Research on Micro-Level Height Control System for Semiconductor Wafer Cutting Machine

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Abstract: Wafer cutting is one of the key steps in the semiconductor chip manufacturing process, which is important for improving wafer utilization and cost effectiveness, ensuring product quality and performance, supporting more integrated and smaller chip manufacturing, and enabling the production of multiple chips. Height measurement is to accurately measure the height between the blade and the wafer when the wafer cutter performs precision cutting, and contact height measurement is required. This paper studies the height measuring control system of wafer cutting machine. The different resistance values of different cutter blades may cause the instability of height measuring. An auxiliary height measuring circuit is designed to trigger the height measuring circuit according to voltage. The circuit uses a single chip microcomputer as the main control chip, the AD converter and the voltage regulator chip TL431 in the circuit ensure the measurement accuracy, and the feasibility is verified by Protues simulation software. The experimental results show that the improved auxiliary height measuring circuit can be used to improve the safety and stability of the height measuring circuit.

Keywords: Wafer; Cutting Machine; Micron Scale; Height Measurement; Control System

1. Introduction

The semiconductor wafer cutter processes semiconductor wafers with cutting tools to achieve the cutting and separation of wafers. During cutting, the wafer is fixed to the cutting platform, and the tool is responsible for cutting the wafer. The control system is used to control the movement of the tool and the cutting process. In the entire cutting process, it is necessary to ensure the precise position control of the tool and the accurate adjustment of the cutting parameters to ensure the accuracy and precision of the cutting. The working principle of the entire cutting machine is to achieve effective separation and processing of semiconductor wafers by precisely controlling the cutting process [1-5].

In this paper, an auxiliary height measuring circuit of wafer cutting machine is designed. By introducing resistance adjusting component and height measuring auxiliary unit, the adjustable resistance can be adjusted to ensure that the height measuring voltage can reach the trigger threshold when the tool is in contact with the workbench, so as to trigger the height measuring circuit. At the same time, the AD converter and the voltage regulator chip in the height measuring auxiliary unit ensure the accuracy of the acquisition voltage, and the real-time display of the adjustment state and measurement results through the display unit greatly improve the accuracy and convenience of height measurement. The design can accurately measure the height according to the difference of the resistance value of different cutter blades through the cooperation of the height measuring auxiliary unit and the height measuring trigger unit. It not only avoids the problem that the height measuring circuit cannot be triggered because the resistance value of the blade is too large, but also improves the safety and stability of the equipment, and reduces the risk of damaging the blade and equipment.

2. Working Principle of Cutting Machine

The wafer cutting machine uses the grinding wheel as the blade, and the spindle drives the blade to rotate at high speed, which can be used for high-precision cutting and separation of semiconductor silicon wafers, and can also

be applied to the segmentation and cutting of materials such as solar cells, ceramic substrates, light-emitting diodes, gallium arsenide and glass. The main process of the working principle of the wafer cutting machine is that the first cut workpiece is adsorbed on the working chuck of the θ axis through compressed air, the X-axis drives the aligned workpiece to be cut, and the high-speed rotating blade divides the workpiece into small pieces of the working chuck, as shown in Figure 1 [6].

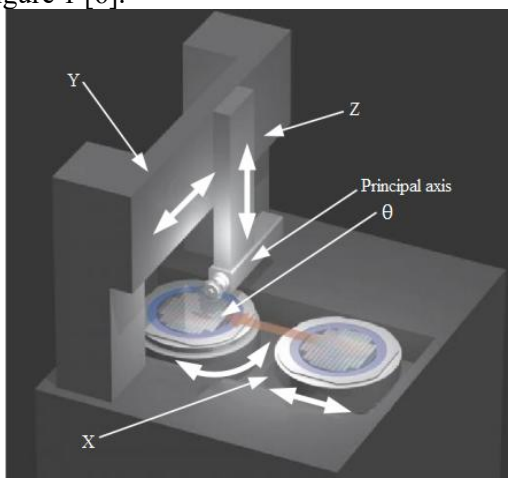
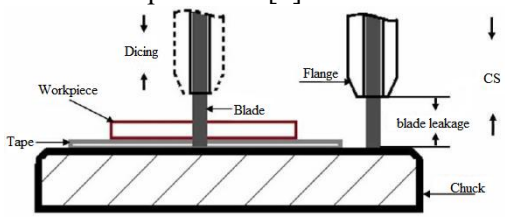


Figure 1. Schematic Diagram of Semiconductor Wafer Cutting Machine

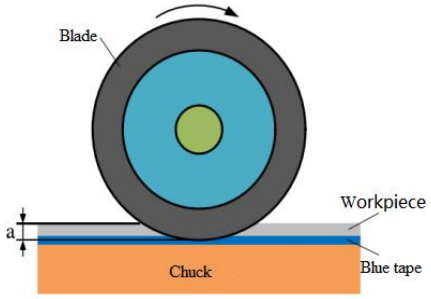
3. Principle of Altimetry System Detection Technology

The main function of the height measurement system of the wafer cutting machine is to measure the height of the spindle that needs to be automatically lowered before cutting, and complete a small and precise cutting task. During the cutting process, the spindle mounted on the slide of the Z-axis system requires continuous tool lifting and tool dropping. In order to completely remove the finished workpiece from the working chuck, it is necessary to repeatedly measure the height before starting the cutting program. In order to ensure the cutting precision of the scribing machine, the design requires that the difference between the adjacent height measurement is not greater than 5μm before it is determined that the height is completed, and the height of the spindle is recorded after the height measurement, and the cutting depth is determined according to the value.

Height measurement refers to determining the Z-direction position relationship between the initial position of the outer edge of the blade and the working suction cup through the instantaneous contact between the blade and the working suction cup. As shown in Figure 2, the height measurement system measures the Z-direction limit displacement of the blade relative to the working suction cup and automatically records the displacement, which is used as the reference value for depth control and blade compensation [7].



(a) Side view



(b) Front view

Figure 2. Schematic Diagram of Height Measurement Process

In order to meet the requirements of cutting, the blade leakage is generally selected at about 2mm, and the blade leakage L1 of the new blade is calculated according to the following formula:

$$L_1 = \frac{D-d}{2} \tag{1}$$

Where D represents the diameter of the blade and d represents the diameter of the flange.

The first height measurement is after replacing the new blade, and the height value H of the z-axis of the height measurement is obtained through the height measurement. After cutting the workpiece, the blade is worn. At this time, the height value h of Z-axis of the height measurement is obtained for the second time. At this time, the wear value of the blade is as follows:

$$\Delta h = H - h \tag{2}$$

The amount of blade leakage at this time:

$$L_2 = \frac{D-d}{2} - \Delta h \tag{3}$$

Under normal circumstances, the blade leakage is less than 0.88mm, it is recommended to replace the blade, otherwise the bottom of the

spindle will encounter the working suction cup, resulting in serious consequences of damaging the flange and the spindle, the blade wear principle schematic diagram is shown in Figure 3 [8].

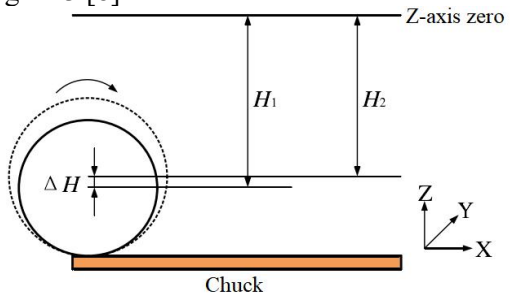


Figure 3. Schematic Diagram of Blade Wear Principle

In height measurement, the water droplets on the surface of the working suction cup need to be blown off before height measurement can be carried out. At this time, the Z-axis moving mechanism drops at a faster speed. When the blade is close to the working suction cup, the Z-axis moving mechanism begins to drop slowly. Then the system compares the difference between the two adjacent height measurements and the wear inspection threshold set by the software. If the difference between the two adjacent height measurements is greater than the wear inspection threshold, the buzzer will send an alarm signal to inform the operator that the height measurement is invalid. If the difference between the two adjacent height measurements is not greater than the wear check threshold, the system automatically saves the height value of the z-axis of the height measurement to complete the height measurement of the system.

Height measurement technology is a key technology of wafer cutting machine, height measurement Z-axis data is the key data of cutting machine cutting accuracy and reliability, but also related to the spindle, blade and working suction safety, so the height measurement system is an important part of the wafer cutting machine equipment performance.

4. Design of Contact Height Detection Circuit

During the cutting work of the wafer cutter, a certain amount of uniform wear will occur on the outer edge of the grinding wheel blade in the process of high-speed cutting, as shown in Figure 4. In the normal processing process, the radius of the blade must be measured through the height measurement circuit in the system to ensure the normal cutting of the workpiece, otherwise it will lead to the workpiece can not be completely cut during the cutting process, and the processing consistency is poor.

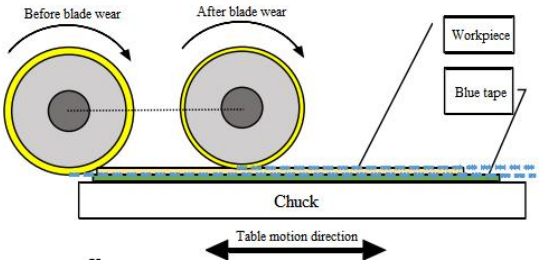


Figure 4. Wafer Cutter Cutting Process Diagram

When using a wafer cutter for precision cutting, contact altimetry is required to accurately measure the height of the blade and wafer. In the wafer cutting machine in the actual cutting process, due to the different materials need to choose different tools, and different tool blade material, shape and size differences, some blade conductivity is very good, the resistance value is almost ignored, and some blade resistance value is particularly large, up to tens of thousands of ohms, so that the height of the wafer cutting machine can not be triggered as a low level. As a result, the height detection circuit cannot be triggered, the light will damage the blade table leaving deep knife marks, and the heavy will collide with the spindle flange and the table, resulting in inaccurate measurement and even equipment damage.

Before cutting the wafer cutter, it is necessary to carry out contact conductive cutter. When the equipment is enabled for work, the system first performs a tool measurement to obtain the Z-direction relative position of the blade edge to the conducting table plane. The spindle rotates at a high speed, the workbench and the spindle move to the designated position, and the z-axis descends step by step until it touches the workbench through the edge of the blade. The Z-axis coordinate value recorded at this time is the tool alignment position, and the Z-axis coordinate recorded at this time is also called the height measurement height H1. At this time, the distance between the spindle axis and the workbench is D1, which is the blade radius, as shown in Figure 5. After H1 is measured, by setting the film thickness L1, H1-L1 is the normal cutting height of the blade edge.

After the blade cuts the workpiece for a period of time, a certain amount of wear will be generated. After the blade is worn, the cutting depth of the blade will be affected. To quantify the amount of wear, the difference between the new tool position H2 and the original tool position H1 must be obtained by contacting the table again [9].

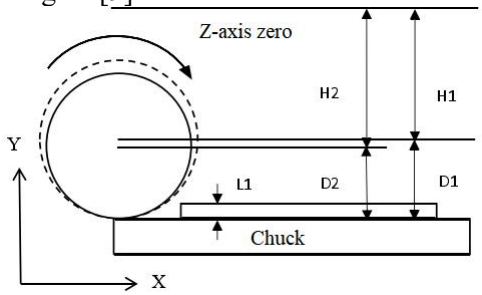


Figure 5. Schematic Diagram of Contact Altimetry

The height measuring circuit is composed of the height measuring circuit board, the main shaft carbon brush and the working suction cup in series with the wire. The connection diagram of the height measuring circuit is shown in Figure 6. The brush behind the main shaft is connected with the ground wire, the main shaft brush as a signal ground, the blade is fixed on the main shaft through the flange, that is, the blade is connected with the main shaft, and then connected with the main shaft brush, that is, the blade is actually connected with the ground wire.

When measuring height, 5V voltage is added to the working sucker, that is, the working sucker is used as the signal source. The emery blade can conduct electricity. When the blade is in contact with the working suction cup, the height measuring board sends a height measuring signal to the motion control card. After receiving the signal, the motion control card immediately makes the Z-axis motor move up to lift the tool. In order to insulate the working suction cup from the housing, marble with high insulation degree and low cost is used as insulation material.

When the carbon brush is seriously worn after a long time of cutting, the level of the input board port will jump, and the workbench is also connected to another port Ix 'of the input board. When the blade is in contact with the workbench, the input board receives a low level signal and the high and low level will be triggered to convert, and the height measurement will be judged by the change of Ix' signal.

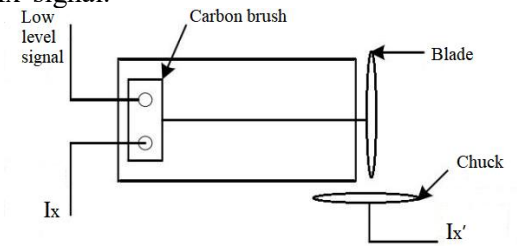


Figure 6. Altimetry Circuit Connection Diagram

The change of signal is a digital signal, only 0 and 1 two states, in time is discontinuous, the general IO port on 0 and 1 two states of change is a range, anti-electromagnetic interference ability is strong, suitable for poor operating environment state.

The trigger principle diagram of the contact detection circuit signal is shown in Figure 7, which is mainly composed of R1, R2, R3 resistors, C2, C4 capacitors and 555 Schmidt flip-flop and other components. The dashed line box in the figure shows the internal circuit diagram of 555 Schmidt flip-flop [10].

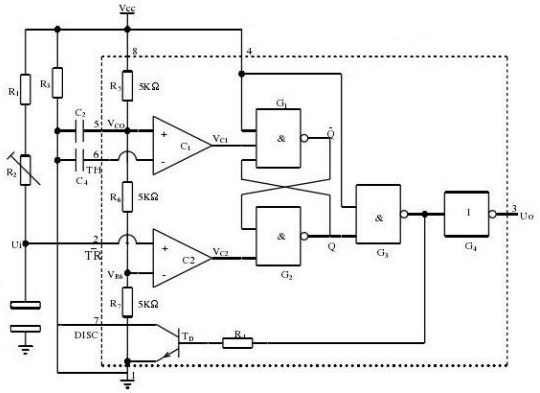
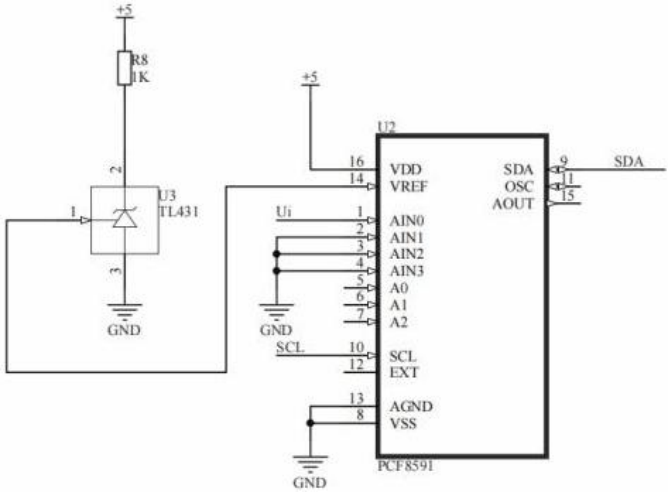


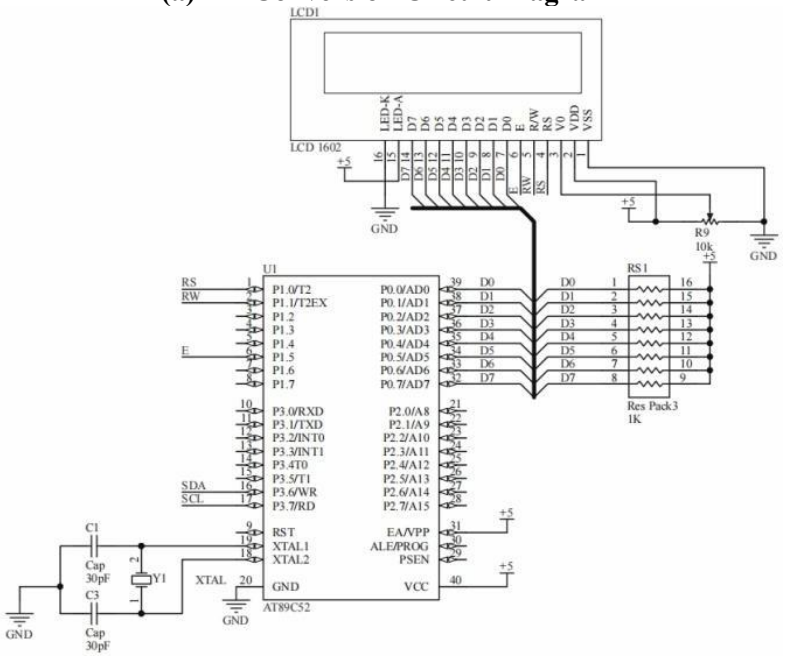
Figure 7. Schematic Diagram of Trigger Circuit of 555 Contact Height Measuring Signal

After the upper grinding wheel blade is installed, height detection begins, the upper computer gives the start signal of height detection, the X axis and Y axis move to the given position, the Z axis begins to rapidly drop to the approach point, and then slowly move at a speed of 0.1mm/s until the grinding wheel blade on the spindle contacts the table, and the carbon brush of the spindle sends a low level signal to the input card. The trigger signal is sent and transmitted to the motion control card of the system. When the motion control card receives the trigger signal, it immediately lifts the tool and records the height of Z-axis at this time, and the height detection is completed. The circuit provides a wafer cutter height

measurement circuit by introducing a resistance adjustment component and a height measurement auxiliary unit, as shown in Figure 8. According to the difference of resistance values of different tool blades, the circuit can adjust the adjustable resistance R2 to ensure that the height measurement voltage Ui can reach the trigger threshold when the tool is in contact with the workbench, so as to trigger the height detection circuit. At the same time, the AD converter and the voltage regulator chip in the height measurement circuit ensure the accuracy of the acquisition voltage, and the real-time display of the adjustment state and measurement results through the display unit greatly improve the accuracy and convenience of height measurement.



(a) AD Conversion Circuit Diagram



(b) Main Control Circuit and Display Circuit

Figure 8. Height Detection Circuit Diagram

AD converter adopts PCF8951 chip, PCF8951 chip is an 8-bit A/D and D/A converter with I²C interface, which is mainly used to collect the output voltage value of the resistance adjustment component, that is, the height measurement voltage Ui, and convert the height measurement voltage Ui into 8-bit digital signal, the converted digital signal is sent to the main control unit through the I²C interface. The voltage regulator chip adopts TL431 adjustable linear regulator U3, which provides a stable reference voltage for the reference power supply end (VREF) of PCF8951 chip, so as to convert the analog input signal into an accurate digital value, thereby improving the acquisition accuracy

and reducing errors.

This design can accurately measure the height according to the difference of the resistance value of different cutter blades through the cooperation of the height measuring circuit and the height detecting trigger unit, which not only avoids the problem that the height detecting circuit cannot be triggered because the resistance value of the blade is too large, but also improves the safety and stability of the equipment, and reduces the risk of damaging the blade and equipment.

5. The Auxiliary Height Measuring Circuit Simulates the Circuit Test

Through the use of Protues simulation software, the height measurement circuit simulation design can be carried out, when the tool change, the blade resistance can be input into the circuit, through the simulation circuit, you can judge whether it meets the requirements, so as to avoid damaging the blade and further improve the safety and stability of the equipment.

The auxiliary height detection circuit is designed in Protues simulation software, and the blade can be replaced by a sliding rheostat. The circuit simulation diagram is shown in Figure 9.

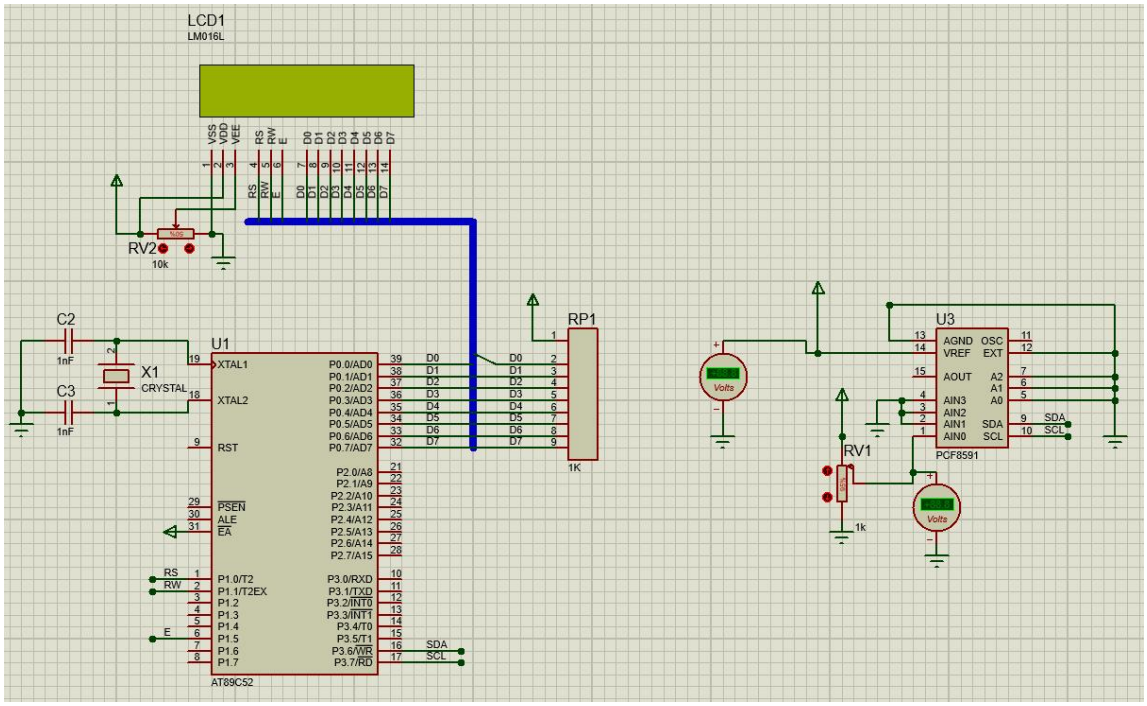


Figure 9. Simulation Diagram of Auxiliary Altimeter Circuit

When the blade is placed in the circuit, the value of Ui can be replaced by the voltage value on the sliding rheostat in the simulation circuit, the total resistance is 10k ohms, the connected voltage is 5V, the percentage represents the resistance value of the access is 10k*76%=7.6k ohms, the voltage of the access PCF8591 chip is 3.8V, and the resistance size is adjusted by the up and down arrow. The size of the voltage value can be adjusted, as shown in Figure 10.

According to the actual situation, the output of the reference voltage of 555 flip-flop less than 1/3 is high, so in the simulation design circuit, when the sliding rheostat voltage is above 1.7V, it is displayed as NG, and when it is less than 1.7V, it is displayed as OK, indicating that the conditions are met and the height can be measured. The simulation display diagram is shown in Figure 11.

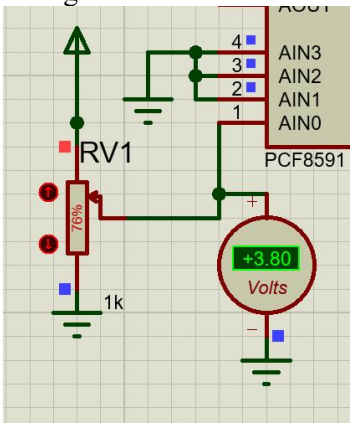
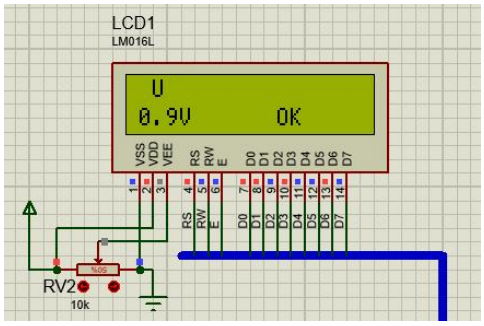
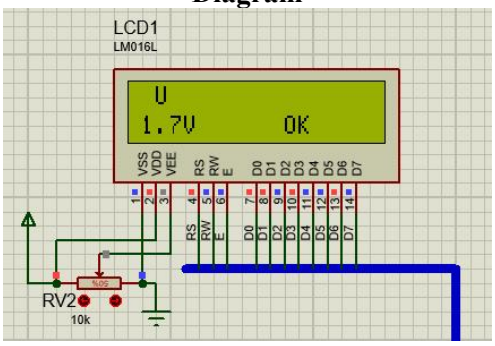


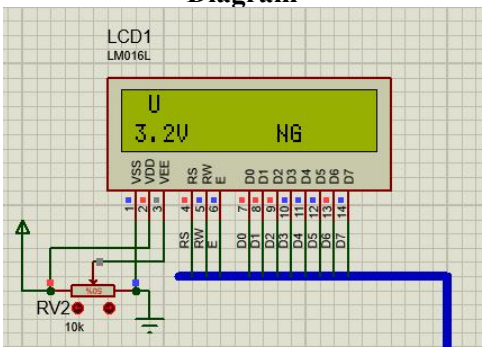
Figure 10. Sliding Rheostat Access Voltage Value



(a) Sliding Rheostat Voltage Is 0.9v Display Diagram



(b) Sliding Rheostat Voltage Is 1.7v Display Diagram



(c) Sliding Rheostat Voltage Is 3.2v Display Diagram

Figure 11. Display Diagram of Simulation State

6. Conclusion

With the development of the semiconductor industry, the industry has higher and higher requirements for chip processing technology, and the overall automation degree of semiconductor wafer cutting machine, the stability of equipment operation, the working rate, and the chip processing accuracy are becoming higher and higher. This paper systematically describes the principle of the height measuring system and the realization of electrical hardware, improves and optimizes the original IO conduction height measuring circuit, and proposes a height measuring system scheme with high precision and strong stability, which can not only improve the efficiency and performance of the cutting machine itself, but also improve the yield of the chip and increase the service life of the tool. At the same time, the service life of the air spindle and the working disc is greatly improved.

Acknowledgments

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