PLASMA POLYMERIZATION : AN ALTERNATIVE FOR DIELECTRIC FILMS ON COMPOUND SEMICONDUCTORS

Y. SEGUI
Laboratoire de Génie Electrique, associé au CNRS - Université P. Sabatier
118 Route de Narbonne, 31062 Toulouse Cédex France

ABSTRACT

An interesting alternative using the plasma polymerization technique to depose a polymer film at the surface of Gallium Arsenide is presented. The polymerization process is briefly described and the results of the electrical properties of the interface Polymer-GaAs is reported. We discuss then, their changes with time under various condition of applied field. These results are compared to those obtained with more conventional materials.

1. INTRODUCTION

The deposition of dielectric films on III-V semiconductors has been a quite active area for the last few years ; however no definitive solution has been yet proposed, especially on GaAs which is so far the most largely used.

GaAs presents the peculiarity to have surface states lying in the conduction and valance band when the dangling bonds are unsaturated, but moving in the gap immediately after saturation by oxvgen for example (1). That is why most of the results obtained with native oxydes are not so good. Moreover, the decomposition of GaAs can occur when T goes up above 500°C, so a "cold technology" has to be found for the deposition of the dielectric film.

Plasma polymerization is now a well know technique (2-5) very useful to depose thin films of polymers, with good electrical properties and free of pin holes. In this paper, we will report some properties of structures Metal-Polymer-GaAs in order to know if a polymer could be a good candidate to be used as a passivating layer for GaAs.

2. RESULTS AND DISCUSSION

A schematic of plasma deposition system is shown on figure 1. Standards condition for the glow discharge were :

Voltage : 500 Vrms
Current : less than 1 ma rms
Frequency :1 to 10 kHz
Distance between electrodes : 0,5 to 3 cm
Partial pressure of the monomer : 0.1 to 1 Torr
Substrate temperature : 22°C

A detailed analysis of the polymerization mechanisms has been carried out in a previous work (6), (7). The figure 2 shows the variation of the thickness of the polymer film, grew up on a GaAs substrate, as a function of the duration of the discharge. Conversely, it is possible, using a high power discharge in $CF_4 + O_2$, to etch the polymer film. Previous work shown that the definition of the etching can be better than 1 μm (8).

The electrical properties of the interface between Polysiloxane and GaAs were controlled by the capacitance -Voltage curve. The theory of C(V) measurements is well known and more informations can be obtained in ref (9) or (10) for instance. Two important parameters can be calculated by comparing the experimental and theoretical characteristics : Q_T the total charge at the interface and Nss, the density of surface states.

The figure 3 shows an experimental curve obtained when the GaAs has been previously cleaned as suggested in (16). In that case Q_T and Nss were respectively 5×10^{11} cm^{-2} and 5×10^{11} cm^{-2} eV^{-1}. In this curve an anticlockwise hysterisis effect is observed indicating an ionic motion through the polymer film.

In order to emphasize the effect of the ionic motion, the shift of the C(V) characteristic with time when a d.c field is applied to the sample was recorded.

Fig 4 (a) shows the shift of the characteristic, for 10^8 V/m and 3 temperatures. No drastic change was observed. When the field is increased up to 2×10^8 V/m, no visible shift if the thickness of the polymer film is lower than 1 300 Å . For thicker films, large shifts with a time constant of the order of 1 hour were observed (fig. 4b). The direction of the shift, $\Delta V > 0$ when the field is negative, is explained by a motion of internal charges of the polymer and the value of the time constant suggest that these charges are ions. In the case shown in figure 4b the value of the shift of the C(V) curve lead to a change in Q_T equal to 3×10^{12} ch/cm^2.

A comparison between polysiloxane films and others dielectrics on GaAs substrate is given on table 1. From this table, it can be seen that the quality of this polymer film for passivation is comparable to those of inorganic films. Moreover plasma polymerized films have additional advantages for example :

- high resistance to irradiation (X or γ.)
- no problem in adhesion due to dilatation coefficient
- a good coating without any cracks, even if angular points are present
- no annealing is required to obtained the values reported in this paper

If the problem due to the presence of ions is solved or reduced it sems that plasma polymerized films are a good candidate for the passivation of III-V semiconductors.

REFERENCES

(1) W.E. Spicer, I. lindau, P. Pianetta, P. W. Chye and C. M. Garner "Thin Solid Films 56 (1971) 1"

(2) F. K. Mc Taggart "Plasma chemistry in Electrical discharges" P. L Robinson ed, Elsevier, Amsterdam (1979)

(3) J. R. Holahan and A. T. Bell "Techniques and applications of plasma chemistry, J. Wiley ed New York (1976)

(4) H. Carchano J. of Chem. Phys 61 36 34 (1974)

(5) A. R. Westwood, Eur. polym. J. 7 363 (1971)
and 7 377 (1971)

(6) Y. Segui and A. Bui, J. of Appl Polym Sci. 20, 1611 (1976)

(7) Y. Segui, Thesis Doct. ès Sci. Phys. Toulouse 1978

(8) M. Aktik, Y. Segui and A. Bui J. Appl. Phys. 50, 6567 (1979)

(9) A. S. Grove,Physics and Technology of Semiconductors devices J. Wiley, N. Y 1969

(10) A. Goetzberger, The Bell Syst. Techn. Journ. 45, 1097 (1966)

(11) R. P. H. Chang and A. K. Sinha, Appl. Phys. Lett 29,56 (1976)

(12) H. Hasegawa, K. E Forward and H. L Hartnagel Appl. Phys. Lett 26,567 (1975)

(13) W. Kern and J.P White RCA Rev. 12,771 (1970)

(14) J. E Foster and J. M Swartz : J. of Electrochem. Soc 117,1410 (1970)

(15) T. Hariu, T. Usuba, H. Adachi and Y. Shibata : Appl. Phys Lett 32, 252 (1978)

(16) T. Ito and Y. Sakaï Sol St Elect. 17,751 (1974)

Dielectric	Growth rate	Qt (cm^{-2})	Nss $cm^{-2} eV^{-1}$
Plasma oxydation (11)	3 500 A° for 10mn	2. 2. 10^{11}	
Anodic oxydation (12)	7 500 A° for 10 to 20 mn		1. 2 x 10^{11}
$Si\ O_2$ (13)	270 A°/mn		1 x 10^{11}
$Si_3\ N_4$ (14)			10^{12} to 10^{11}
Reactive Sputtering of GaN (15)	150 A°/mn		7. 6 x 10^{11}
Siloxane films (this work)	1 000 A°/mn	5 x 10^{11} to 10^{12}	5 x 10^{11}

Table 1 : Comparative results for dielectrics on GaAs

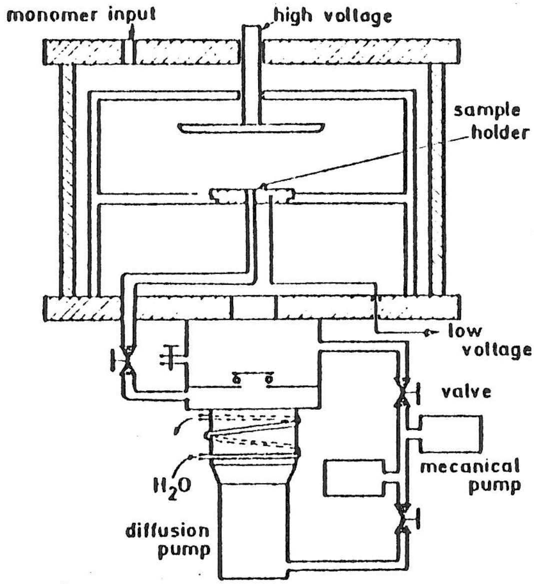

Fig. 1. Experimental apparatus for deposition of thin films.

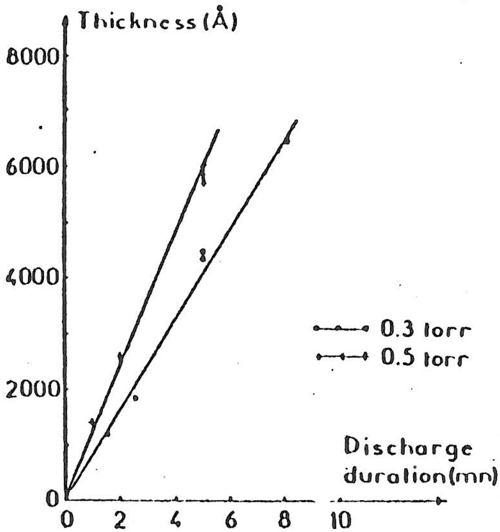

FIG 2 . Growth of plasma-polymerized siloxane on GaAs substrate for two pressures of monomer gas, 0.3 and 0.5 Torr. Discharge conditions: $j = 0.17$ mA rms/cm², $V = 340$ V rms, $f = 2$ kHz.

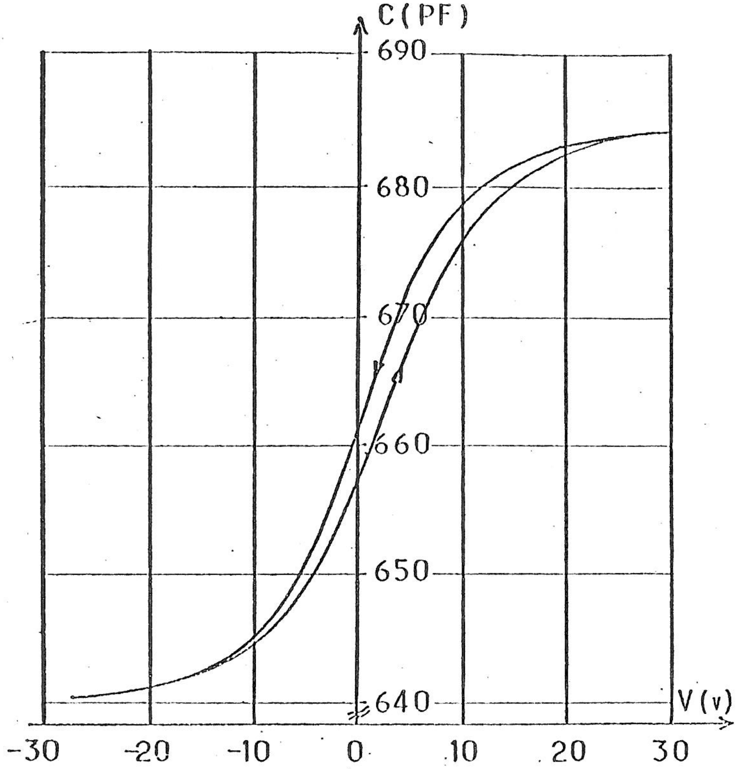

FIGURE 3 : A typical Capacitance-Voltage curve of a M. Polymer- GaAs structure; f= 10 kHz, $N_D = 6.9 \times 10^{17}$ cm^{-3}, Polymer thickness: 1020 Å, sweep rate 0,5V/s.

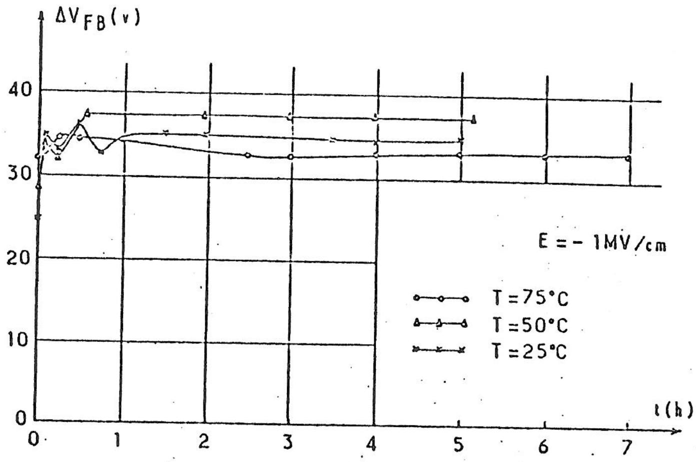

Figure 4(a): Shift of a C(V) curve of a M-Polymer - GaAs structure when a d.c. field of 1 MV/cm is applied.

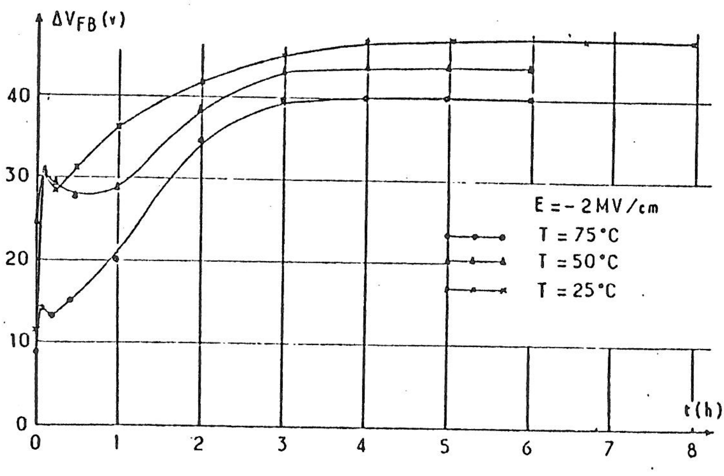

Figure 4(b): Shift of a C(V) curve of a M-Polymer)GaAs structure when a d.c. field of 2 MV/cm is applied.