INTEGRATED RESISTORS ON POLYCRYSTALLINE SILICON

A THESIS

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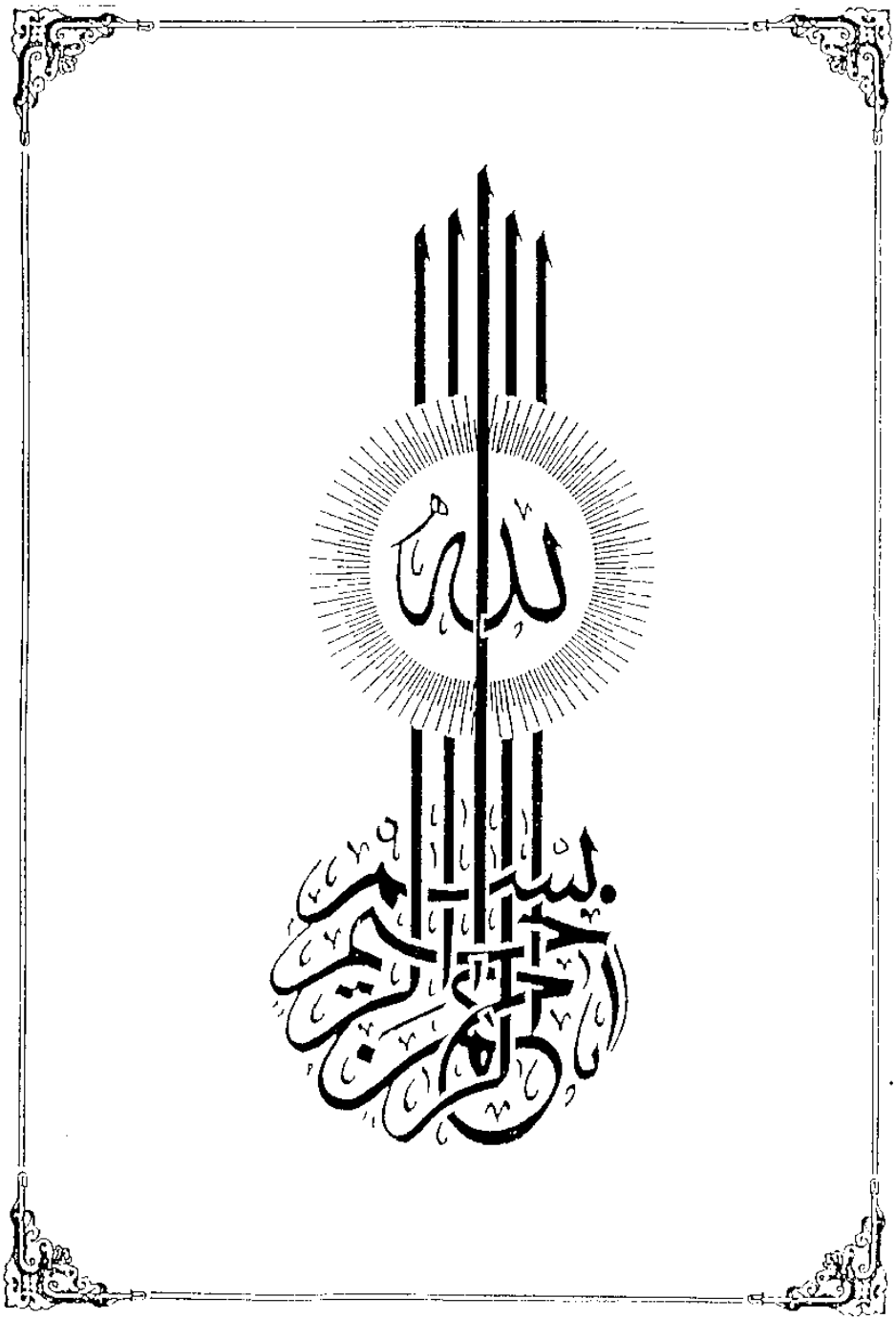

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ABSTRACT

Polycrystalline silicon films has recently many important applications in integrated circuit technology. Films with high resistivity and small dimensions, therefore, have been widely employed as resistors in both BJT and MOS technologies and promise to be one of the most significant elements in the coming era of VLSI.

This research investigates polycrystalline silicon technologies, properties, conduction models, and applications in integrated resistores.

The different deposition methods of polycrystalline silicon are discussed and the optimal method is introduced with a suggested LPCVD reactor. Both physical and electrical properties of polycrystalline silicon films are reviewed.

The different electronic conduction models are discussed in detail to select the suitable conduction model with the available polycrystalline silicon wafers in IC'S laboratory at Ain Shams University. The large grain model is applied in this work.

The different methods for measuring the sheet resistance are introduced and discussed. The concepts and processing parameters for polycrystalline silicon resistors are given.

The technology processes for sheet resistance patterns and integrated resistors are carried out on both single

crystal and polycrystalline silicon wafers in IC's laboratory at Ain Shams University by using the masks which we have designed and fabricated.

Finally, the results of measurements are interpreted, and based on the comparison between sheet resistance measuring methods, the more accurate methods for single and polycrystalline silicon are introduced. The important parameters of single and polycrystalline silicon integrated resistors are measured and interpreted.

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CHAPTER I

POLYCRYSTALLINE SILICON TECHNOLOGIES AND PROPERTIES

I.1. Introduction

For many years, epitaxial layers of silicon have been grown on single crystal silicon substrates by chemical vapour deposition. The deposition temperature for single crystal growth ranges between 1000° to 1300°C for the silane (SiH_4) or silicon tetrachloride ($SiCl_4$) processes. If the deposition temperature is lowered, or if the silicon substrate is amorphous instead of being single crystal, the resulting deposit of silicon is polycrystalline rather than single crystal.

Two types of chemical vapour deposition (CVD) reactors are used for deposition of polycrystalline silicon (polysilicon) films. The atmospheric pressure reactors (APCVD), and the low pressure reactors (LPCVD).

Polysilicon has been introduced in many important applications in integrated circuit technology. During the last decade, heavily doped polysilicon films have been used as interconnection lines and as gate electrodes in silicon-gate MOS integrated circuits. Lightly-doped films, on the other hand, have been used in the fabrication of high-voltage planar devices and high-value resistors in static memory circuits. Other applications include low-cost solar cells, source for dopant diffusion, and dielectric isolation between active devices [*].

Because of these various applications, a thorough understanding of the physical properties of polysilicon films is

essential. In the following, the different technological methods for depositing polysilicon films will be presented. Also, the structural and electrical properties of these films will be discussed in detail.

I.2. Chemical Vapour Deposition (CVD)

Polysilicon films are generally prepared by either vacuum evaporation of silicon on heated substrates [2,3] or chemical vapour deposition [4,5,7,10-18].

Silicon tetrachloride ($SiCl_4$), trichlorosilane ($SiHCl_3$), dichlorosilane (SiH_2Cl_2) and silane (SiH_4) are widely used as silicon sources for silicon film deposition in semiconductor industry. Equilibrium reaction efficiency (i.e. percentage of silicon from a chlorosilane that deposits as solid silicon) depends on the reactant concentration, temperature and pressure [5]. Due to higher costs of SiH_4 and SiH_2Cl_2, $SiHCl_3$ and $SiCl_4$ are preferred for low cost deposition processes. However more recent applications favor the use of silane (SiH_4) or dichlorosilane (SiH_2Cl_2) because of their lower reaction temperatures and better nucleation. Fig. 1.1 shows the normalized deposition rates from the three gases as functions of reciprocal temperature in hydrogen carrier gas [4].

Most polysilicon films are deposited in hydrogen or nitrogen as carrier gases. Other inert gases have been used with silane, especially at the lower temperatures. The deposition system generally operates with a continuous flow of gas over the wafer surface. The silicon-containing gas comprises