SOME PROPERTIES OF LOW PRESSURE DISCHARGE IN Ar-SiH_4 ATMOSPHERE

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Compounds : Silane, Mixture Silane + Argon

ABSTRACT

The electric field, the electron energy and the neutral gas temperature in the discharge plasma in pure silane and in its mixtures with argon were investigated. The measurements show typical character of the molecular electronegative discharge plasma.

1. INTRODUCTION

During the past several years there has been a rapidly growing interest in monosilane SiH_4 namely as a material for the fabrication of amorphous silicon (a-Si) and its applications in the semiconductor industry /1-3/. The monosilane is unstable at higher temperature. It decomposes at 420° C in silicon and hydrogen

$$SiH_4 \xrightarrow{420^\circ C} SiH_2 + H_2$$

$$SiH_2 \rightleftarrows Si + H_2$$

This property is used in Chemical Vapor Deposition to produce a-Si. With the development of the plasma chemistry it was found that the monosilane can be decomposed at ambient temperature in the electric discharge using the energy content of the discharge plasma namely the energy of the electrons /4,5/. It is highly probable that the properties of the deposed a-Si depend on the parameters of the plasma namely on the density n_e and the energy T_e of electrons, on the gas temperature T_g and on the composition of the discharge atmosphere, on the electric field E etc. Unfortunately these dependences were not studied till now. The aim of this study is the investigation of some plasma parameters in pure silane and in argon-silane mixtures.

2. EXPERIMENTAL

The semiconductor industry requires a highly pure and well defined a-Si. To produce this a-Si it is necessary to have a pure discharge atmosphere, a reproducible procedure and well defined conditions. Unfortunately this demand was often underestimated. The discharge vessel is often evacuated by means of a rotary pump only and no wonder that the properties of the deposed a-Si are influenced by remaining oxygen /5/. In our experiment great precaution was taken in the purity of the discharge atmosphere. A vacuum of 10^{-6} torr was obtained in the discharge tube by means of a rotary pump in series with a turbomolecular pump. The limit pressure was measured by means of a ionization gauge. The apparatus was evacuated and for some hours heated in order to outgas the tube walls, the electrodes and the probes. After leaving the tank the pure silane passed through a low-pressure regulator, through a flow-meter to a needle valve and entered the discharge tube. The silane pressure was measured by means of a Mc Leod gauge in series with a dry-ice-trap avoiding the contamination of the discharge atmosphere with mercury vapor. The gas leaving the rotary pump was mixed with nitrogen to avoid its selfcombustion. The glow discharge was produced in a Pyrex tube 70 mm in diameter and 600 mm long between two stainless steel electrodes, the cathode was especialy arranged, cooled and covered partially with a quartz screen. A Cr-Al thermocouple and two W wires probes were placed in the discharge tube to measure T_g, E, T_e and n_e.

3. MEASUREMENTS AND DISCUSSION

Our measurements were realised in pure silane and in mixtures argon - silane between 0.5 - 2 torr, and for discharge currents in range 5 - 50 mA. The results of our measurements are presented in Figs. 1 - 3.

a) Electric field

In the steady column the electric field must have such a value that the number of electrons produced per sec. just balances the loss of charges. In atomic gases, i.e. pure argon ionization occurs only by collisions between fast electrons and atoms and the loss is due to ambipolar diffusion to the walls, where the electrons recombine with the positive ions. In electronegative gases like silane many electron loss volume processes occur :

the dissociative attachment

$$e + MN \rightarrow M + N^-$$

the attachment

$$e + MN + P \rightarrow MN^- + P \qquad \text{etc.}$$

A part of the negative ions recombine with the positive ions. Therefore the electric field in electronegative gases is much higher than in atomic gases. Fig. 1 shows how the reduced electric field E/p depends on the pressure p in different mixtures Ar + SiH_4. The curve a) is pure argon, b) 70 % Ar and 30 % SiH_4, c) 40% Ar and 60% SiH_4. As seen with increasing concentration of silane the value of E/p increases.

The occurence of negative ions in the discharge influences also the ambipolar diffusion and the radial structure of the positive column, especially at higher pressure. This is shown from the shape of the striations which occur in the electric discharge. The occurence of different kinds

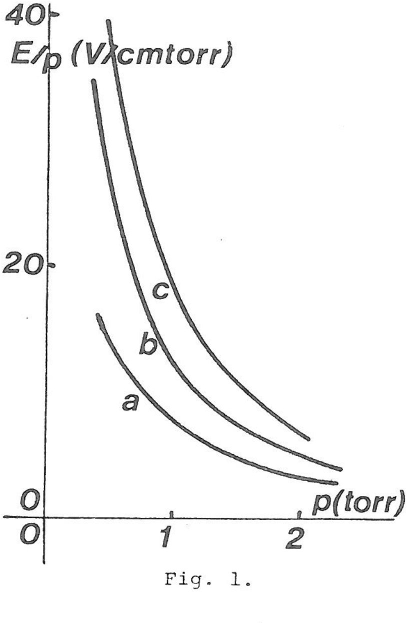

Fig. 1.

of particles neutrals,positives as well as negatives was confirmed with mass spectrometry. This investigation will be reported elsewhere.

b) Electron temperature

The electron temperature T_e, i.e. the mean electron energy depends on the electric field, on the pressure, on the nature of the gas and on the geometry of the discharge tube namely on its radius R. T_e increases with the increasing E and decreases with the pressure because of the increasing collision frequency and energy loss during the collisions namely during the inelastic collisions. T_e is much lower in molecular gases because of these numerous inelastic collisions. Fig. 2 shows how the T_e depends on the pressure p in different mixtures of $Ar+SiH_4$. As seen T_e diminishes with the increasing pressure and with the increasing percentage of the molecular component in the mixture,i.e. of the silane.

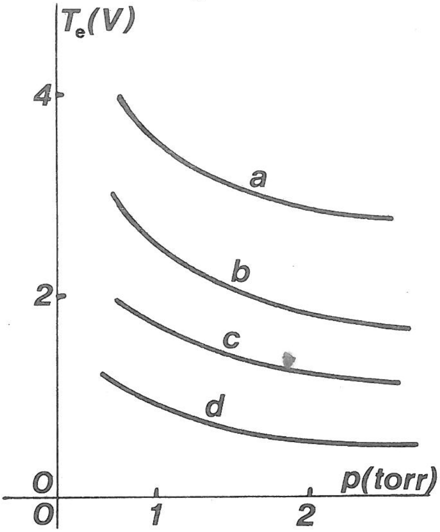

Fig. 2. The curve d) concerns pure silane.

c) Neutral gas temperature

The discharge atmosphere is heated by the elastic collisions of the electrons with the neutral particles. With the increasing collision frequency the gas temperature increases. Because of higher potential gradient in molecular gases the gas temperature is higher in molecular gases as in atomic gases. It is necessary to note also that in the molecular gases and namely in electronegative gases a supplementary source of heating occurs, i.e. the volume recombination processes.

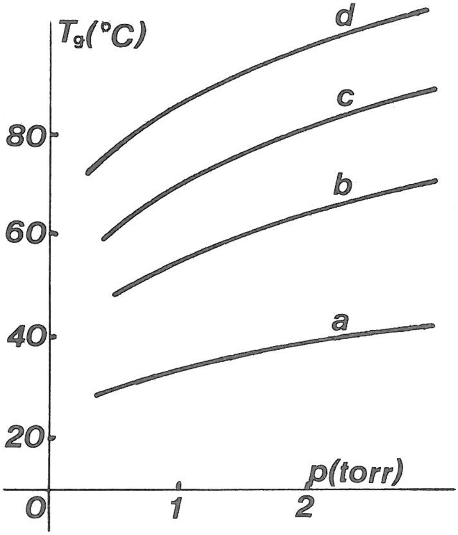

Fig.3. The curve d) concerns pure silane.

Fig. 3 shows the dependence of T_g versus the pressure, for different mixtures of Ar+SiH_4. T_g increases with increasing pressure and increases with increasing percentage of the silane in the mixture.

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