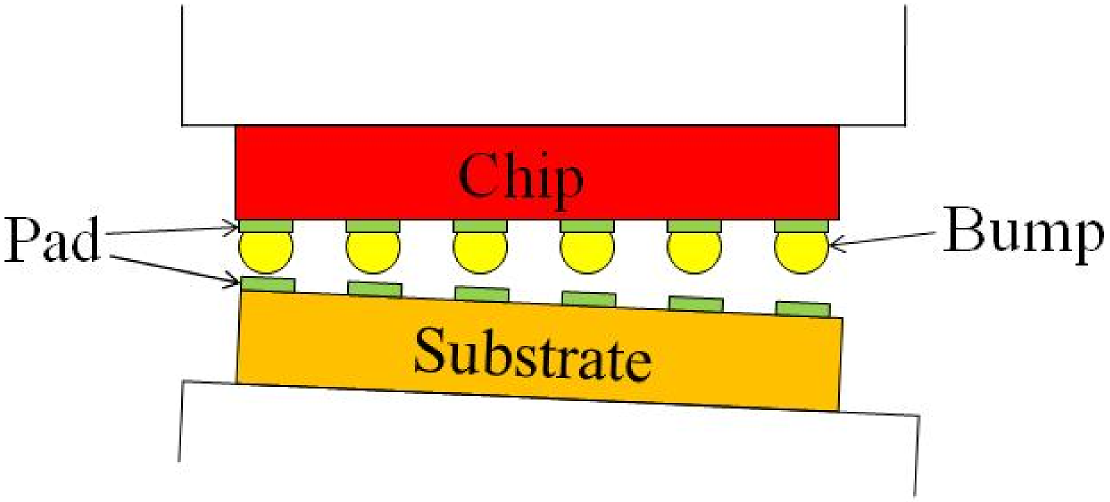


Figure1.1 There is a small angle between these two surfaces

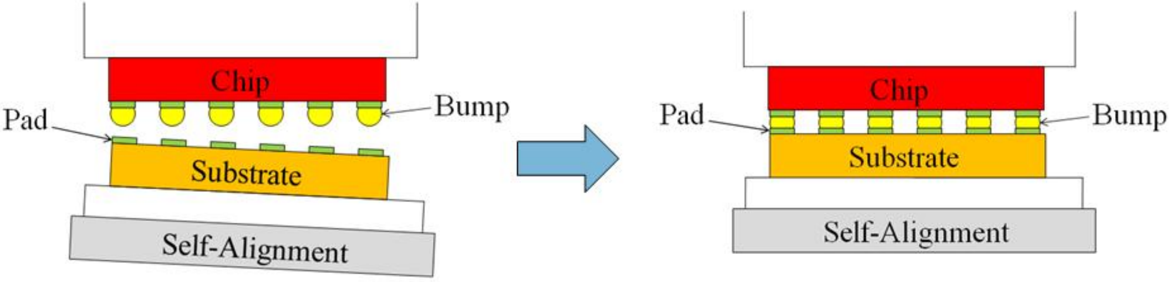


Figure1.2 Change coplanar calibrations of the substrate and the chip by self-alignment mechanism.

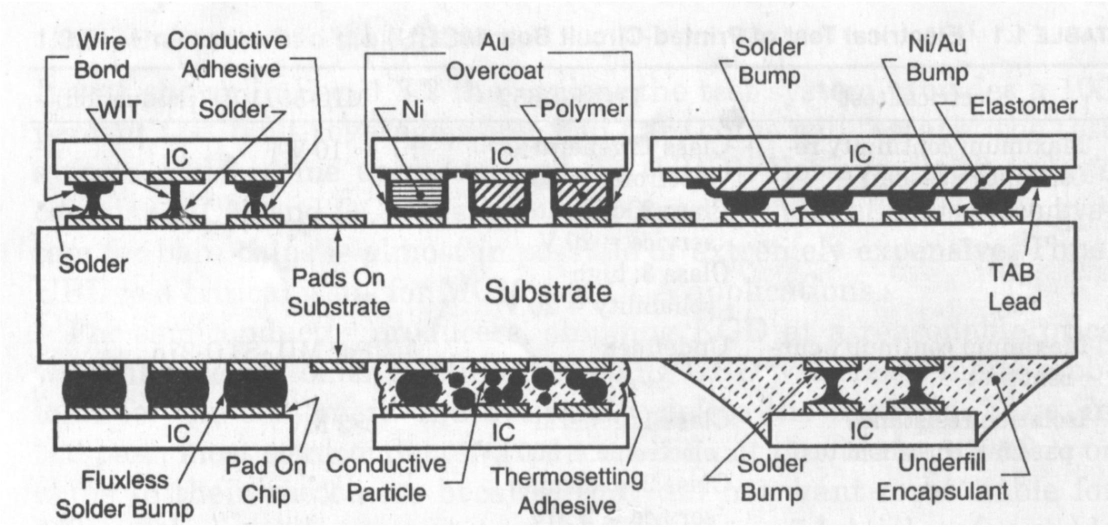


Figure1.3 Various flip chip technologies

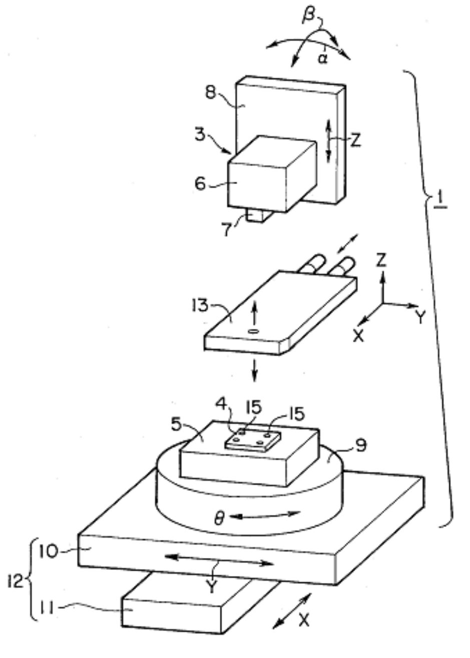


Figure2.1 Device of chip placed

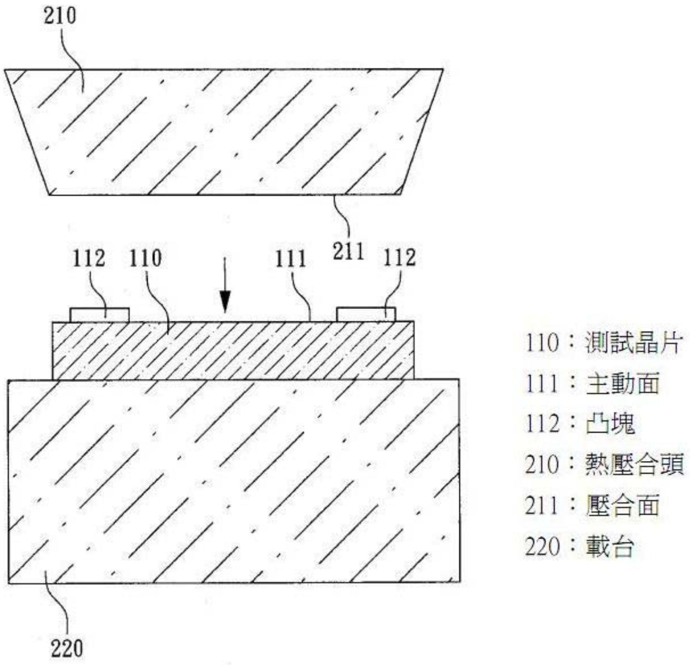


Figure2.2 Advice for method for adjusting coplanarity calibration of a thermocompression head

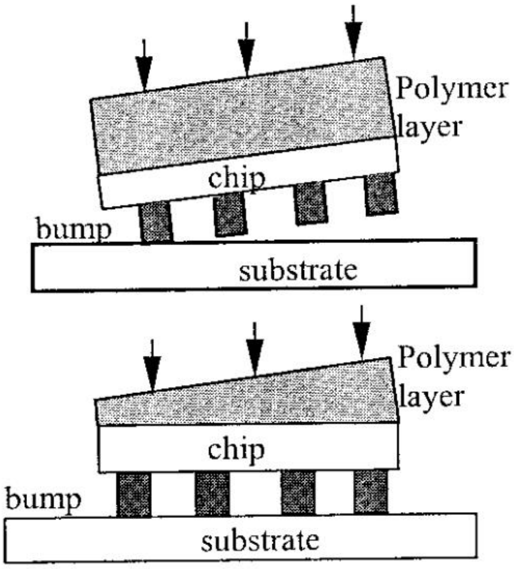


Figure2.3 Self-planarization concept using polymer layer

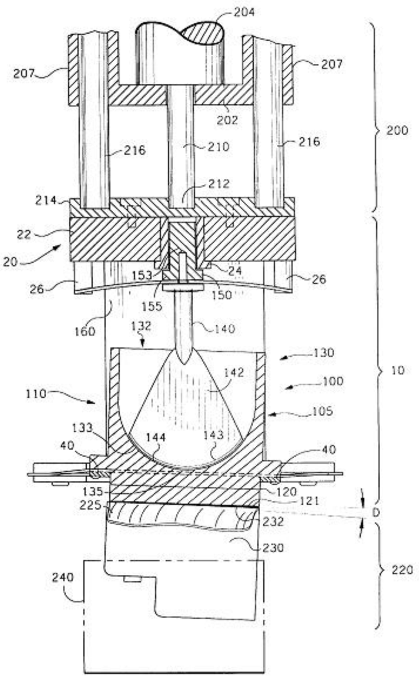


Figure2.4 Bonding Head by Swanson

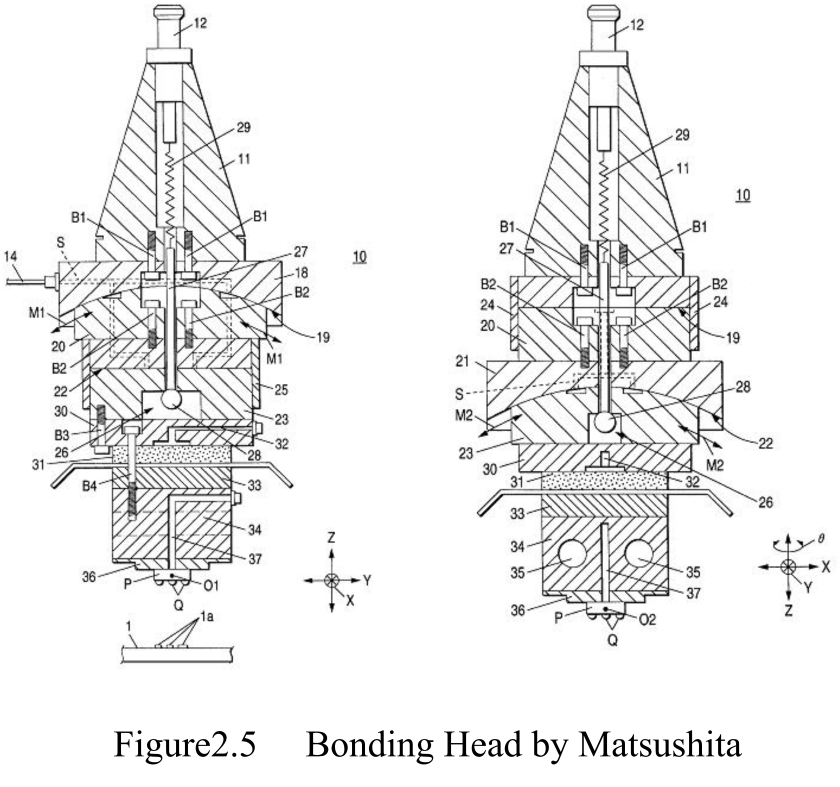


Figure2.5 Bonding Head by Matsushita

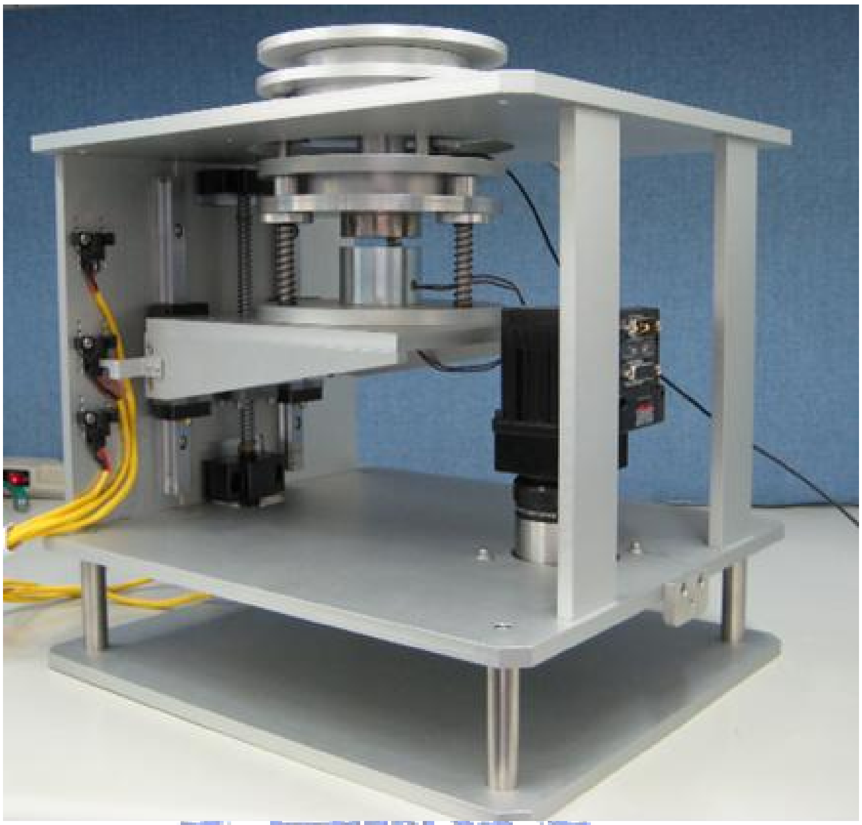
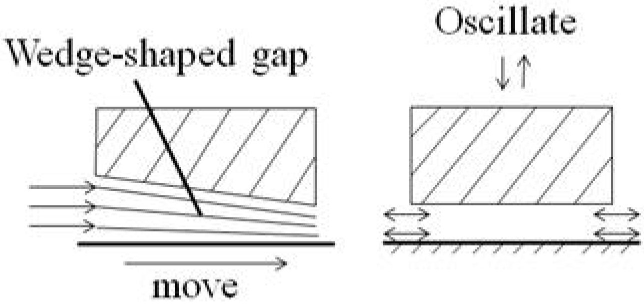
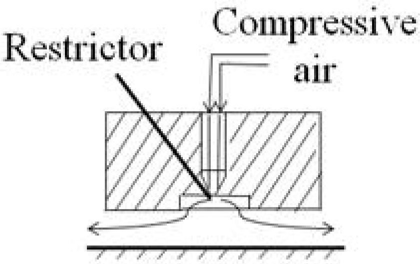


Figure2.6 Z-axis vertical positioning system and force control system



(a) Aerodynamic type



(b) Aerostatic type

Figure2.7 Types of air bearing

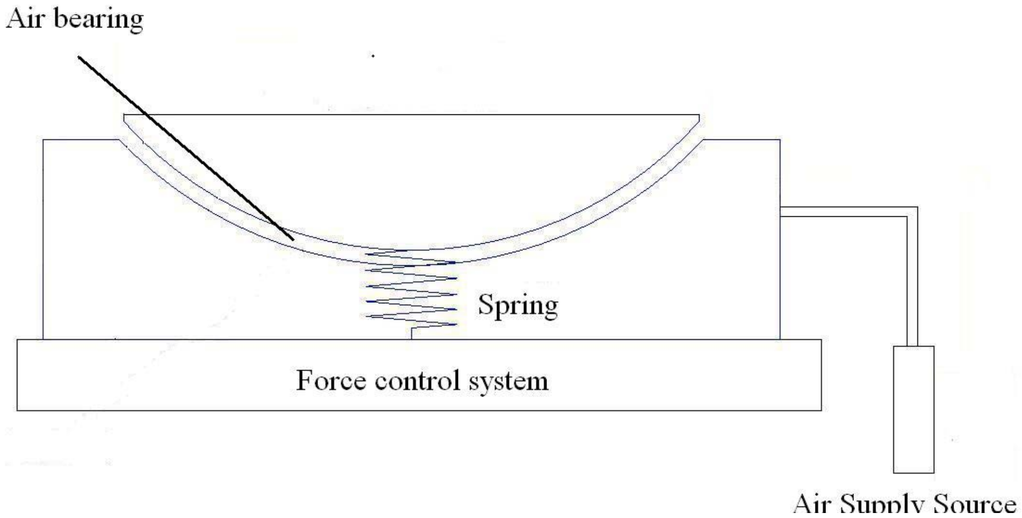


Figure2.8 Conceptual mechanism of self-alignment

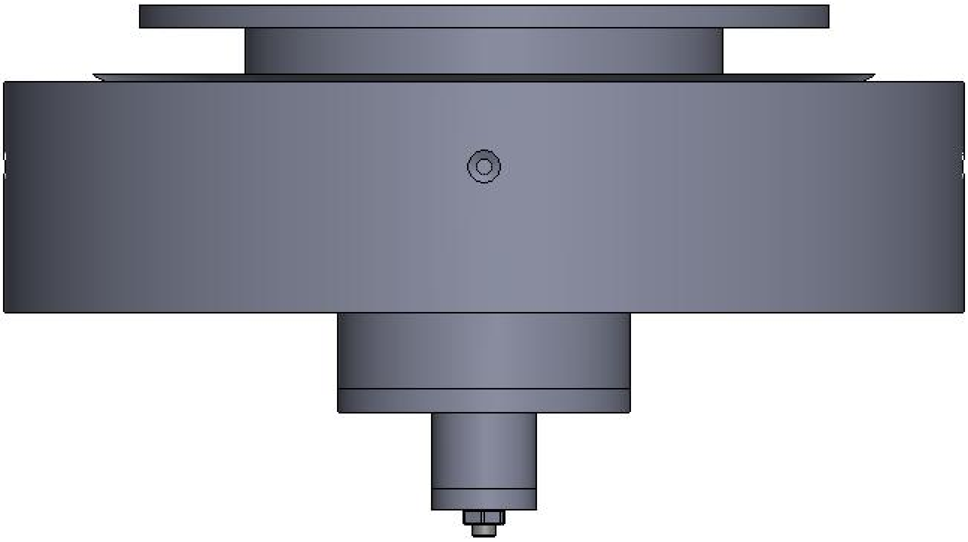


Figure2.9 Self-alignment mechanism

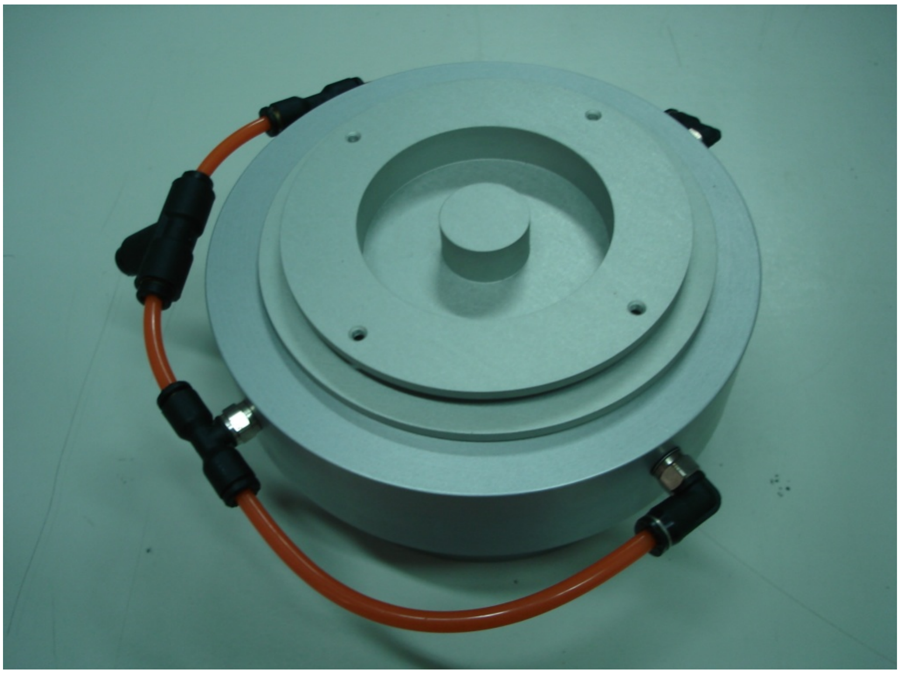


Figure2.10 Self-alignment mechanism

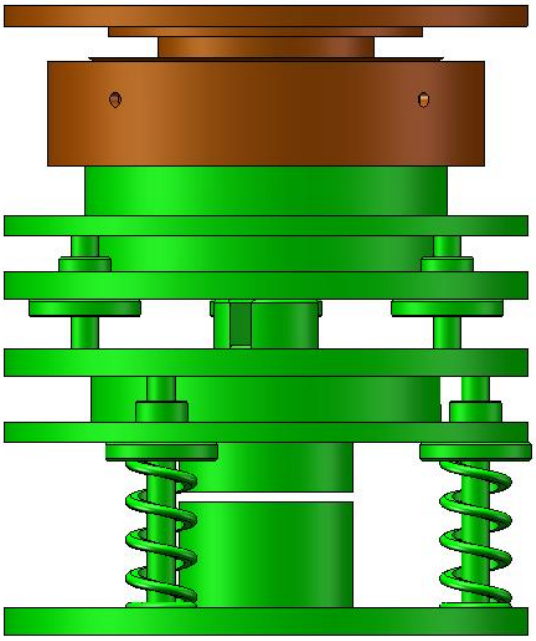


Figure2.11 Combined force system and self-alignment mechanism

Figure2.12　Combined force system and self-alignment mechanism

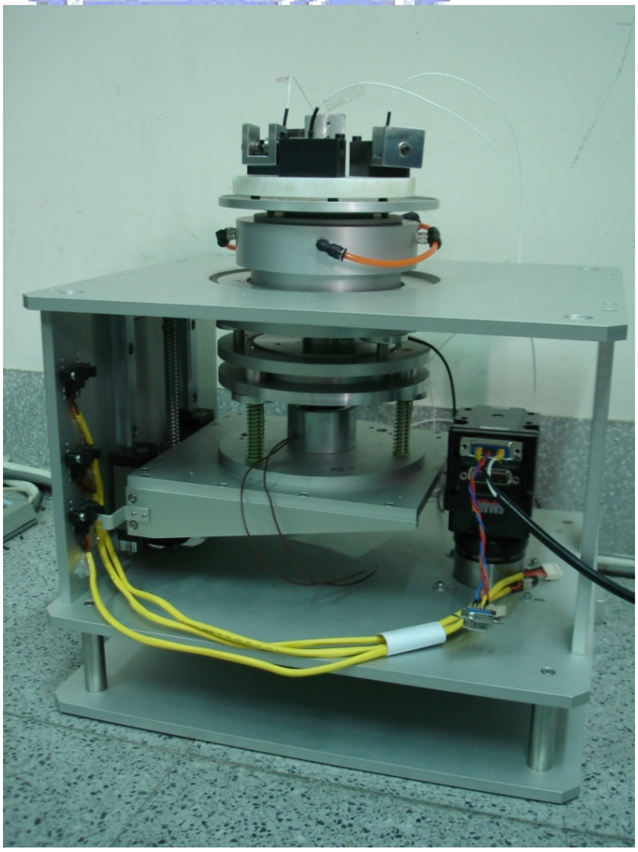


Figure2.13　Actual picture

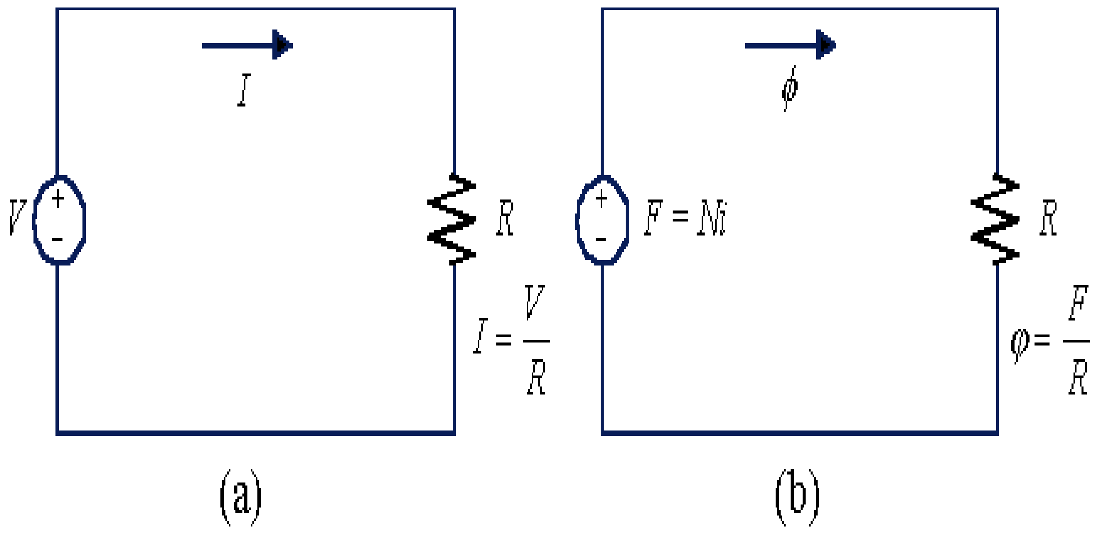


Figure3.1 Similarities of circuit and magnetic circuit

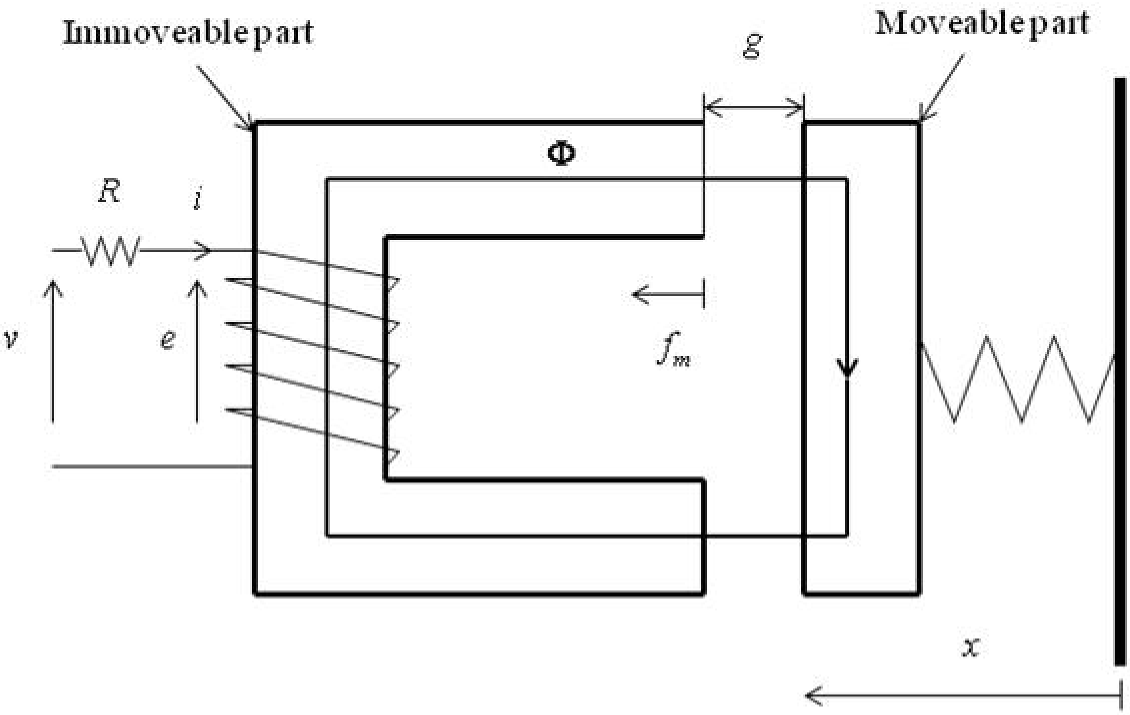


Figure3.2 Example of an electromechnical system

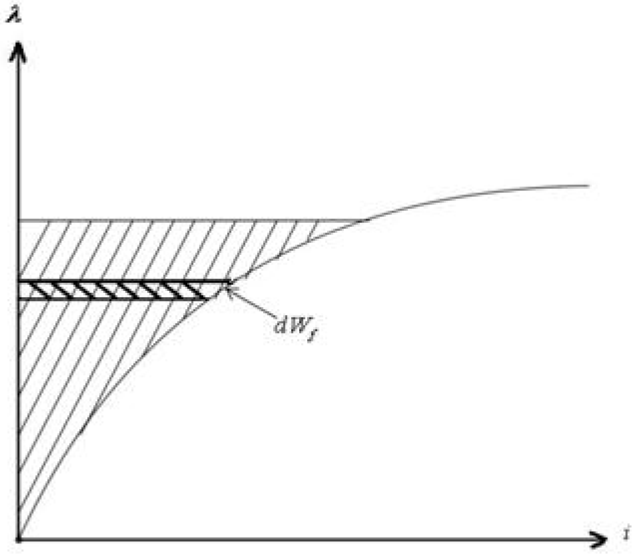
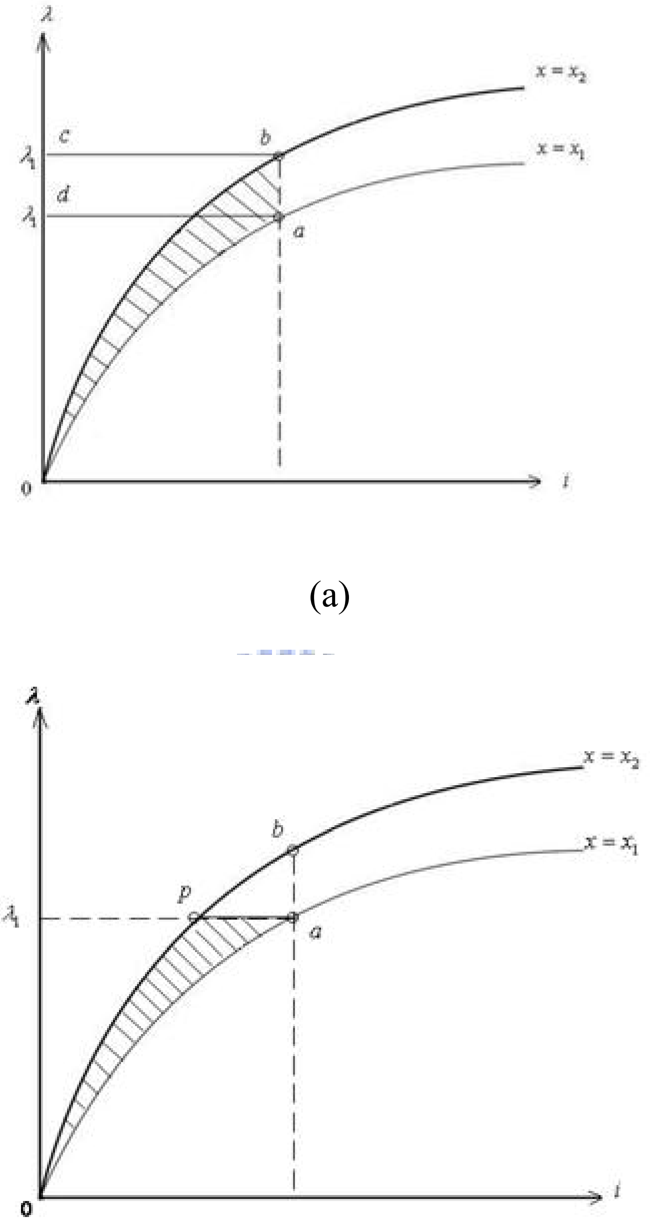


Figure3.3 Steering wheel system and front wheel system



(a)

(b)

Figure3.4 Locus of the operating point for motion in system of Fig. 3.2.(a) At constant current. (b) At constant flux linkage

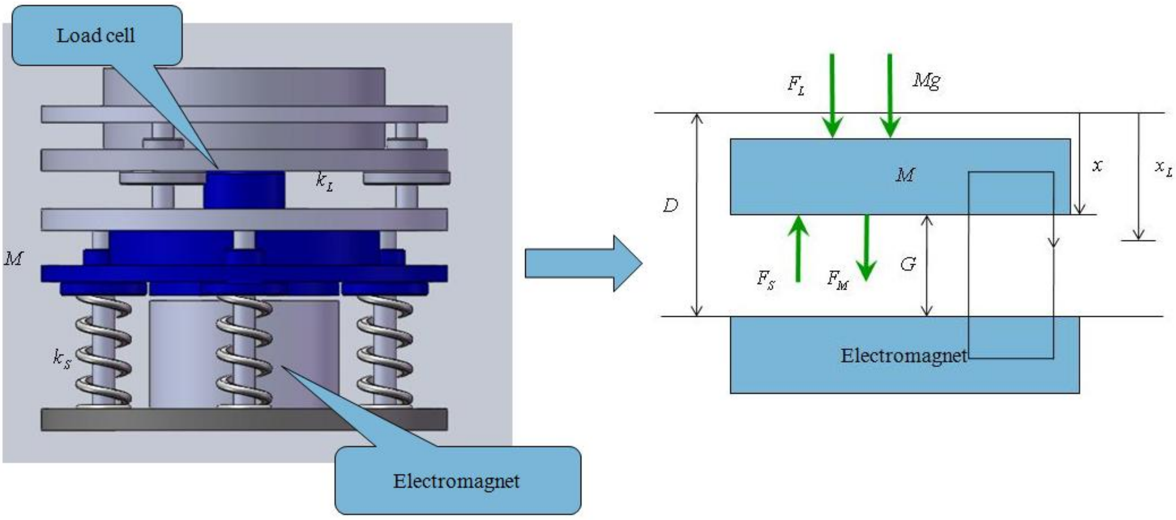


Figure3.5 Model of Force Control Mechanism

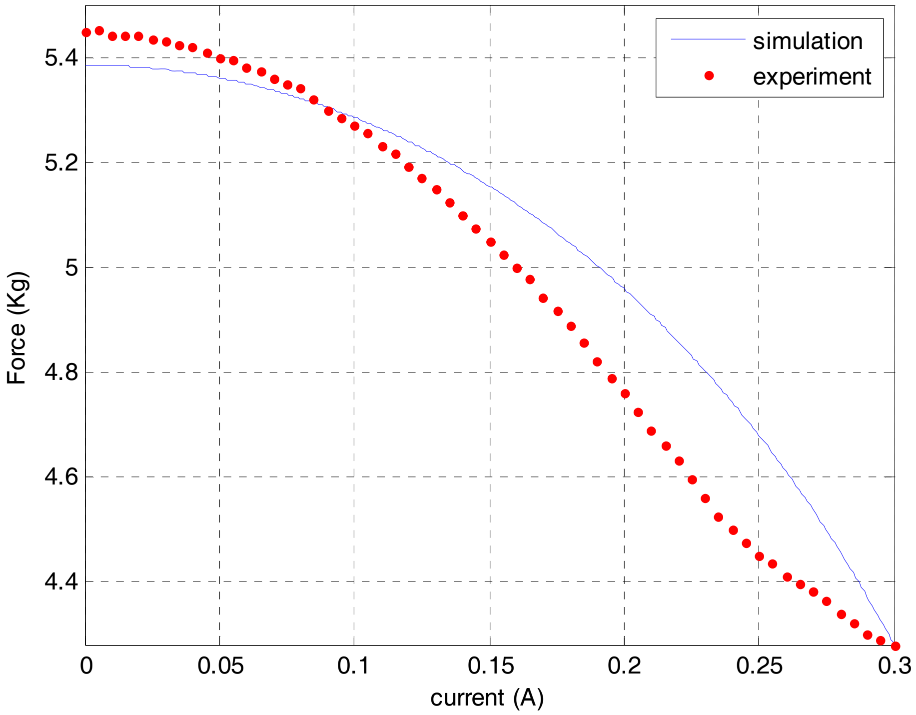


Figure3.6 Current=0.3A, start point=4.28kg, , resolution=10g

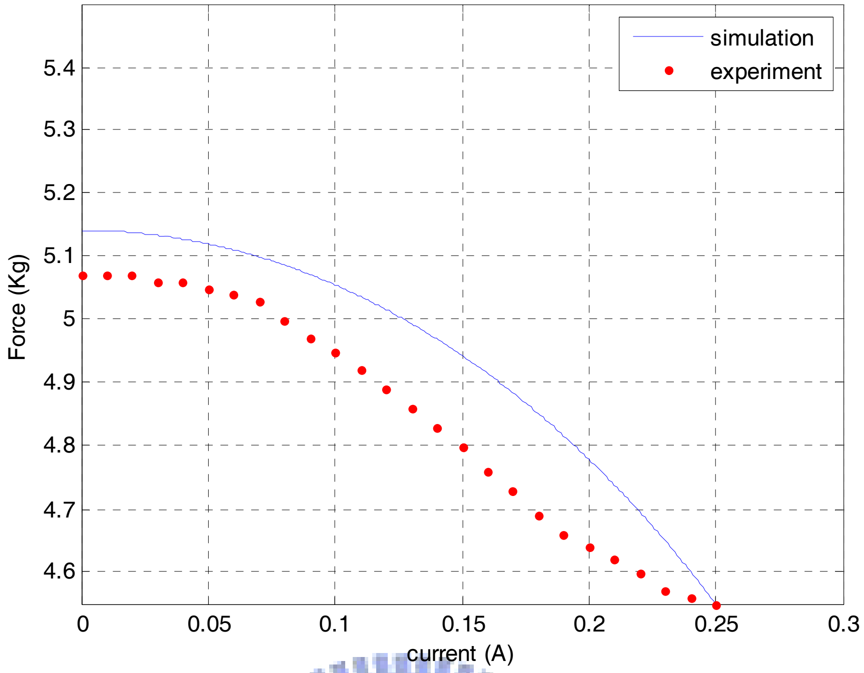


Figure3.7 Current=0.25A, start point=4.56kg, , resolution=10g

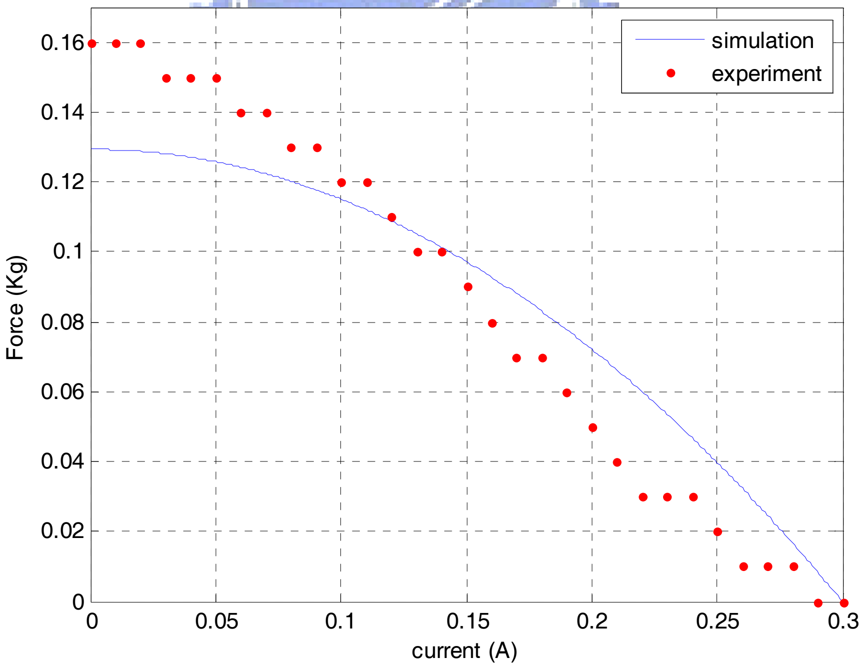


Figure3.8 Current=0.3A, start point=0kg, resolution=1g

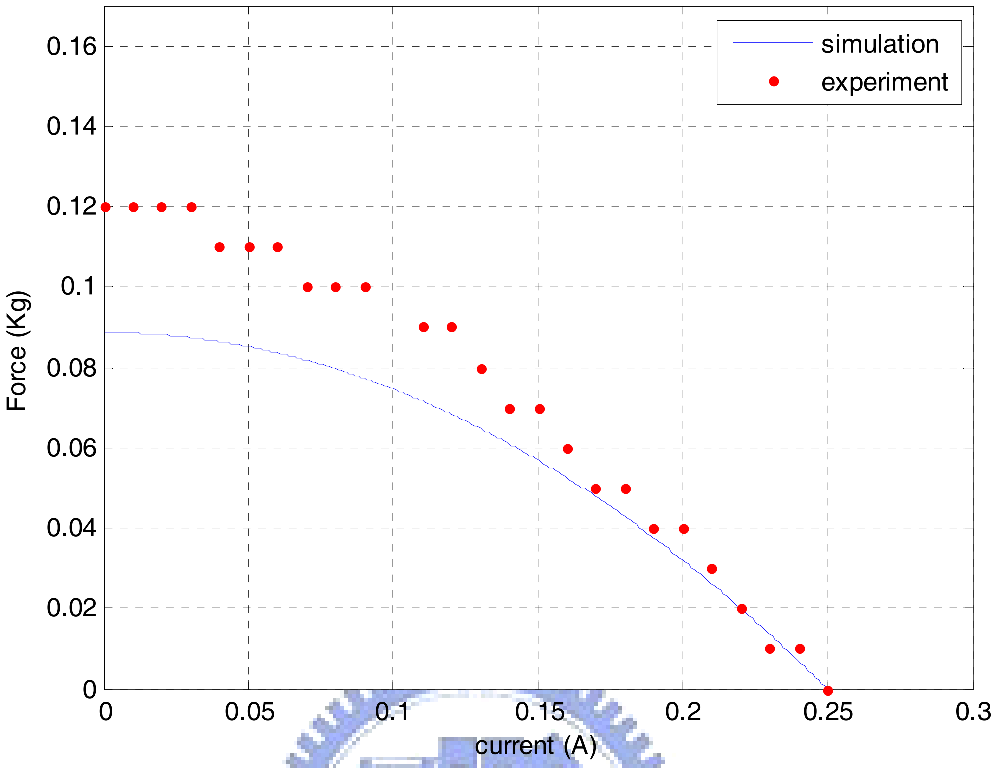


Figure3.9 Current=0.25A, start point=0kg, resolution=1g

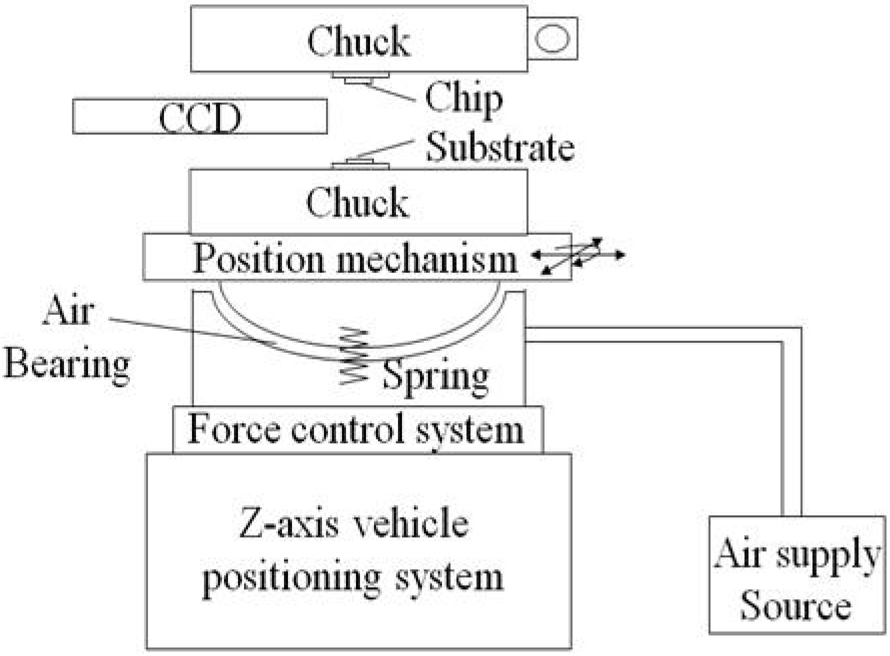


Figure4.1 Original Design flip chip mechanism

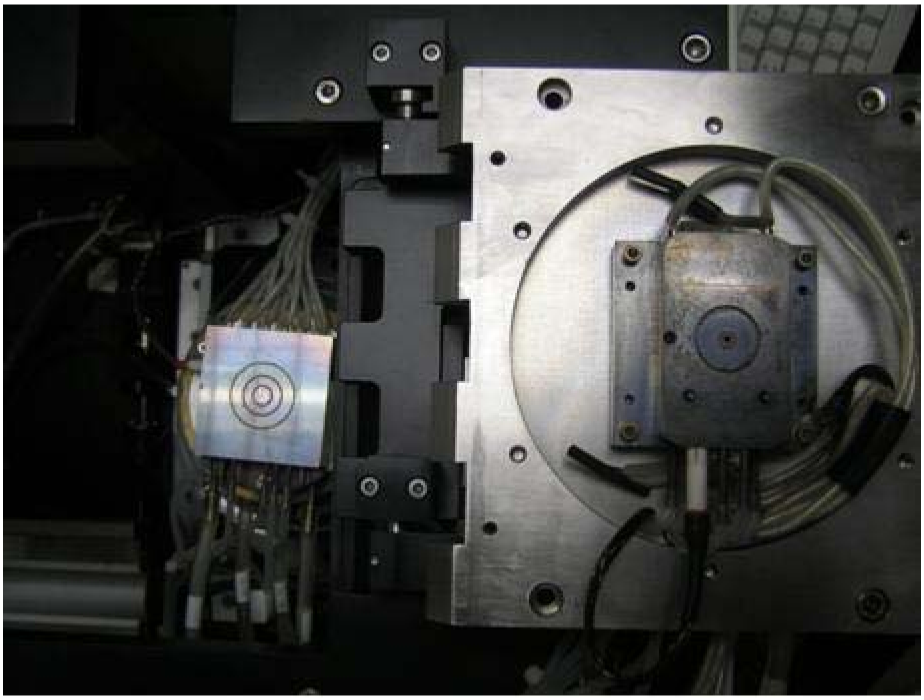


Figure4.2 Upper chuck and lower chuck

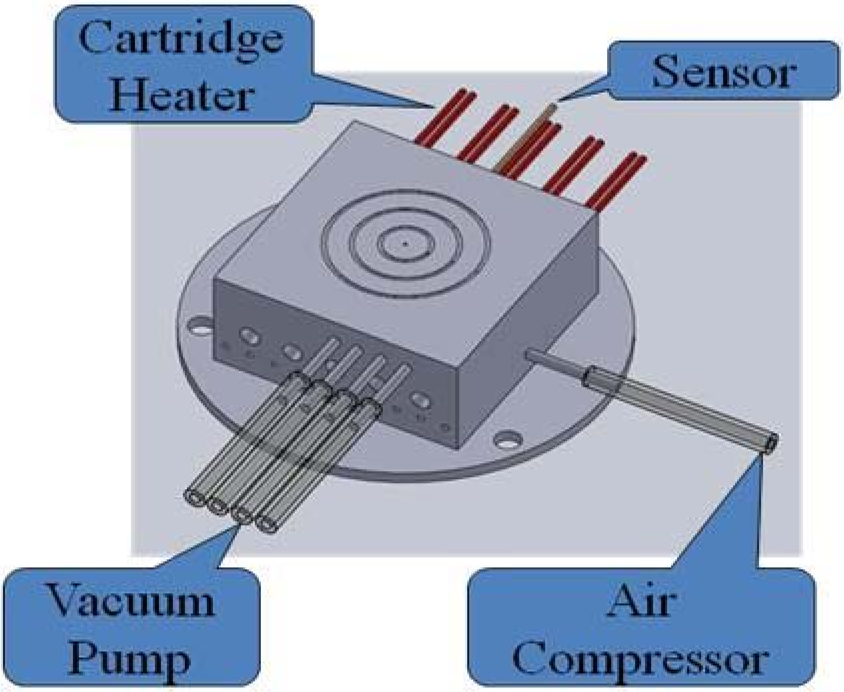


Figure4.3 Conceptual lower chuck

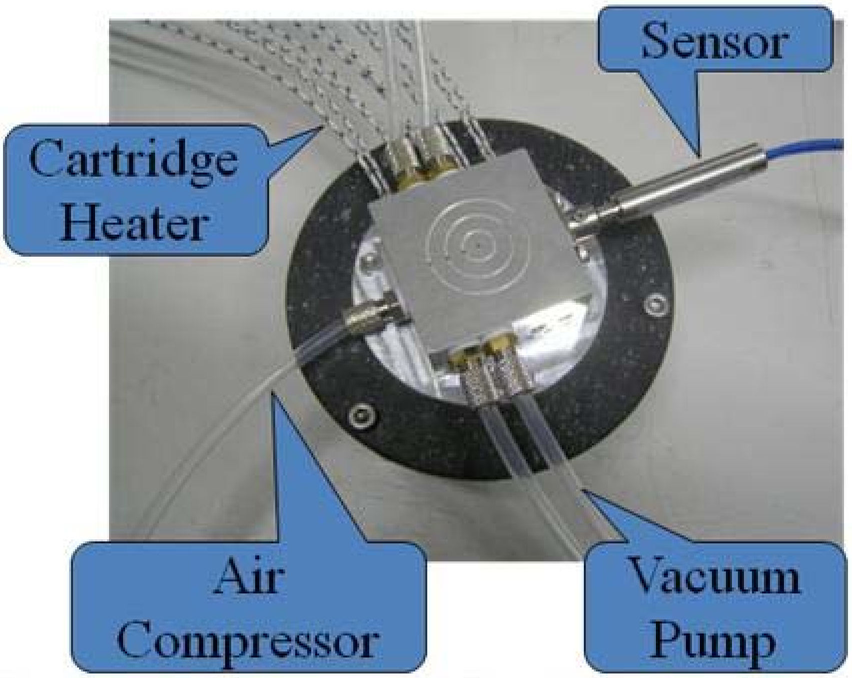


Figure4.4 Lower chuck and glass

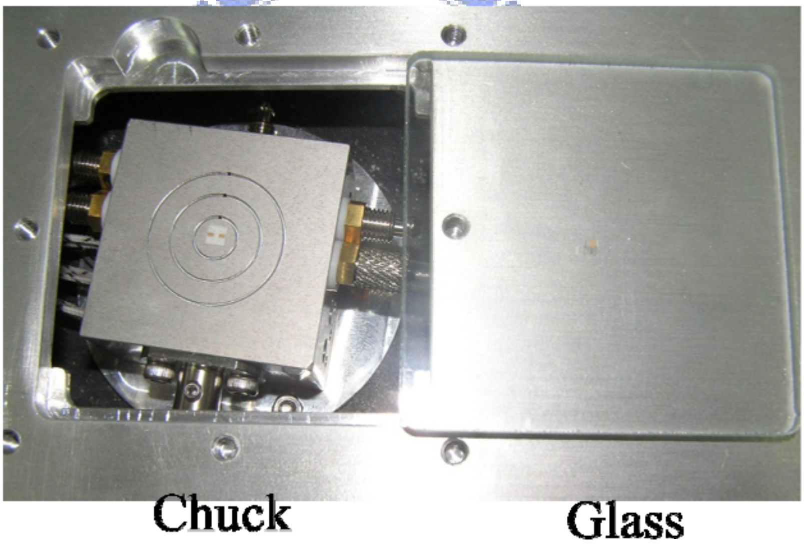


Figure4.5 Lower chuck and glass

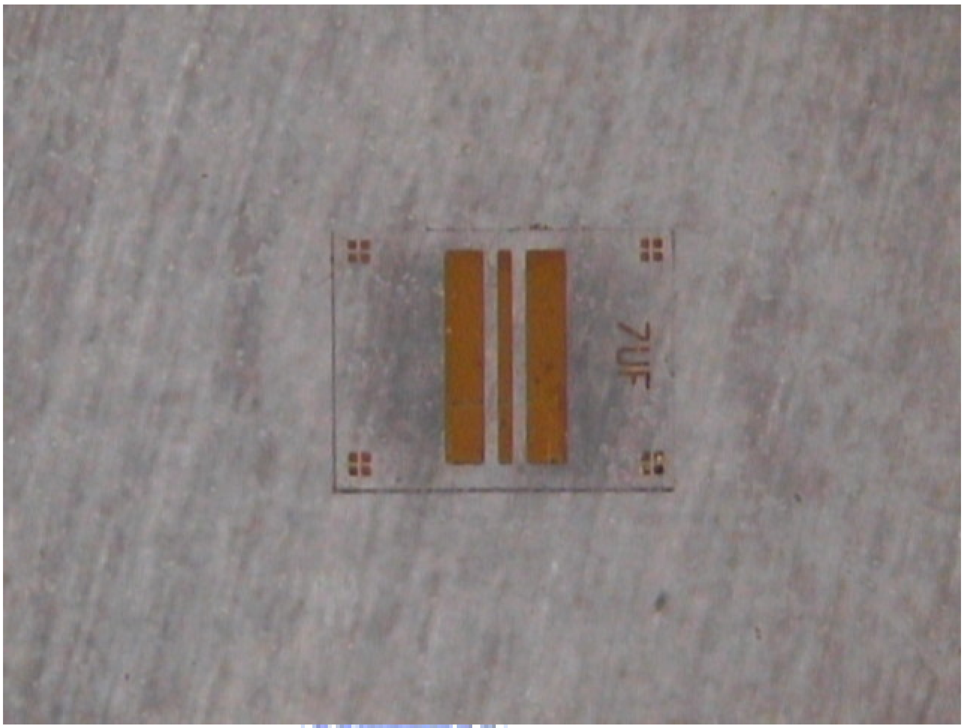


Figure4.6 Glass chip

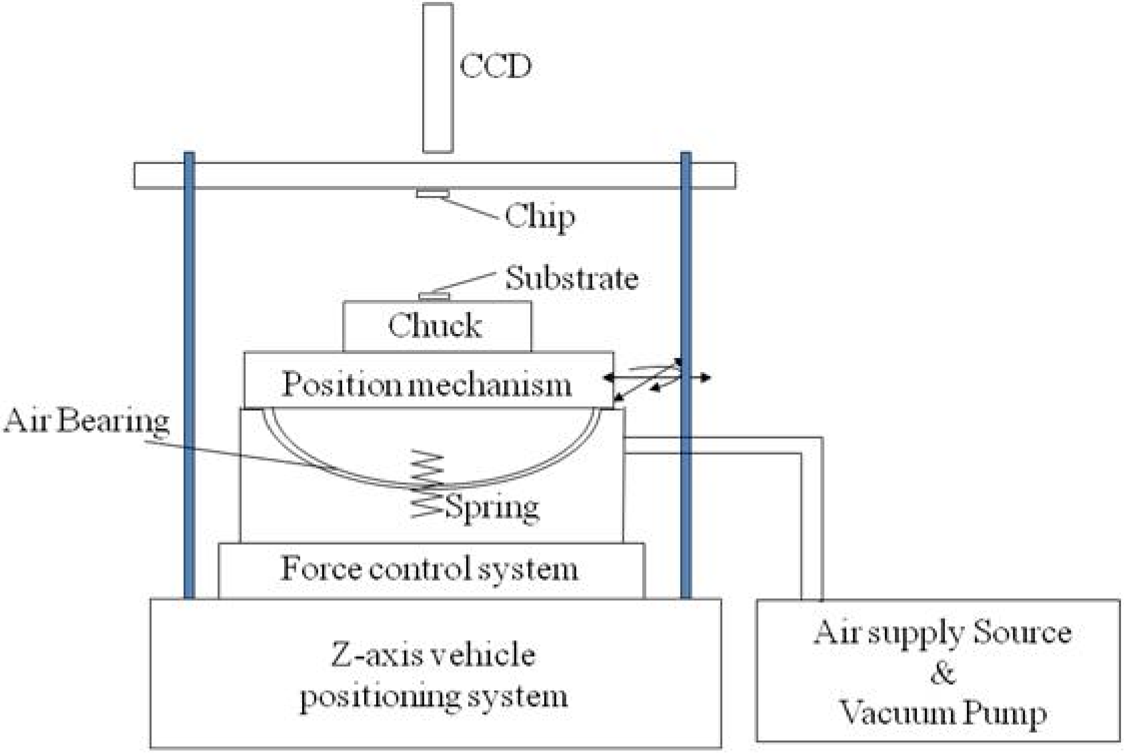


Figure4.7 Conceptual flip chip mechanism

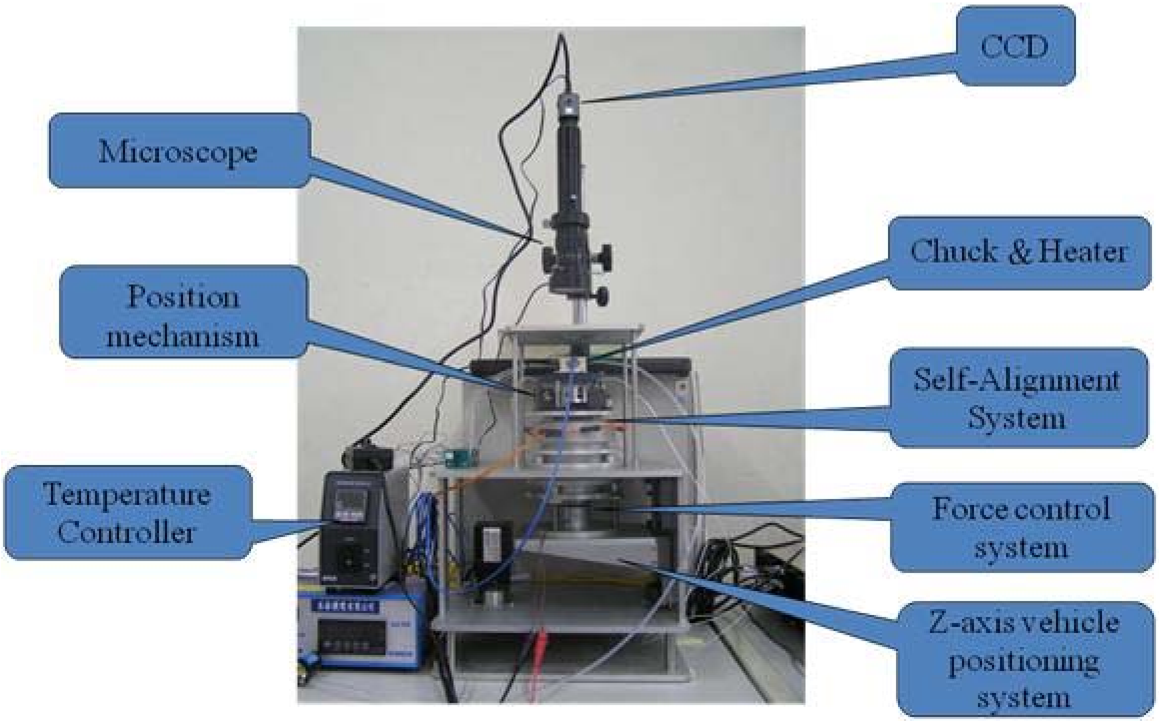


Figure4.8 Actual flip chip mechanism

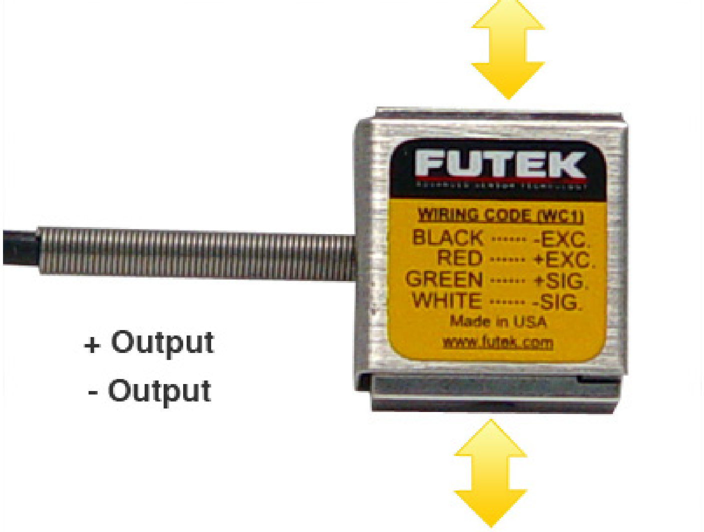


Figure4.9 Load cell(FUTEK LSB200 25lb)

Tables

Circuit	**Magnetic circuit**
$E = i \cdot R$	$F = \Phi \cdot R = N \cdot i$
$J = i/A$	$B = \Phi/A$
$\sigma = 1/\rho$	μ
$R = \rho \dfrac{l}{A}$	$R = \dfrac{l}{\mu A}$

Table3.1 Duality of circuit and magnetic circuit