

Stepper Motor Control Using Microprocessor for Preparation of Homogeneous Compound Semiconducting Materials

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Abstract: *The various properties such as optical, electrical and device characteristics of compound semiconductor films depend critically upon the composition, stoichiometry and the homogeneity of their bulk compounds. Therefore, the identification and control of the composition and related characteristics of these materials are important. Thus, if a compound semiconductor thin film (binary, ternary or still more complex) is to be prepared by various deposition techniques, it is usually necessary to have the evaporant charge in a compound form with homogeneity and stoichiometry. Here we have developed a setup of microprocessor based stepper motor control to get homogeneous growth of compound material by continuously mixing the evaporant charge kept in vacuum sealed quartz ampoule at high temperature using furnace. The shaft of the stepper motor is connected to the quartz ampoule via proper mechanical coupling arrangement. The stepper motor is interfaced with programmable peripheral interface IC 8255 which is controlled by microprocessor 8085. Suitable instrumentation is developed to drive the stepper motor having step angle of 1.8° . We can change the speed of the motor by suitable programming as per requirement. The detail implications are discussed.*

Keywords: Compound semiconductor, Stepper motor, Microprocessor, Homogeneity, EDAX, Stoichiometry

1. Introduction

Thick films and thin films of compound semiconductors in different applications to device structures plays a vital role having a wide range in the electrical parameters and the acceptable level of structural and chemical proportions. The tailoring of properties to suit the material and its particular applications is of utmost importance in the fabrication of device structures. Many researchers [1, 2, 3] have studied that the structure and hence the properties of such films are dominated by the nucleation and growth process which basically depends on the composition and homogeneity of compound (Bulk) material.

A compound (Bulk) material is chemically formed by mixing different individual constituents in stoichiometric proportions. After formation of the Bulk the individual properties of the constituents is changed. Mixing two or more materials i.e. forming a compound material at high temperature is done to modify and enhance the properties of the material. But if mixing is not done properly it can result in improper crystallization of the constituents and weak electrical, mechanical as well as other properties[4,5].

The influence of various methods used for mixing the individual constituents at high temperature to form the melt was studied by various researchers to identify the homogeneity, stoichiometry and kinetic behavior of crystallization of a variety of materials. Temperature profiles have also been studied for compound materials [6]. Here an attempt has been made to grow a stoichiometric bulk material of compound semiconductors by taking an individual element and mixing the melt at high temperature by rotating the molten charge with the help of microprocessor controlled stepper motor at fixed speed.

Stepper motor plays an important and vital role for control applications. They are widely used in measurement and

control applications in research laboratories and industries. They are also used in many appliances and devices that are part of our everyday routine life. Some applications include inkjet printers, computer peripherals, machine tools, robotics and volumetric pumps [7,8,9]. Several features common to all stepper motors make them ideally suitable for these types of applications. The control of various sensing parameters like velocity, current or position is very commonly used in number of research and industrial drive applications.

The stepper motor used here is based on an open-loop system where the motor operates according to the programming and does not have any feedback from the output to the input. Open loop position of stepper motors move in quantified increments of step. Holding torque characteristics is able to hold the shaft stationary. Stepper motors come in a variety of sizes and strengths from tiny floppy disk motors to huge machinery steppers. The stepper motors are available in wide varieties with different sizes, shapes and ratings from very small motor used in floppy disk to a very large motors used for servo stabilizers. There are two basic types of stepper motor (i) the permanent magnet stepper motor (PMMC type) and (ii) variable reluctance type stepper motor.

This paper focuses and describes how the speed of the motor can be controlled by programming using microprocessor 8085 for homogeneous growth of compound semiconducting materials.

2. System Design and Instrumentation for Stepper Motor Control with Furnace and Temperature Controller

This section discusses the system design considerations and related electronic instrumentation. The system architecture

part shows the whole set up in graphical view. Fig.1 show system control design for stepper motor control system.

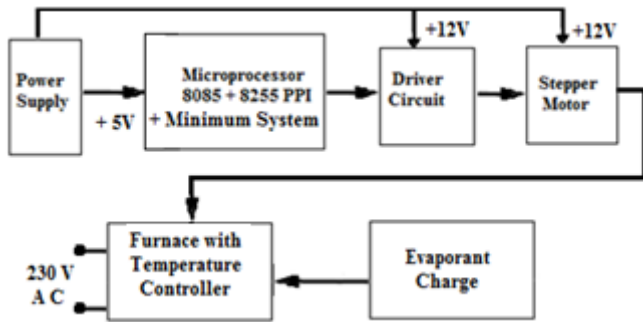


Figure 1: Architecture of Stepper Motor Control system

The control system of stepper motor based on microprocessor 8085 consists of:

- 1) DC regulated Power supply.
- 2) Microprocessor 8085 as CPU and Programmable Peripheral Interface (8255), EPROM(2764) and RAM(6264) memory for program and data storage, INTEL 8279 – to interface keyboard and six number 7-segment LED display.
- 3) Driver circuit.
- 4) Stepper motor.
- 5) Furnace Set Up with Temperature Controller.

3. Detail Description of Hardware Development

3.1 Electronic Circuit Development

The circuit diagram of control system for stepper motor is designed and developed using Power Supply, Microprocessor 8085 with minimum system and driver circuit.

3.1.1 Power Supply Unit

The schematic of power supply is as shown in Fig.2. The output of the circuit is +12V and +5V which is used to operate the stepper motor and microprocessor and related interface respectively. The 230VAC mains power is applied by pressing switch SW. This high voltage AC is reduced to 12 VAC by using step down transformer. This AC voltage is further rectified using four diodes D1 to D4 (1N 4001) connected in bridge configuration. The output of the bridge rectifier is in the form of pulsating DC. The capacitor C1 (2200 μF/63V) is used as a filter. The output of the filter section is connected to pin 1 of IC 7812 which is used as +ve linear voltage regulator. At pin3 of IC7812, the regulated output of +12V is obtained.

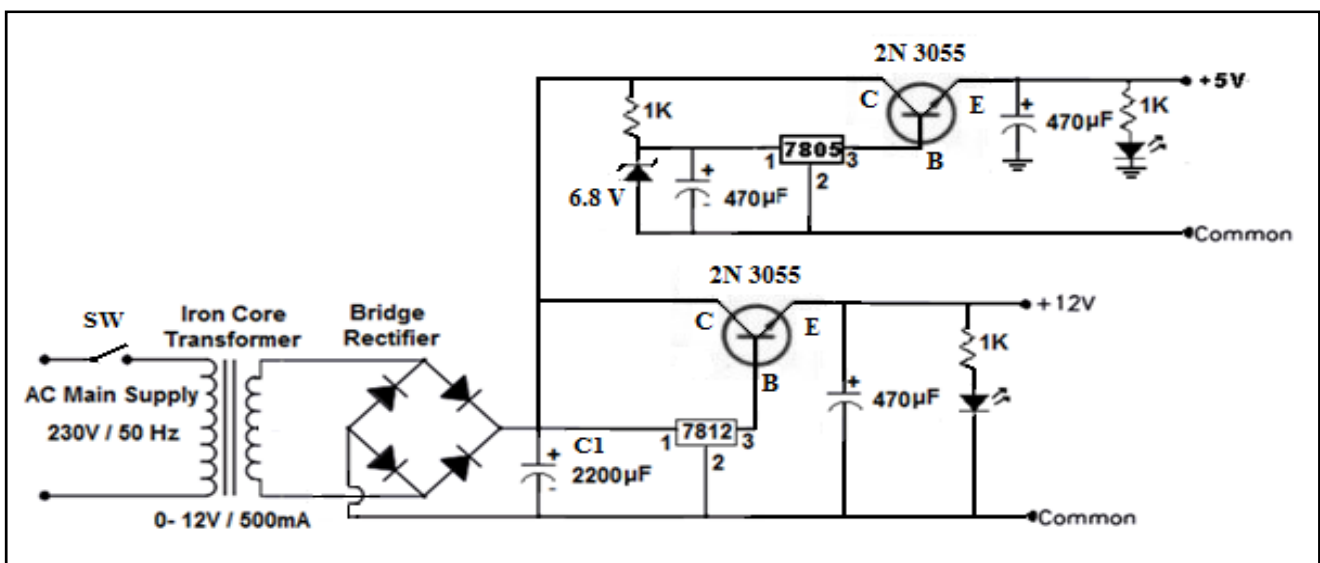


Figure 2: Power Supply Unit

3.1.2 Microprocessor 8085 with Minimum System

Here we have used microprocessor 8085 CPU with minimum system[11] which consists of IC 8255 peripheral interface, IC 8279 : Keyboard/Display Interface, RAM(6264), EPROM(2764), Address Latch, Buffer, Decoder etc. The minimum system required to interface stepper motor is as shown in Fig.3

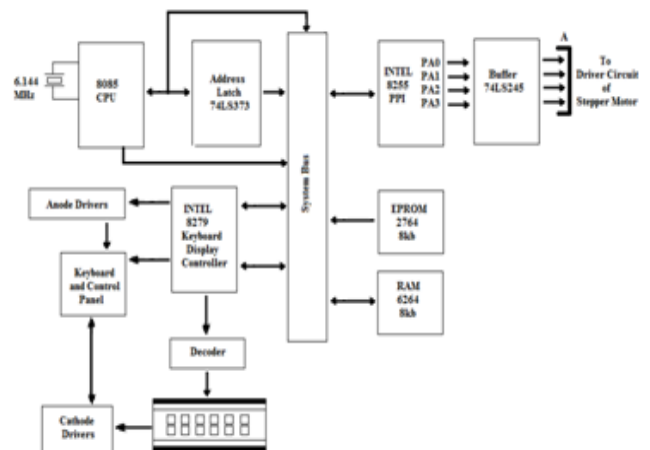


Figure 3: 8085 Minimum Systems with Peripheral Interface

3.1.3 Driver Circuit

Since Microprocessor 8085 and supporting chips does not provide sufficient current to DRIVE/RUN the stepper motor, additional driver circuit for stepper motor is developed which is shown in Fig.4. The most common and important consideration for applications of stepper motor is the use of proper and appropriate drive circuits. Driving a stepper motor requires the switching of current from one winding to another. This switching function is provided by driver circuit which arranges, distributes and amplifies pulse trains from the signal circuit. The windings of the stepper motor are excited by specific sequence.

The stepper motor has four different coils. Therefore total four driver circuits are required for motor. Two NPN transistors (SL 100 and 2N 3055) are used and configured as darlington pair [12] in design of Each driver circuit for stepper motor. The windings of the stepper motor are connected to the collector of darlington pair transistors. The transistors are switched ON/OFF by the microprocessor 8085 through the ports of 8255 (Port A) and buffer (74LS 245).

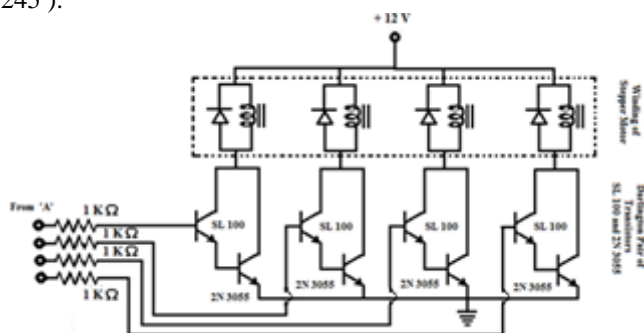


Figure 4: Driver Circuit for Stepper Motor

3.1.4 Stepper Motor

The stepper motor works on the electromagnetic principle. Its input is in the form of digital pulses and output is corresponding mechanical shaft rotation. Stepper motor has a lot more advantages like less cost brushless, simple in design, good reliability. It has very high torque even at low speeds with very good accuracy of motion. The stepper motor is actually a digital motor. This characteristic makes it very suitable for digital interfaces such as with a microprocessor. Stepper motors are relatively inexpensive as compared to other motor types. Most important is the fact that a stepper motor can actually be used without any type of feedback loop. i.e. stepper motors are ideal for open loop control.

When digital pulses are applied to the base of the transistors, it starts conducting. A magnetic field is developed around coil. So, motor starts to rotate. A freewheeling diode is connected across each coil (winding) of stepper motor. When a transistor stops conducting, magnetic field energy stored in coil is collapsed so there is a production of high reverse voltage which is absorbed by freewheeling diode.

Since the motor moves in distinct steps as defined by a steep angle, we need to count the number of steps to position the motor accordingly.

Stepper motor used here is permanent magnet type. One can determine the speed of motor using following formula.

- 1) Total number of steps in one revolution
= One full rotation (360°) / Step Angle
- 2) Total number of digital pulses in one second (PPS)
= (Required RPM / 60 seconds) X (No. of steps in one revolution)

This tells us how much number of steps is required in one second to get the required speed of stepper motor in RPM.

3.2 Furnace Set Up

The front view of furnace set up to get homogeneous growth of Compound material is as shown in Fig.5.

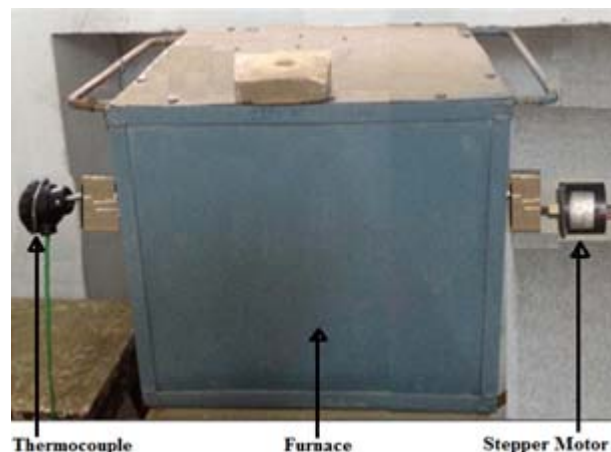


Figure 5: Front View of Furnace Set up

The furnace consists of a hollow cylindrical region of 6 cm diameter and 20 cm length. The desired temperature is maintained constant over a length of about 7 cm on either side from the center of this region using Temperature Controller. Co-axially to this region passes a quartz tube of length 23 cm having inner diameter 3 cm and is firmly held at the ends with the help of couplers capable of rotating freely which is operated by a stepper motor so as to provide uniform and constant rotation to the tube. The vacuum sealed quartz ampoule filled with high purity (99.999%) individual elements (Ag - 24.92%, Ga - 16.11%, Te - 59.05%) in stoichiometric proportions. Each material is having different melting point. The length of the ampoule was about 16 cm which is placed in the other quartz tube. On both ends of the ampoule, porcelain beads are kept throughout the tube so that the ampoule remains in the constant temperature zone of the furnace. Fig. 6 shows complete inside view of the furnace with quartz tube and vacuum sealed ampoule.

The charge was heated to a temperature above the melting point of compound material by gradually increasing the temperature of the furnace using temperature controller. Then stepper motor is operated by sending the commands from microprocessor. Thus, the ampoule is rotated slowly and uniformly in the constant temperature zone of the furnace by rotating the quartz tube throughout the melting operation in order to ensure complete mixing and reaction of the individual constituents.

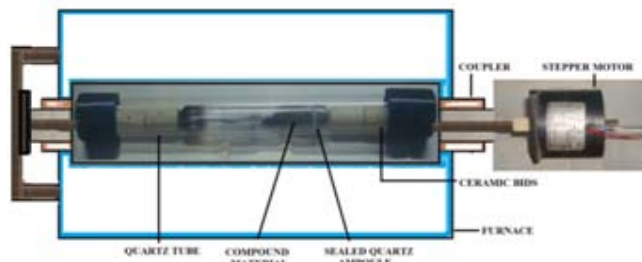


Figure 6: Inside View of Furnace

The charge was held at the high temperature for 24 hours before being slowly cooled to room temperature. Due to gradients in the furnace, nucleation occurred at the ends of the tube. The ingot thus obtained by breaking the ampoule was converted to fine powder by grinding in a small agate mortar. This powder form of the compound is further used for fabrication of Thick and thin films which is further used for x- ray diffraction study and EDAX analysis because Synthesis is an important part of any work.

4. Results and Discussion

The flow chart for operational flow of the stepper motor control system is shown in Fig.7. The processor outputs a switching sequence and waits for few milliseconds (5 to 50ms) before sending next switching sequence. This delay time is required to allow the transients of the motor to die-out.

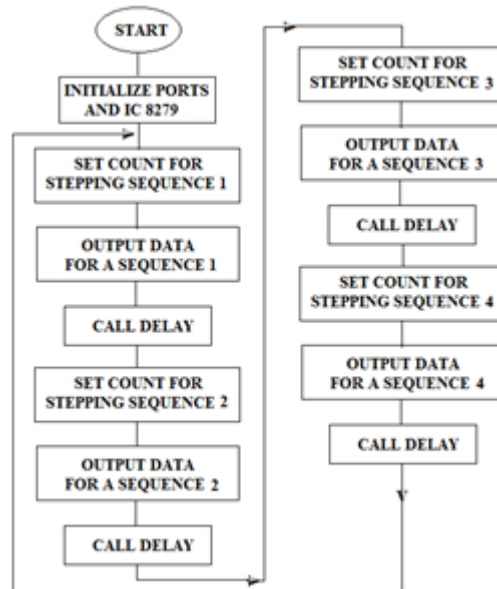


Figure 7: Flow Chart of Stepper Motor Control

The switching sequence of microprocessor based programmable control system for stepper motor is as shown in Table 1. The Stepper Motor winding connection is as shown in Table 2.

Table 1: Switching sequence for full step rotation

Switching Sequence	Clockwise Rotation				HEX DATA	Anticlockwise Rotation				HEX DATA
	PA3	PA2	PA1	PA0		PA3	PA2	PA1	PA0	
First Sequence	0	1	0	1	05 H	0	1	1	0	06H
Second Sequence	1	0	0	1	09H	1	0	1	0	0AH
Third Sequence	1	0	1	0	0AH	1	0	0	1	09H
Fourth Sequence	0	1	1	0	06H	0	1	0	1	05H

Table 2: Stepper Motor winding connection with Port A of 8255

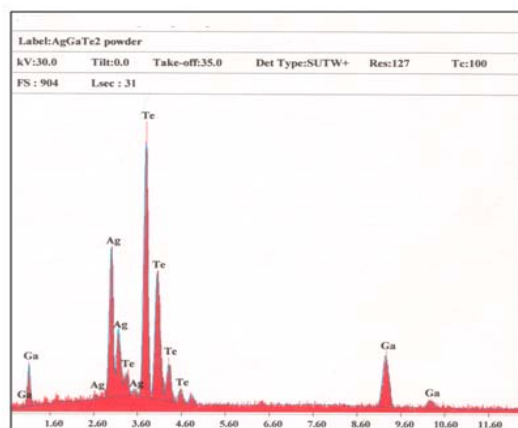
PORT A	PA0	PA1	PA2	PA3
Stepper Motor Winding Colour Code	Red	Yellow	Violet	Green

The Grown compound semiconducting material is as shown in Fig.8. We obtained a fine ingot of the compound material.



Figure 8: Ingot of compound semiconductor material

Fig.9 shows the EDAX analysis of the grown compound (Bulk) and related stoichiometric proportions of individual constituents.



EDAX Analysis of the bulk AgGaTe₂

EDAX ZAF Quantification

Element	Wt %	At %	K-Ratio	Z	A	F
AgL	25.02	25.02	0.2244	1.0325	0.8470	1.0256
TeL	58.50	49.46	0.4547	0.9626	0.8076	1.0000
GaK	16.4	25.51	0.1611	1.0748	0.9092	1.0000

Figure 9: EDAX analysis of the grown compound

5. Conclusions

A microprocessor based Stepper motor control instrumentation and related circuits for homogeneous mixing and growth of compound semiconducting materials was designed, developed and tested successfully. Proper mixing of the melt produced Bulk compound having very good degree of stoichiometry and homogeneity. The EDAX analysis and related stoichiometric proportions of individual's constituents was in good agreement with the original proportion taken into the ampoule.

References

- [1] Patel S.S, Patel B.H, Patel T.S, Crys.Res.Technol, 43, No.5, pp. 542-547 (2008).
- [2] Patel B.H, Patel P.G, Patel S.S, "Semiconductor Devices" Edited by Krishanlal, Narosa Publishing House, pp.412, 1995.
- [3] Patel B.H, Patel S.S. "Journal of Pure and Applied Sciences" Pragna, 12, 2003.
- [4] Vadhar P., Kyo T., Polym. Eng. Scie., 27 pp. 202, 1987.
- [5] Gedde U.W., Jansson J.F., Polymer Sci. 26, pp. 1469, 1985.
- [6] Patel Shahera S., Patil D.R., Brahmabhatt B.H., International Journal of Research in Engineering and Technology, Vol.3, Special Issue 03, pp.187-192, 2014.
- [7] Mazidi M.A., Mazidi J.G. and McKinlay, "The 8051 Microcontroller and Embedded System", Prentice Hall India, 2006.
- [8] Singh Hausila and Sharma Sudhansu, IEEE Transaction and Industrial Electronics, 38(4), pp.283-287, 1991.
- [9] Sekman Ali, Koku Ahmet Burga and Sabatto saleh Zein, IEEE International Conference on Systems, Man and Cybernetics, 4, pp.3937-3942, 2003
- [10] www.ti.com
- [11] Gaonkar R.S. "Microprocessor Architecture, Programming and Applications with the 8085", Prentice Hall PTR, 2002.
- [12] www.kitronik.co.uk

Author Profile



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