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Operation of the mask aligner MJB-55

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1 Introduction

The mask aligner is an essential tool required for the fabrication of semiconductor devices. Its main purpose is to transfer a pattern from an optical mask onto the semiconductor wafer which is covered with a light-sensitive coating (*photoresist*). Analogous to the technique used in traditional photography, the light-sensitive coating changes its chemical properties upon exposure to a light source. Depending on the type of photoresist used, either the exposed (*positive photoresit*) or the unexposed (*negative photoresist*) of the coating will become soluble in a *developer solution*.

In order to be able to pattern complex structures onto the semiconductor wafer, several consecutive exposures with different masks have to be performed which allow to structure the wafer in vertical direction. Consequently, in order to have reproduceable results, masks used in consecutive exposures have to be accurately aligned with each other. Both the exposure and the alignment of the different masks are performed by a single device called *mask aligner* whose operation is to be covered in this short manual for the *Karl Suess MJB-55* mask aligner located in the clean room at MiNaLab.

2 Description of the MJB-55 mask aligner

The MJB-55 mask aligner basically consists of a table with a high-power light source (UV light), an electromechanical alignment and transport mechanism which allows for batch processing as well as an integrated microscope used to perform accurate manual alignments with micrometer accuracy.

2.1 Light source

The integrated UV lamp is powered and controlled by an external power supply which runs independently from the mask aligner. The power supply is solely responsible for regulating the output power of the lamp as well as maintaining a safe operation which essentially means that the lamp temperature is kept within a predefined operating temperature, i.e. the lamp has to be actually warmed up to a defined operating temperature before it can be used for exposure. In order to keep the lamp temperature constant within a safe regime, external cooling is achieved through a nitrogene supply which is provided within the clean room facility and has to be turned on prior operation of the lamp. Since overheating can lead to a possible hazardous explosion of the lamp, it is mandatory that cooling is provided throughout operation and afterwards to prevent accumulation of residual heat which will also detorioate lamp life or, in the worst case, lead to the destruction of the lamp.

It is therefore mandatory that the nitrogene supply is turned on *before* operation of the lamp and not turned off until at least 60 minutes after the lamp has been shut off. The power supply of the lamp is originally designed to monitor the flow of nitrogene throughout the operation, however this functionality is not available in the current setup and the input signal for the nitrogene monitor has been bridged with a dummy device which will fake the power supply that the nitrogene supply is available throughout usage. It is therefore important to make sure that there is actually a nitrogene flow available for cooling, since the power supply is unable to detect a failure of the flow.

2.2 Mask alignment mechanism

The alignment mechanism is completely controlled through electro-mechanical actuators which allow for precise and reproducable positioning of mask and wafer during exposure. After alignment has been achieved, the mask aligner can be operated in automatic mode which allows batch processing of multiple wafers with the same alignment settings. The batch processing facility is usually not used in the laboratory, since usually only single wafers are processed.

In the simplest case of two consecutive exposures, wafer and mask require precise alignment during the second exposure only, while it is sufficient for first exposure to have just a rough alignment towards the wafer geometry which will transfer the pattern such that the second, precise alignment will be easier to be performed. This simply means that the flat side, if available, of the wafer should be aligned parallel to one of the sides of the mask and it makes sure, that during second exposure only minimal fine alignment has to be performed when the second mask and the wafer can already be roughly aligned with the help of the flat side of the wafer.

The alignment mechanism allows to move mask and wafer independently as well as both of them with regard to the microscope. Alignment is therefore achieved by locating the alignment marks on wafer or mask with the microscope first, moving wafer and mask simualtanously, then matching marks on the wafer and masks by moving them individually and aligning for congruence.

2.3 Optical microscope

The optical microscope does not have any special capabilities which it would distinguish from regular optical microscope used in day-to-day labwork. It is a stereo-type microscope with an integrated light source which provides enough luminescence to illuminate wafer and mask bright enough that the alignment marks both of mask and underlying wafer[1]

The two objective lenses can be positioned independent of each other allowing it to adjust it to different alignment masks where the (usually) two alignment marks are seperated at different distances. Additional shutters for each of the objective lenses allow to close the two lenses individually, making the individual alignment of both marks easier.

3 Operating instructions

3.1 Precautions & prerequisite tasks

Before the mask aligner can be used, several precautions have to be taken care of and prerequisite tasks have to made. The following check list should be gone through each time before the mask aligner is turned on:

- Turn on nitrogene supply located beneath the floor panel labelled with “Nitrogene” in the lithography room; a clearly audible click sound followed by a hiss of the gas flowing indicates that there is a sufficient gas supply. if no such sound is heard, the nitrogene supply should be checked before the UV lamp is turned on.
- Turn on the vacuum pump located in the corner below the table where the spin-coating machine is located. The vacuum is easily checked by reading the respective gauge on the mask aligner, it should read a pressure of 0.8 bars.
- Turn on the pressurized air supply located at the backside of the mask aligner. The valve is attached at the left side corner of the mask aligner table. The air pressure can be controlled with the second gauge next to the vacuum gauge of the mask aligner.
- Attach the power cable to the fan located at the back side of the mask aligner. This fan provides additional cooling for the electronic circuit boards inside the mask aligner. The fan should spin up immediately, if not check the electrical contacts and the fan.

[1] The wafer does not have any alignment marks until after the first pattern has been transferred onto it.

- Retrieve the dummy device labelled from the cabinet where the masks are stored. Attach it to the back of the power supply.

If each of the above checklist items have been successfully performed, mask aligner and lamp are now ready for use. Turn on the mains switch of the mask aligner first, then turn on the power to the power supply of the UV lamp. Push the button labelled "START" on the power supply and wait for the lamp to warm up. It will take 5-10 minutes until the lamp has reached operating temperature. During that time, the display of the power supply will read "COLD START" and emit a periodic acoustic signal. Once the operating temperature has been reached, the lamp will be automatically turned on and the mask aligner is then ready for use.

3.2 First exposure

First make sure that both the vaccum and air pressure read the correct values. The mask aligner should be in idle mode, none of the lamps on the left button pad should be lit. If this is not the case, push the button "RESET" (**#5**), in order to perform a system reset.[2]

Retrieve the first mask from the cabinet and place it onto the bottom of the mask holder, with the mask shiny side facing upwards. The side on which the chrome has been coated onto the glass substrate should always be facing the wafer in order to prevent shadowing which will reduce resolution during exposure.

Place the wafer onto the chuck and align its flat parallel with one side of the mask, preferably with the flat facing towards the front. This will make alignment during consecutive exposures much easier. Set the mask holder with the mask onto the wafer and trigger the mask holder lock **#12**. The mask holder will be locked and the microscope should automatically suspended into downwards position.

Set the exposure time in seconds[3] with the dial **#23**, make sure that the proper separation distances **d1** and **d2** are set.

Press buttons **#19** (first exposure) and **#21** (quick program). Press **#1**, the chuck should now be moved towards the mask holder.

Since no fine alignment is necessary at this step, the wafer can simply be exposed now. First press **#3** to move mask and wafer into contact, then press **#14** to start the actual exposure process.

After exposure has been performed, press **#12** to release the mask holder, this should also lift the microscope. Remove the wafer from the chuck.

3.3 Second exposure

The second exposure is actually a bit more tricky than the first exposure since mask and wafer have to be aligned very accurately with each other.

For this, the wafer and the second mask ("dark field mask") have alignment crosses which have to be matched during alignment. Even though the wafer is usually covered with a thin metal film before the second exposure[4], the alignment crosses can still be easily seen when holding the wafer in an angle towards a light source as well as under the microscope.

To perform the alignment, the wafer is placed onto the chuck again and the mask holder is placed over it like for the first exposure. If the pattern from the first exposure has been aligned parallel to one of the flats of the wafer, coarse alignment of the wafer is already achieved by simply placing the wafer onto the chuck with the flat side facing to the same direction as it was placed during first exposure (usually with the flat side facing towards the front).

Once wafer and mask holder are in place, alignment is started by pressing **#19** (first exposure) and **#21** (quick program) again.

[2]This reset should be performed whenever the mask aligner is not reacting in an expected way or is not reacting to any user input. A reset should *always* be preferred over a power cycle since the latter will disable the vacuum to the mask holder risking in dropping and destroying the expensive glas mask.

[3]The time is actually shown in hundreds of seconds.

[4]The second exposure is usually performed to pattern the metal contacts of the diodes when fabricating pn junctions

Using the joystick, mask, microscope and wafer can now be aligned with each other. For this, buttons **#2** and **#4** are important: While button **#2** switches the joystick control between mask and microscope, button **#4** locks the movement of mask and microscope to each other.

First, the microscope is moved across the mask surface to find the two alignment crosses (buttons **#2** and **#4** turned off). Then the movement of mask and microscope is locked together such that they can be positioned with respect to the wafer. With a bit practice, one will quickly be able to match the crosses on mask and wafer. Once the crosses match on both sides, the wafer is ready for second exposure. Thus press **#3** and then **#14**.

3.4 Turning the mask aligner off

3.5 Remarks

3.5.1 Using other than 4-inch wafers

The mask aligner is designed to be used with 4-inch wafers only. If other sizes, i.e. smaller wafers or irregular wafer shapes are supposed to be exposed, an additional thin 4-inch wafer has to be put under the smaller wafer for padding the remaining space of the chuck surface. Without the wafer fully covering the chuck surface, the chuck vacuum cannot be engaged and the mask aligner program refuses to start.

A practical way to make such an adapter is using a standard 4-inch wafer on which the smaller wafer is taped onto using double-sided cohesive tape. The position of the smaller wafer on the 4-inch wafer should be indicated with some alignment marks carved into the wafer, such it can be accurately replaced at the same position before alignment for second exposure. As mentioned before, a reproducable wafer alignment on the chuck will dramatically simplify fine alignment for consecutive exposures after the first exposure. Both the small and the padding wafer should be alignment with some distinct features like flats towards the sides of the mask.

3.5.2 Mask aligner program failures

Due to the complex nature of the mask aligner, the electronics run into unexpected program states from time to time. When this happens, buttons may stop working or some of the mechanical actuators may be in an unexpected state[5].

The designers of the mask aligner knew of this problem and thus the machine is equipped with a RESET button (**#5**). Pressing this button will reset the machine and the automatic cassette loading mechanism while the vacuum of the mask holder stays intact. This is very important since an unexpected loss of the vacuum will cause the mask to fall out of the mask holder risking a damage of the glass mask when it is dropped. One should therefore always try the RESET button first once the machine program hangs.

In some cases, it might not be enough to press the RESET button and a power cycle is required, i.e. turning the mask aligner off and on again. In this case, the mask holder has to be removed from the machine and turned upside down so that the mask cannot fall off once the mask vacuum is lost. **THE MASK ALIGNER MUST NOT BE TURNED OFF BEFORE THE MASK HAS BEEN SECURED AGAINST FALLING OFF.**

4 Appendix - Button quick reference

- **#1**: Automatic program START/STOP
- **#2**: Switch manipulator control between microscope and mask
- **#3**: Move mask into contact with wafer
- **#4**: Move microscope and mask simualtaneously

[5] One very common observations is, for example, that the microscope will be lifted up even though the mask holder is locked. Normally the microscope is automatically suspend once the mask holder is locked with button **#12**.

- **#5**: Reset machine and cassette holder, mask holder vacuum stays intact
- **#6**: Lift microscope up and down
- **#7**: Move microscope and mask into center position (**#2** and **#4** should be turned OFF)
- **#8**: Trigger vacuum of left transport plate
- **#9**: Trigger vacuum of right transport plate
- **#10**: (lamp only) flashes with contact counter
- **#11**: Return
- **#12**: Lock mask holder into position (use after placing mask holder over the wafer)
- **#13**: Trigger vacuum mask holder
- **#14**: **Exposure**
- **#15**: Operate in single step mode (useful for debugging)
- **#18**: Automatic program 1: contact exposure without shielding gas
- **#19**: First exposure
- **#20**: Automatic program 2: contact exposure in vacuum chamber (hard contact)
- **#21**: Quick program, without using the cassette loader
- **#22**: Automatic program 3: shadow projection exposure
- **#23**: Trigger shielding gas below mask
- **#24**: Move cassette 2 (left) one step upwards
- **#25**: Move cassette 1 (right) one step upwards
- **#26**: Move cassette 2 (left) one step downwards
- **#27**: Run single step of cassette loader program
- **#28**: Move both cassettes into start position (left cassette is moved down, right cassette is moved up)
- **#29**: Run automatic cassette loader program
- **#30**: Run cassette program without using cassette loader (used for pre-alignment)
- **#31**: Reset cassette loader unit
- **#32**: (Dial) Exposure timer with light integrator; to use light integrator, flip switch into "Integr." position
- **#33**: Count contact movements (counts downwards)
- **#34**: Digital switch 1 (d1): Set separation between mask and wafer during exposure
- **#35**: Digital switch 2 (d2): Set separation between mask and wafer during alignment