

A MULTIPOLE DC DISCHARGE FOR THIN FILM DEPOSITION
FROM SILANE PLASMA

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ABSTRACT

A low pressure Silane discharge initiated by thermoionic electron emitted by a hot filament and confined by a magnetic multipolar wall is studied in term of density, electron energy distribution and ion content.

1 - INTRODUCTION

Silane glow discharges either RF or Dc positive column have been widely ^{used} to provide amorphous silicon thin films (1,2,3), with a very poor plasma characterisation. Turban et al (4) have characterised a RF discharge. We present some results obtained in a so-called multipole plasma (5,6) which allows a range of parameters not accessible in self-sustained discharges. The diagnostics are presently electron density and energy distribution measurements and ion mass spectrometry. In the near future free radical mass analysis and optical spectroscopy will be added. This last technic has proven to allow gas rotational temperature measurement (7).

2 - DESCRIPTION OF THE APPARATUS

The 32 cm ferrite magnet bars are distributed with alternate polarity around a 22 cm diam cylindrical copper grid. As shown in fig.1, the plasma volume is closed by a temperature controlled substrat holder and symetrically a plate where a 0,1 mm diam hole allows ion extraction. In this volume two tungsten filaments, 8 cm long and . 3 mm diam, are heated by a 7 to 10 A direct current and polarized from -25 to -60V with respect to the walls. The movable Langmuir probe is made of a loop of 0,1 mm diam tungsten wire. In order to prevent probe pollution the wire is heated by a 10 Kc pulse train, the heating is stopped regularly during 5 ms to allow current sampling of the probe. The pure SiH₄ gas is fed through a piezzo valve regulated by feed back from a membrane manometer.

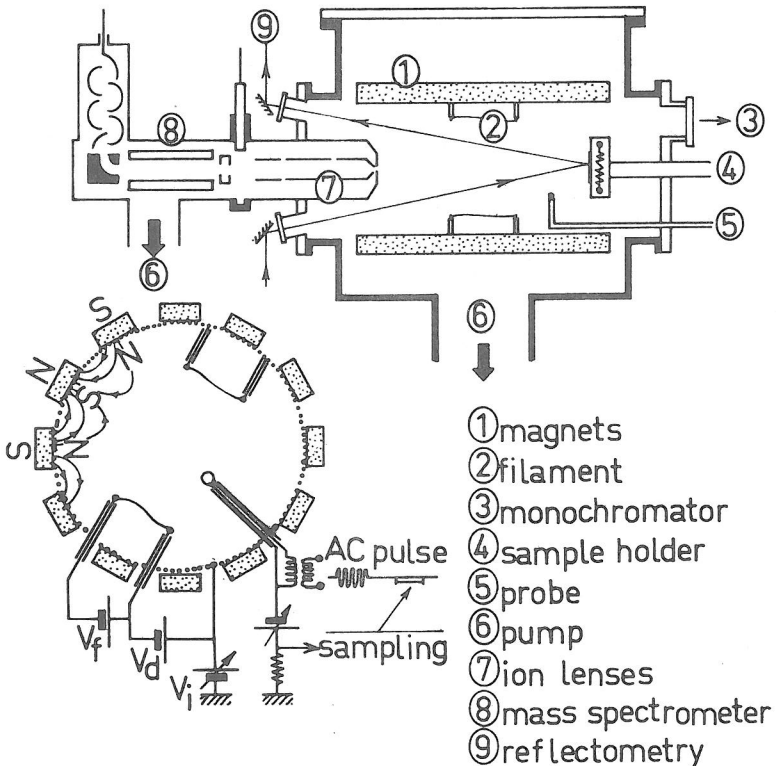


Figure 1 - Experimental set up. Typical figures for the voltages are $V_f = 10V$, $V_d = -60V$, $V_i = + 15V$

3 - EXPERIMENTAL RESULTS

As shown in figure 2 for given discharge electric parameters the plasma density is proportional to the pressure in the range of 0,1 to 10 mTorr, this refers to the total pressure (no measurement of the respective weight of SiH_4 , H_2 and possibly Si_2H_6 was made). The electron distribution function is typical of multipole discharges (8) with a primary electron hot tail and a bulk electron lower temperature. The bulk temperature decreases for increasing pressure and in weak discharges it can go below the definition limit of the probe (0,05 eV) somehow near room temperature. This is due to the cooling effect of inelasting collisions between ion and mole-

cules in vibrational and rotational energy range

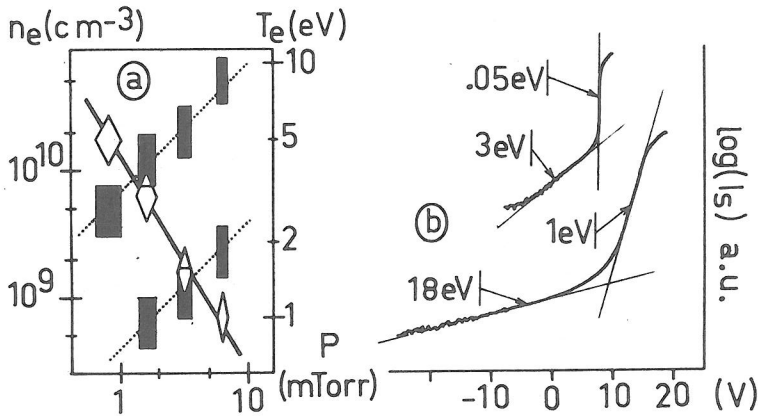


Figure 2a - Density variations (black boxes) as function of gas pressure ; the upper and the lower traces are for a 60V discharge with 0,5A et 15mA respectively. The diamonds give the bulk electron temperature for the condition corresponding to the upper trace. **Figure 2b** gives two examples of probe characteristics, the upper trace for a 40V, 15mA, 3,2 mTorr discharge and the lower trace for a 60V, 0,5A, 6,4 mTorr discharge.

The ion mass spectrum shows a majority ion for mass 31 corresponding mostly to the ion SiH_3^+ is observed (the masses 32 and 33 correspond to the isotopes Si 29 and Si 30). The relative abundance of these ions depends on the discharge conditions. For example $\text{H}(30)/\text{H}(31)$ corresponding essentially to $n(\text{SiH}_2^+)/n(\text{SiH}_3^+)$ decreases as the inverse of the pressure (figure 3). At very low pressure it is of the order of 1,3 as observed in mass spectrometry (9), then in the mTorr range it decreases due to the reaction (10)



Simultaneously other reactions take place leading to the formation of heavier ions (figure 3b). This ionic polymerisation is of great interest because it is related to the gas polymerisation observed at large pressure in many amorphous silicon synthesis experiments (4).

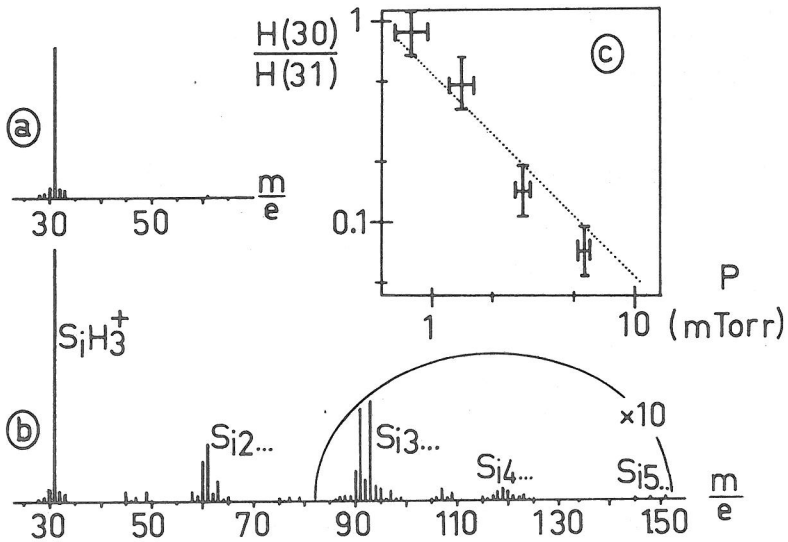


Figure 3a and b shows the ion mass spectrum in a 6,4 mTorr Silane plasma for a 60V, 0,5A and 15 mA discharge respectively. Figure 3c - Variations of the relative intensity of mass 30 (SiH_2^+) and 31 (SiH_3^+) as a function of pressure in a 60V, 0,5A discharge.

The beginning of ionic polymerisation is observed at pressure as low as 1 mTorr [$n(\text{Si}_2\text{H}_n^+)/n(\text{SiH}_3^+) \sim 0,1$] and this for very weak discharges. This may be attributed to secondary reactions of ions monomers with silane (11).

However for strong discharges (0,5A) the ionic polymerisation turns out to be comparatively poor (figure 3a), this for two reasons, i) the SiH_4 partial pressure is lower, ii) the chain ions are probably instable at the high gas rotational-vibrational temperature induced by the strong discharge.

We shall complete these informations by other diagnostics.

We anticipate that these informations connected with the knowledge of cross sections available in the litterature (12) will allow a comprehensive description of the Silane plasma.

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