

# COMPUTER AIDED RETICLE MAKING FOR A MICROMOTOR

Stephen B. Clemens  
5th Year Microelectronic Engineering Student  
Rochester Institute of Technology

## ABSTRACT

The creation of MANN files, generated by computer programs, to produce other than rectangular features for the design of reticles required for the manufacturing of a micromotor has been investigated. The reticles have been designed to compensate for the lateral loss of polysilicon and silicon dioxide during the etching process and for the loss of silicon during oxidation. Three computer programs were designed to generate MANN files that would control the GCA Pattern Generator and expose emulsion coated glass plates yielding images of circles, washers, and the placement of rectangles at any orientation with respect to the center of the reticle. The reticles were developed using standard and reversal processing. The GCA MANN 4800SW Stepper will utilize these reticles to image wafers for the manufacture of micromotors.

## INTRODUCTION

The technology and processes used to produce integrated circuits has been applied to the construction of micromachines such as motors, cantilevers, sensors, gears, relays, and actuators. These micromachines provide an interface between the electrical and the physical world. Integrated circuit processing technology has provided the means to develop micromachines that can rotate, slide, and store mechanical energy in a ready made form. These structures can be formed of numerous movable parts without the problems of assembling each individual component.

This project involved the design of a micromotor, similar to that developed by Fan, Tai, and Muller[1]. Differences between the two designs lie in the formation of the fixed axle pin joint. An additional polysilicon deposition is used in this design to decrease the surface area of the rotor that is in contact with the silicon substrate thereby decreasing the frictional forces thus requiring a lower operating potential. Other variations between the two designs is the dry etching of polysilicon and silicon dioxide used by Fan, Tai, and Muller and the wet etching process used at RIT.

Micromotors are driven by electrostatic forces induced between the stator and rotor poles. When a positive potential is applied to one pole of the stator and an equal but opposite charge is applied to a stator pole 180 degrees with respect to the first stator pole, the respective applied potentials will induce an opposite charge on the rotor poles. The remaining stators are grounded. The applied potentials are then switched to the poles that were originally at ground potential and the initially charged stators are grounded. The electric field on the now charged stators will attract the opposite charge on the rotor poles causing the rotor to rotate towards the opposing charge.

The reticle design project of a micromotor that consists of a rotor and six stators, required five reticles patterned with circles. The rotor reticle was designed using a washer then projecting eight rectangles at 45 degrees around the outer edge of the washer to create the rotor poles. The stators and contact pads were imaged in the same manor as the rotor poles.

The integrated circuit layout software program (ICE) used at RIT, is incapable of generating circles of sufficient resolution for implementation in the micromotor project. ICE also is incapable of orientating rectangles at any other angle than 90 degrees. This lead to the necessity of developing computer programs that would generate MANN files that would overcome some of the limitations of ICE.

## THEORY

Design of the reticles must be realizable with RIT's processing capabilities. The Fan-Tai-Muller motor [2], was produced utilizing the processing techniques of phosphosilicate glass (PSG) deposition and anisotropic dry etching of polysilicon and PSG. Since neither technique is currently available at RIT, substitute processes and their effects on the reticle designs, had to be considered, i.e. thermal oxidation and wet isotropic etching of polysilicon and silicon dioxide.

The etch rates of silicon dioxide and doped and undoped polysilicon along with the amount of silicon and polysilicon lost due to oxidation, must be considered in the reticle design. These etch rates must be measured and the reticle designed to compensate for the lateral losses of material due to the isotropic etching. The calculation of these losses will be extremely critical when attempting to resolve the 1.5 micron gap between the rotor and stator poles. This resolution will require strict control and uniformity of the thicknesses of the deposited polysilicon and thermally grown silicon dioxide films.

Cross sections of the micromotor along with diagrams of the reticles are shown in the appendix. As can be seen from these figures, the need for circular and rectangular features at arbitrary orientations on the mask, are essential for fabrication of the micromotor. Therefore special MANN files are required.

A MANN file contains instructions for the MANN Pattern Generator. These instructions control the carriage position of the pattern generator and the angle of the exposing tool. The exposing tool is capable of exposing a emulsion coated glass plate (reticle) with a series of rectangles. The pattern generator is capable of rotating its exposing tool between the angles of 0 and 89.9 degrees. This rotating capability of the pattern generator allows features other than rectangles to be manufactured.

The first computer program required for the design of a micromotor, needs to give instructions to the pattern generator to rotate a rectangle around its center to produce a circle. The width of the rectangle must be equal to the diameter of the circle. The height of the rectangle depends on the desired resolution of the reticle; the larger the height of the rectangle, the poorer the resolution of the circle edge. Once the height of the rectangle has been determined, the angle of rotation must be calculated. The angle of rotation (theta) is determined by the equation:

$$\theta = \text{atan}(2H/W)$$

where H and W are the height and width of the rectangle respectively. The program must rotate the rectangle from 0 to 89.9 degrees. This will generate the first and third quadrants of the circle. The program must then exchange the H and W values and again rotate the rectangle from 0 to 89.9 degrees. This will generate the second and fourth quadrants of the circle. The output of the program must be written using the MANN file format. This can be accomplished by a series of format instructions.

The rotor of the micromotor requires two programs. The first program will generate a washer and the second produces the rotor poles, stators and contact pads. The washer is generated similar to the circle with the exception that the rectangle is rotated about the center of the reticle. A rectangle is chosen with the width equal to the diameter of the base of the washer. The height of the rectangle is again chosen for best resolution. The angle of rotation is different for the washer generation. This angle is determined by the equation:

$$\theta = \text{atan}(H/2W)$$

This program then rotates the rectangle in the same manner as the first program. The last program uses the inputted values of the rectangle height and width and will place the rectangles at any orientation and distance from the center of the reticle. Output from both files is in the MANN file format.

## RESULTS/DISCUSSION

The computer programs were written and the MANN files generated. A problem that could not be resolved was the leaving of spaces in the MANN file when a value was less than the allowed

space. This was overcome by editing the MANN file and deleting the spaces.

Tapes containing the instructions for the pattern generator were made. These tapes were then run through the pattern generator in the edit mode to check for errors (this is why the rectangles are rotated to a maximum angle of 89.9 instead of 90 degrees). Once the errors were eliminated, the reticles were produced. Examination of the reticles revealed no apparent flaws.

A process for production of the micromotor was designed to use along with the reticles. The reticles were designed specifically for this process sheet. A change in the process will require a change in the reticles. With the micromotor computer programs a design change is not difficult.

### SUMMARY

Three computer programs were written with output in the MANN file format. These programs generate circles and washers and will place rectangles at any distance and orientation from the center of the reticle. Six reticles containing the micromotor subassemblies were produced.

A process for the building of the micromotor with the use of these masks has been completed. Etch rates for silicon dioxide and doped and undoped polysilicon have been determined and compensation for the loss of material has been accounted for in the reticle designs.

### ACKNOWLEDGEMENTS

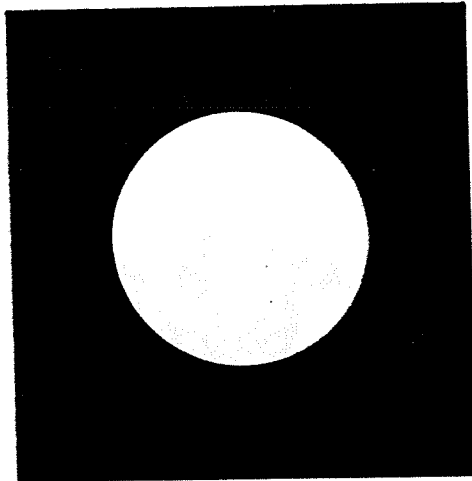
I would like to thank the following people for their assistance on the micromotor project: Dr. Lynn Fuller, Mike Jackson, Robert Pearson, and Kathy Hesler.

### REFERENCES

- [1] "Integrated Movable Micromechanical Structures for Sensors and Actuators", Long-Sheng Fan, Yu-Chong Tai, and Richard S. Muller. IEEE Transactions on Electron Devices, Vol. 35, No. 6, June 88, page 724
- [2] "MICROMACHINE", R. Gannon, Popular Science, March 89, pg.88

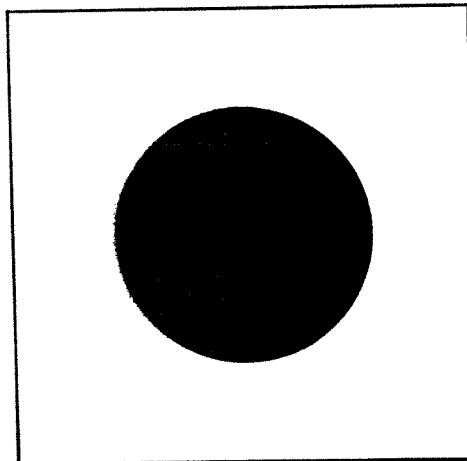
## APPENDIX

STEP 1: GROW 0.1um OF SILICON DIOXIDE ON SILICON WAFER



STEP 2: MASK 1. FIRST SILICON DIOXIDE ETCH FOR LOWER SLEEVE CONTACT  
DIAMETER OF CONTACT CUT IS 20um

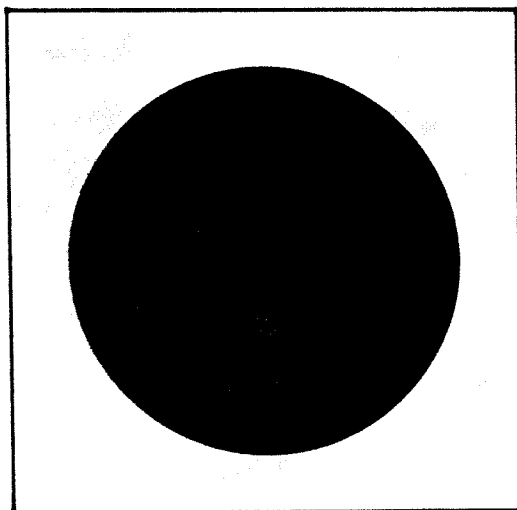
STEP 3: FIRST POLYSILICON DEPOSITION (0.3um)



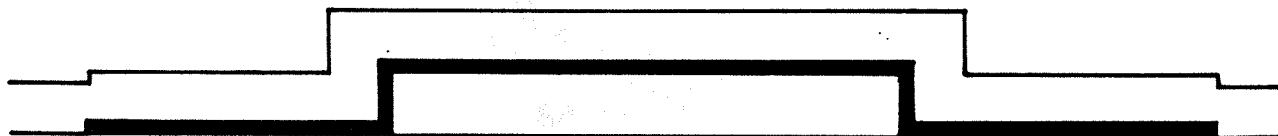
STEP 4: MASK 2. FIRST POLYSILICON ETCH FOR LOWER SLEEVE  
DIAMETER OF LOWER SLEEVE IS 20um



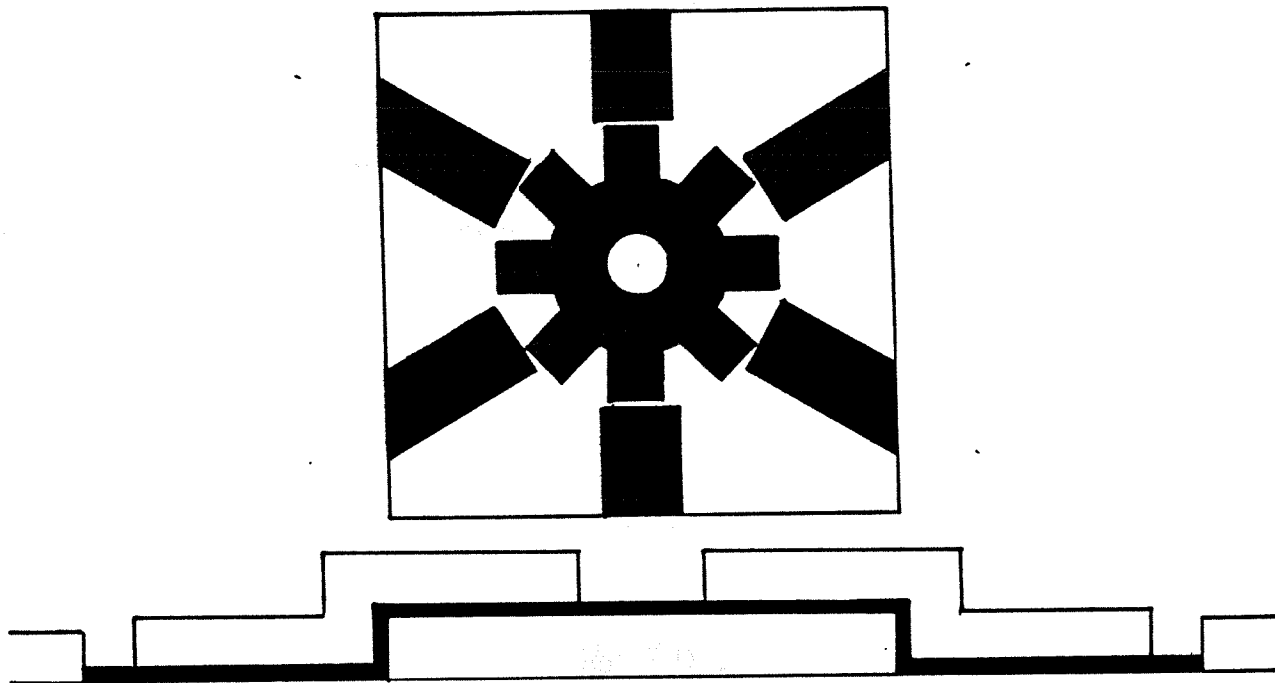
STEP 5: GROW 0.1um OF SILICON DIOXIDE FOR FIRST INSULATING LAYER



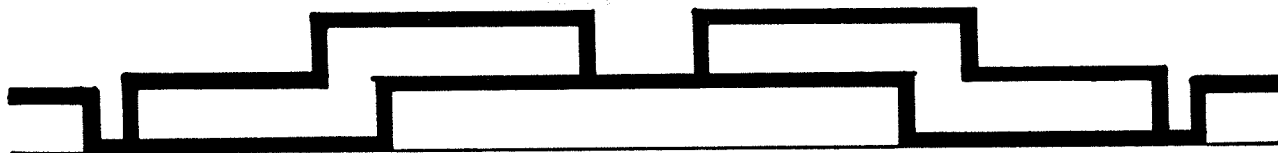
STEP 6: MASK 3. SECOND SILICON DIOXIDE ETCH FOR STATOR CONTACT  
DIAMETER OF CONTACT CUT IS 42um



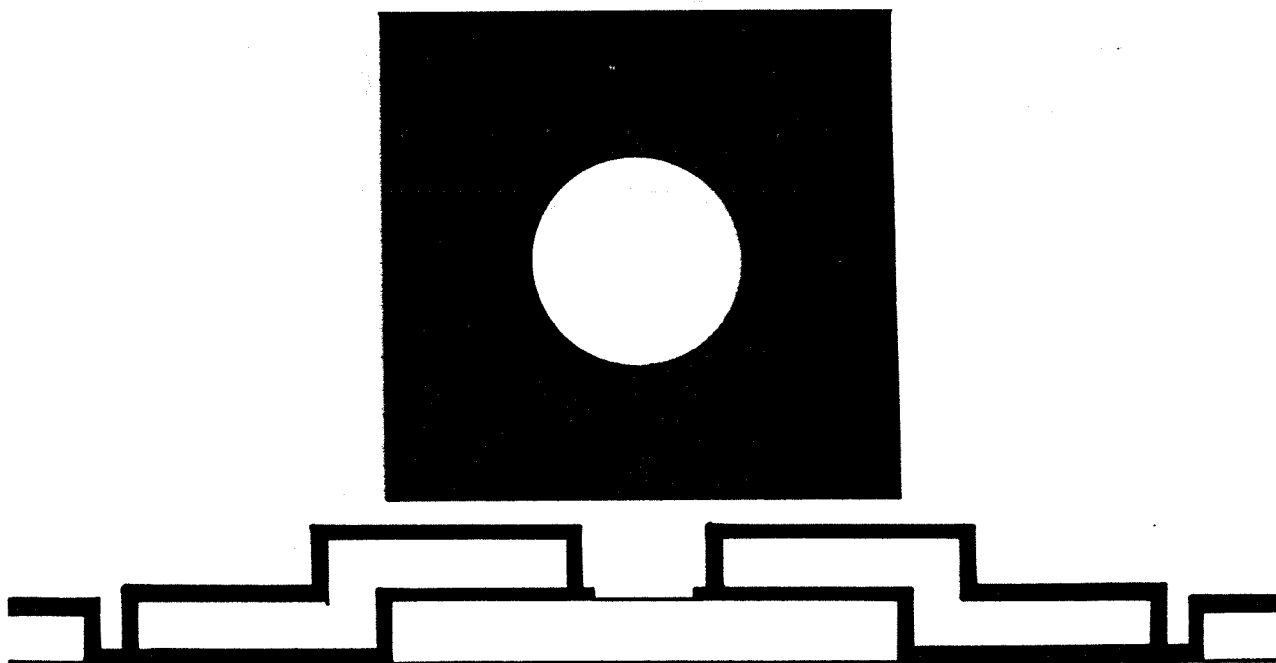
STEP 7: SECOND POLYSILICON DEPOSITION (0.4um)



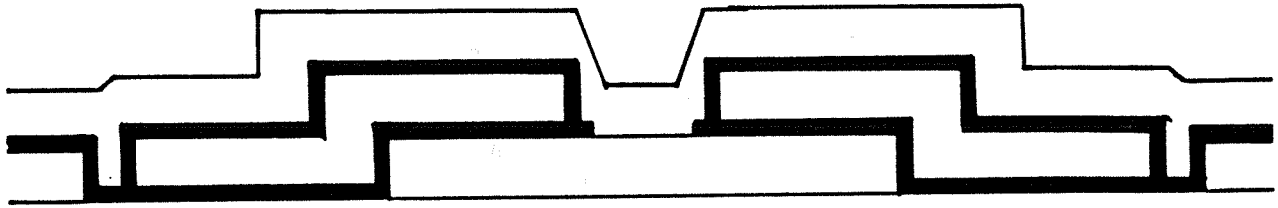
STEP 8: **MASK 4. SECOND POLYSILICON ETCH FOR STATORS AND ROTOR**  
 OUTER DIAMETER OF ROTOR IS 40um  
 INNER DIAMETER OF ROTOR IS 10um  
 LENGTH OF STATORS IS 100um  
 CONTACT PADS ARE 10,000um<sup>2</sup>



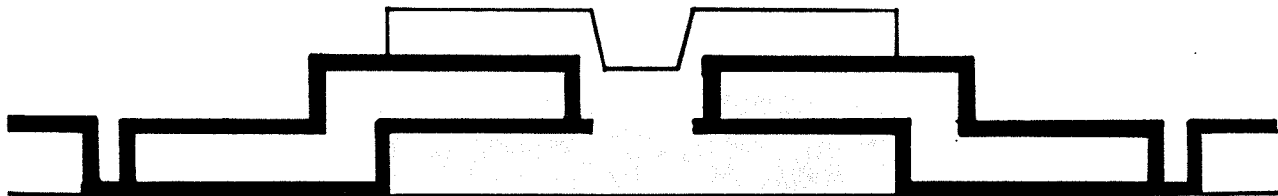
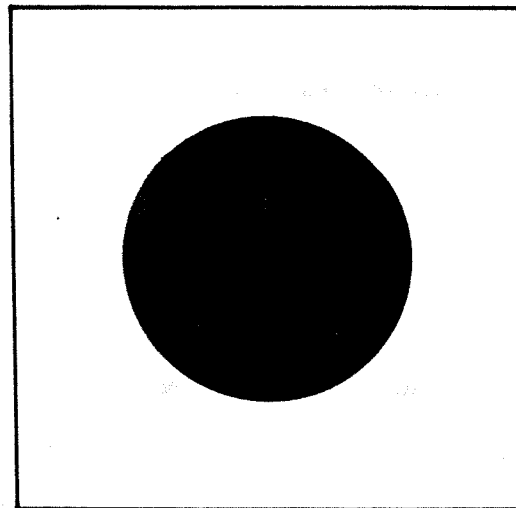
STEP 9: **GROW 0.1um OF SILICON DIOXIDE FOR SECOND INSULATING LAYER**



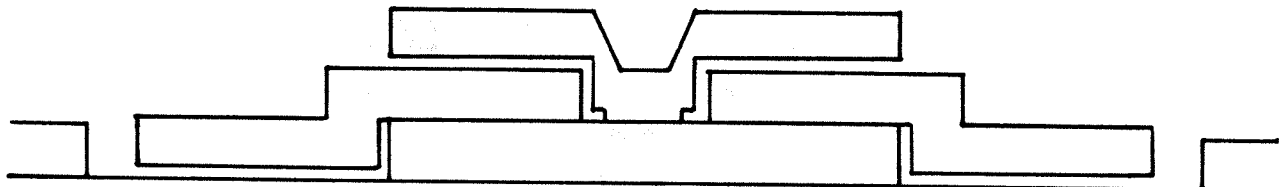
STEP 10: **MASK 5. THIRD SILICON DIOXIDE ETCH FOR UPPER SLEEVE CONTACT**  
 DIAMETER OF CONTACT IS 8um



STEP 11: THIRD POLYSILICON DEPOSITION (0.4um)



STEP 12: MASK 6. THIRD POLYSILICON ETCH FOR UPPER SLEEVE  
 DIAMETER OF UPPER SLEEVE IS 20um



STEP 13: FOURTH SILICON DIOXIDE ETCH TO RELEASE ROTOR  
 DIAMETER OF ENTIRE DEVICE IS 442um