Semiconductor Damage from Inert and Molecular Gas Plasmas

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The change in sheet conductivity of a thin, highly-doped layer of GaAs is measured after exposure to inert gas plasmas (He, Ar, and Xe) and to molecular gas plasmas (CCl_2F_2, CF_4, SF_6, and O_2) in a parallel-plate rf discharge. In order to compare these data, the change in sheet conductivity is converted to a damage depth scale. A different linear relationship is found for the damage dependence on the rf-induced dc bias for each plasma. An inverse-mass relationship is derived from the data for He, Ar, and Xe plasma exposures. Using this, two models are tested for their ability to predict the damage from the molecular gas plasmas. Only the lightest ion(s) present in the molecular gas plasmas appear to cause the measured damage effect. In mixtures of inert and molecular gas plasmas, the inert ions were not always observed. Such data lead to a general conclusion that ions with high ionization potentials will be quenched in plasmas that also contain gases with low ionization potentials.

1 Introduction

Changes that occur to materials exposed to semiconductor processing plasmas are usually referred to as "plasma damage." The manifestation of damage depends on the species present in the plasma, on the properties of the material that is exposed to the plasma and often on the role the material plays in the operation of an electronic device or circuit. In the fabrication of compound semiconductor devices such as MESFETs, MODFETs and HBTs, the most important form of plasma damage is loss of carriers in active device regions. This is particularly true when plasma etching is used to recess the gate in field effect transistors because the gate channel itself is directly exposed to a plasma environment. Comparable processes in silicon device fabrication are those where a selective etch stops at the silicon surface in a region where the doping of the silicon is important. In practice, silicide formation is usually the next step and this consumes the layer of silicon that is damaged by plasma exposure.

In this work, we measure loss of carriers in Si-doped GaAs by exposure to a variety of processing plasmas. For these plasmas, it is thought that ions are responsible for loss of carriers in n-type GaAs.[1-5] The goal of this work is to identify which ions are responsible for the measured damage effect.

In this endeavor, it is useful to divide processing plasmas into three categories: (i) those containing hydrogen, (ii) inert gas plasmas, and (iii) molecular gas plasmas. Carrier loss from exposure of GaAs, silicon and InP to plasmas containing hydrogen has been studied by many laboratories and the damage shows certain characteristics which will be described shortly. Damage to GaAs and silicon from inert gas plasmas and inert gas ion beams has a different set of characteristics that correlate well with ion mass. Carrier loss from molecular gas plasmas has also been observed; interpretation of these results is complicated because it is difficult to determine which ions are present in molecular gas plasmas and how they contribute to the damage.

The effect of hydrogen plasmas on GaAs, InP and silicon is dopant deactivation, whether the hydrogen is from H_2, H_2O, C_xH_y, or CHF_x species.[6-12] The particulars, however, vary by dopant.[13] The consensus from these studies is that hydrogen forms a complex associated with dopant atoms and the complex can be broken up by moderate annealing which restores the activity of the dopant. Hydrogen is found at depths that are more than an order of magnitude deeper than is calculated by LSS theory[6] using the plasma dc bias voltage as an estimate of the hydrogen ion energy. The behavior of hydrogen is diffusive and lattice damage is not thought to be involved in the dopant deactivation effect.[13]

Inert gases are often added to GaAs and silicon processing plasmas. Ion beams and plasmas of He, Ne, Ar and Xe have been used to study the effects of ion mass on semiconductor damage. The general conclusion from work on GaAs involving Schottky barrier diodes,[14] van der Pauw measurements,[3] Rutherford backscattering measurements,[15] and cathodoluminescence intensity,[1,5] is that carrier loss is proportional to the inverse of the ion mass. Similar studies on silicon by Rutherford backscattering[16] and Schottky barrier diode evaluation[17] also indicate an inverse-mass dependence. As well, these studies show that this type of damage increases with plasma dc bias or ion beam accelerating voltage. The inverse-mass dependence indicates that the damage does not fit a model based on mass-matching like the model used to predict sputtering yield.[18] The most damage is caused by the lightest ions impinging on silicon, which has a mass of 28, and on GaAs, composed of masses 70 and 75. However, as is the case for damage caused by hydrogen-containing plasmas, the depth of damage for the inert gases is on the order of ten times greater than is calculated by LSS techniques.[4,5,19] In contrast to the damage caused by hydrogen, annealing of damage from inert ions is often incomplete, especially for He, the lightest ion.[5]

Carrier loss has been observed after exposure of semiconductors to a wide variety of molecular gas plasmas that often include an inert gas. Although measurements from different reactors using different parameters are often difficult to compare, some trends are evident. Hydrogen dominates in mixed gas plasmas, as expected, if one of the gases contains hydrogen. For example, in a study of silicon oxide etching on GaAs,[11] which is nearly infinitely selective, carrier loss in GaAs after exposure to a plasma containing CHF_3, C_2F_6, and He was ascribed to the hydrogen in CHF_3. For silicon etching in SF_6,[17] addition of H_2, as compared to addition of He, N_2, O_2, or Ar, caused the greatest electrical degradation but was the easiest to anneal. In molecular gas plasmas without hydrogen, carrier loss in n-type GaAs is less than what is observed for exposure to He plasma[3,5,20] and often similar to that of Ar plasma.[5,20]

In this work, carrier loss is measured on n-type GaAs samples after exposure to *nonetching* plasmas of He, Ar, Xe, O_2, and CCl_2F_2 (containing He) at different rf-induced dc biases. An estimate of the depth of damage is made by the method used in our previous work, which treated damage from CF_4 and SF_6 plasmas.[21] The data, expressed in angstroms per volt (damaged-layer thickness/dc bias), are compared with those of other studies of carrier loss in GaAs. An inverse-mass relationship for the damage dependence on dc bias is derived from the data for He, Ar, and Xe plasma exposures. An immediate implication of this for molecular gas plasmas is that the lightest ions cause the deepest damage and we assume that this is what we measure with our test structures. For O_2, CCl_2F_2, CF_4, and SF_6 plasmas, two models are tested for their ability to predict the measured damage dependence on dc bias. One model assumes that the damage results from the impact of molecular ions as single particles. The other model assumes that the molecular ions fragment completely upon impact and the damage results from the impact of a fragment with its associated share of energy. Only the lightest ions expected to be present in O_2, CCl_2F_2, CF_4, and SF_6 plasmas need to be considered to evaluate the two models.

Although the test structure for these investigations is Si-doped GaAs, some of the conclusions apply to other semiconductors. For example, in plasmas containing both molecular and inert gases, quenching of certain inert gas ions by molecular gas species is observed by Optical Emission Spectroscopy. We show that this quenching corresponds to a reduction in damage in GaAs. Since the quenching is an observable effect in some plasmas, a reduction in damage would be expected in any material exposed to such plasmas.

2 Experimental Methods

GaAs samples were exposed to plasmas in a Materials Research Corporation RIE-51. This system has a stainless steel bell jar with parallel plate electrodes. Samples were loaded from a nitrogen glove box to the lower electrode which is powered with 13.56 MHz rf. The chamber was pumped below $1x10^{-6}$ Torr before gases were introduced. He, Ar, Xe, O_2 and CF_4 plasmas were generated at 20 mTorr and a flow of 30 sccm. SF_6 plasma was generated at 15 mTorr and 23 sccm. CCl_2F_2 was mixed with He or Ar in a ratio of 1:1 at a total flow of 20 sccm and pressure of 30 mTorr. The lower electrode was covered with a quartz plate when using plasmas that would not produce significant quantities of quartz etch products (He, Ar, Xe, O_2, CCl_2F_2); a CaF_2-coated quartz plate was used for CF_4 and SF_6 plasmas. In all cases, conditions were chosen so that the GaAs samples would not etch. Physical sputtering did occur and this effect will be discussed in section 3. All plasma exposures were for 120 seconds. A range from -50 to -200 V dc bias was investigated for most plasmas.

Test samples consisted of semi-insulating GaAs that had a 5000 A buffer layer and a 330 A layer of silicon-doped GaAs ($3\mathrm{x}10^{18}/\mathrm{cm}^3$) grown by MBE. The sheet resistance of these samples was measured with a Tencor Sonogage before and after plasma exposure. The change in sheet resistance was translated to a "damage depth" by way of a model that we have already presented and that will be discussed further in the next section. The effects of mixing inert and molecular gas plasmas were observed by Optical Emission Spectroscopy with a system described previously that has a resolution of 0.6 nm.[21]

3 Review of Damage Model and Justification

We recently published a simple model of plasma damage that assumes that the observed carrier loss is caused by the introduction of deep acceptor levels into the doped GaAs sample.[21] The acceptor concentration was assumed to be greater than the donor concentration from the GaAs surface to a certain depth, the "damaged-layer thickness." This is depicted in figure 1. The damaged-layer thickness, W_a, is calculated from equation 1 which was derived previously.

$$W_a = (330\ \text{Å})\frac{\Delta\sigma}{\sigma} + \left(1 - \frac{\Delta\sigma}{\sigma}\right)\left[\frac{2\varepsilon\,\Phi_{ss}}{qN_D}\right]^{1/2} - \left[\frac{2\varepsilon\ E_a}{qN_D}\right]^{1/2} \qquad [1]$$

N_D is the original dopant concentration, $\Delta\sigma$ is the change in sheet conductivity and σ is the original sheet conductivity. This model produces a linear relationship between plasma dc bias and the damaged-layer thickness for GaAs samples exposed to CF_4 and SF_6 plasmas. In effect, the model explained the data but did not give much insight into the mechanism for damage. At this time, we wish to review the assumptions of the model and provide supporting data.

The conclusion that ions cause plasma damage is well-documented. For the case of carrier loss, studies using Deep Level Transient Spectroscopy indicate that acceptor levels are introduced into n-type GaAs by plasma exposure. These experiments involved CF_4 plasma[4] and CCl_2F_2:He plasma, for which the total number of acceptors qualitatively scaled with plasma dc bias.[22] These studies suggest that ion impact generates the acceptor levels.

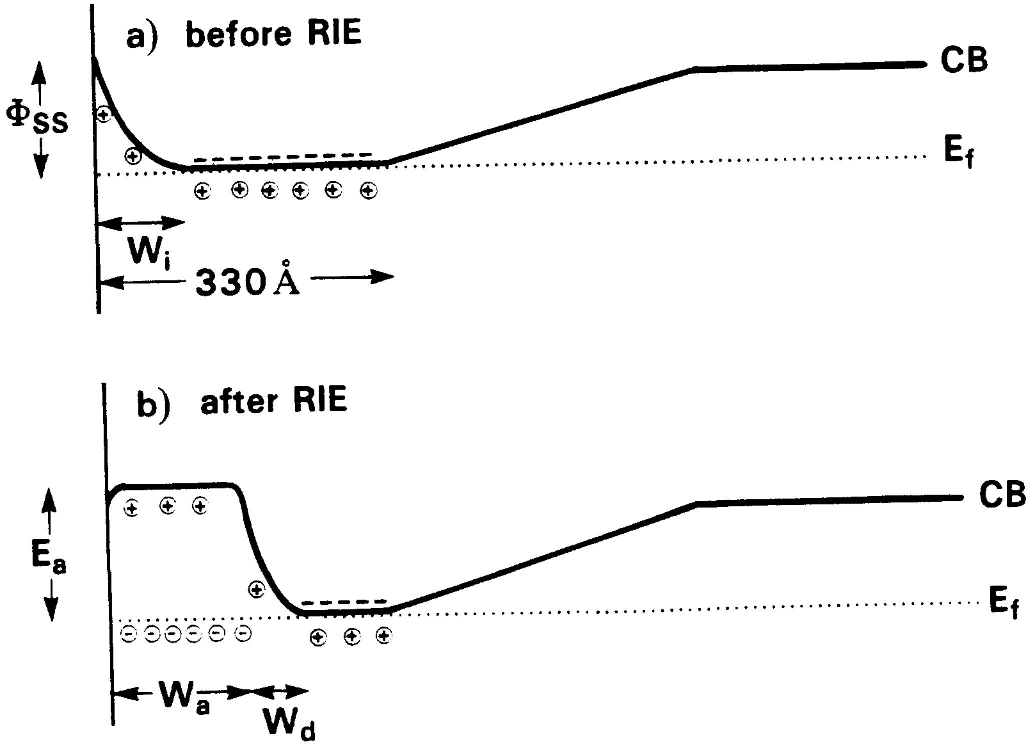

Figure 1. Schematic conduction band energy diagrams for the damage test structure (a) before and (b) after plasma exposure.

In our previous work, a saturation in damage was observed after 60 seconds of plasma exposure. This has also been found in the etching of silicon,[17] oxide on silicon,[23] and GaAs.[5,11,20,24] Thus the damage from our plasma exposures of 120 seconds is expected to fit the simple model of a layer devoid of carriers. In addition to carrier loss from generation of acceptor levels, the plasma exposures include a small loss of sheet conductance due to physical sputtering of the doped GaAs. We have measured this sputtering effect for SF_6 plasma and for Ar plasma; it is expected to scale with the plasma dc bias and is small enough to be ignored for the data to be presented.

Another parameter to consider is ion flux since we plan to compare plasmas with lower power density (for example, argon) to plasmas of higher power density (for example, SF_6). Ion flux appears to be sufficient in the plasmas studied to create more than enough acceptor levels to compensate the silicon donors within the damaged layer. The evidence for this is that the damage saturates with plasma exposures in excess of 60 seconds.

All of the above observations support our simplified model of damage from nonetching plasmas being represented as a region devoid of carriers from the GaAs surface down to some depth that depends on plasma dc bias. To compare the plasmas more exactly, measurements should be made of damage as a function of ion potential. The algebraic difference between ion potential and plasma dc bias is the plasma potential. In this work we assume that the plasma potential is small[25] and use the approximation that dc bias is proportional to ion potential in a similar way for all the plasmas studied. This assumption is revisited in the Summary section.

4 Damage Data and Interpretation

4.1 Inert Gas Plasmas

To determine the inverse-mass dependence for inert gas plasmas, the damaged-layer thickness was calculated from sheet resistance changes after He, Ar and Xe plasma exposures by using equation 1 with E_a set to 0.7V. These data are shown in figure 2. The damage dependence on dc bias (the slope of the lines in figure 2) is used to compare the damage from He, Ar, and Xe plasmas. Use of the slope allows us to compare damage from different plasmas even though we are using an arbitrary value for E_a in equation 1. The values for damage thickness dependence on dc bias are 1.8 A/V for He plasma, 0.65 A/V for Ar and 0.38 A/V for Xe. The best fit for the mass dependence is

$$\frac{\text{damaged-layer thickness (A)}}{\text{plasma dc bias (V)}} = 3.9\left[\frac{1}{m^{0.5}}\right] \qquad [2]$$

where m is the ion mass. An inverse-square root of mass dependence suggests that the damage may be related to the ion velocity.

Our value for the damage thickness dependence on dc bias of 1.8 A/V for He compares well with the value of 2.0 A/V from a study where Raman was used to measure a change in depletion region thickness.[20] Our value for Ar of 0.65 A/V is on the low side compared to a value of 0.86 A/V using Raman[20] and a value of 1.0 A/V by measuring the depth of damage as the amount of GaAs removed to restore a Schottky barrier to its original value.[4] Considering the margin of error in the Raman technique (about 300 A), our value for Ar damage compares reasonably well with the value from ref. 20. Studies of Xe damage that could be compared with our value of 0.38 A/V were not found.

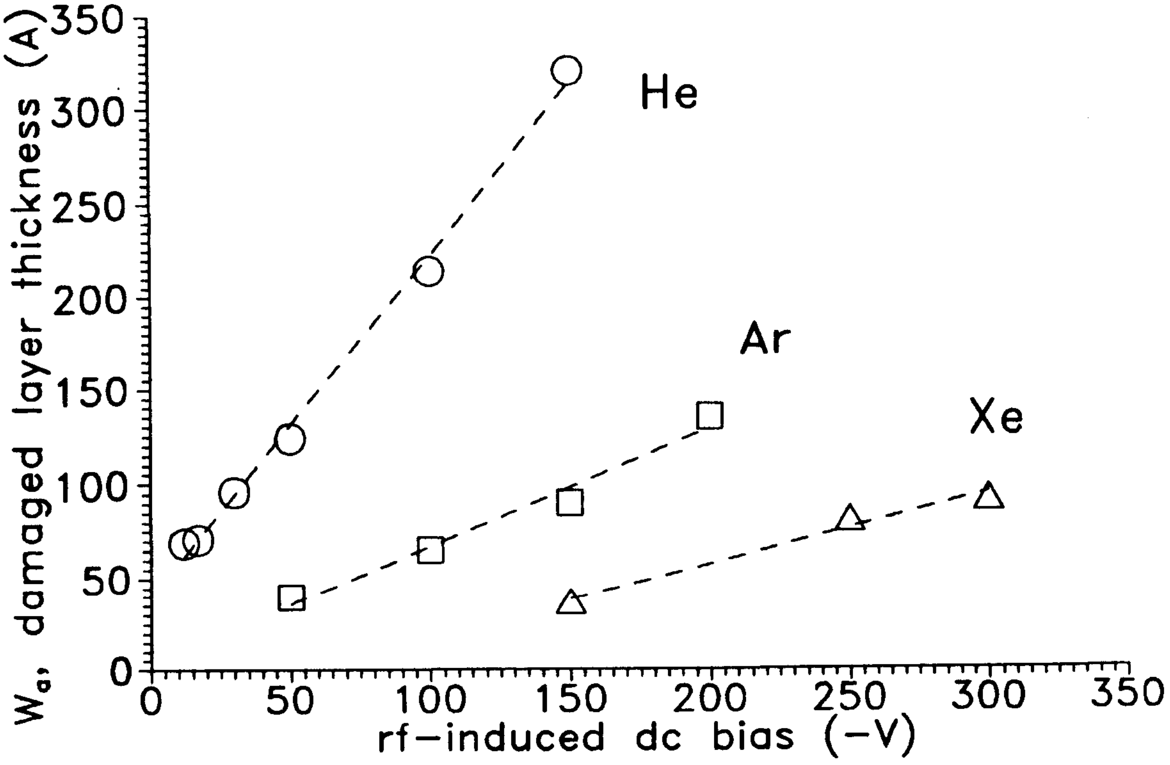

Figure 2. The damaged-layer thickness, W_a, indicated in Figure 1 and calculated by eq. 1, as a function of dc bias for He, Ar and Xe plasma exposures of 120 sec. E_a is set to 0.7 V.

4.2 Molecular Gas Plasmas

Data for the molecular gas plasmas are shown in figure 3. The damaged-layer thickness dependence on dc bias is 0.59 A/V for CCl_2F_2 plasma diluted 1:1 with He; 0.35 A/V for SF_6 plasma; 0.49 A/V for CF_4 plasma; and 0.17 A/V for O_2 plasma. Note especially that the CCl_2F_2:He plasma has a much lower damage dependence than He plasma. This suggests that He^+ ions are not present in CCl_2F_2:He plasma. This will be verified later in the section on Optical Emission Spectroscopy. In our analysis we will treat CCl_2F_2:He plasma as though it is a pure CCl_2F_2 plasma.
Our value of 0.59 A/V for the damage dependence on dc bias in CCl_2F_2 plasma is lower than 0.86 A/V which was measured by Raman.[20] Other measurements of damage from CCl_2F_2 plasma indicate much higher values: 1.4 - 2.3 A/V from cathodoluminescence (CL)[5] and 1.1-1.6 A/V from defect penetration measured by transmission electron microscopy.[26] However, these latter two techniques, rather than measuring the extent of carrier loss, are measuring the extent to which the semiconductor lattice has been disrupted. Both the test structure and the technique employed for analyzing damage determine the sensitivity of plasma damage detection.[20,27] Although the CL experiments detect damage deeper than our conductivity measurements, relative values are still comparable. For example, Ar plasma damage measured by CL is ~ 1.3 times that of CCl_2F_2;[5] in our work the ratio is 1.1. Our value of 0.49 A/V for the damage dependence of CF_4 is very low compared to the value of 4.0 A/V derived from the penetration depth of fluorine detected by Vanner[24] using Secondary Ion Mass Spectrometry. However, electrical data from our work and Vanner's work, which had similar CF_4 plasma exposures, compare very well. The electrical measurement was percent reduction in I_{dss} on Schottky barrier FETs which were processed with plasma exposure of the gate recess prior to gate metal deposition. The linear correlation between damaged-layer thickness and percent reduction in I_{dss} is shown in figure 4. The data of Vanner[24] on figure 4 fit the line fairly closely. Studies of SF_6 or O_2 plasma damage with which to compare our damage dependence values were not found in the literature.

The data shown in figure 3 will be interpreted based on two different hypotheses. The first hypothesis assumes that the ions impinging on the GaAs surface impart energy as single particles according to their mass; we refer to this as the molecular ion model. The second hypothesis assumes that the ions completely fragment upon impact, and each of the resulting atomic fragments then causes damage according to its mass and share of energy. Such fragmentation is found in experiments measuring the sputtering yield of gold by CF_3^+.[25] We refer to this as the fragmentation model. To test the models, we are guided by the damage produced by the inert gas plasmas which indicates that we need to consider only the *lightest ions* known or likely to be present in the molecular gas plasmas. For CCl_2F_2 plasma, we consider both Cl^+ and CF^+ since they are so close in mass; for SF_6 plasma, SF^+; for CF_4 plasma, CF^+; and for O_2 plasma, O_2^+.

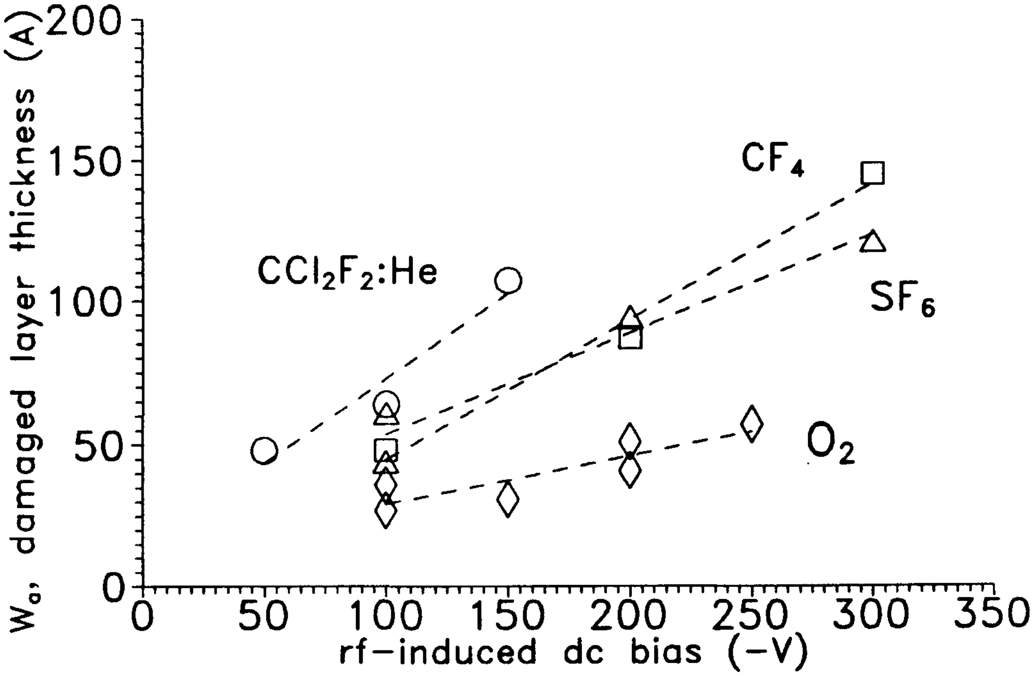

Figure 3. The same as figure 2 for the molecular gas plasmas CCl_2F_2:He, CF_4, SF_6, and O_2.

For the molecular ion case, we match the measured damage dependence to that predicted by equation 2 using the mass of the ions listed previously. The values are shown in table 1. The mass dependence equation itself was derived as a best fit to damage data from He, Ar and Xe plasmas. We note, from table 1, that it predicts the damage dependence of He^+ to within 10%, Ar to within 5% and Xe^+ to within 11%.

For CCl_2F_2 plasma, the damage dependence predicted by the molecular ion model from ions Cl^+ (0.66 A/V) and CF^+ (0.70 A/V) is somewhat higher than the measured damage dependence (0.59 A/V). For SF_6 plasma, the predicted damage value SF^+

(0.55 A/V) is not a good match to the measured value (0.35 A/V). As well, for CF_4 plasma, the measured and predicted damage dependences from CF^+ do not match. Furthermore, the very low damage levels measured for O_2 plasma do not correspond to the damage predicted by this model.

In the other interpretation of the damage dependence on dc bias the assumption is that all molecular ions fragment upon impact and the ion energy (in our case, the dc bias) partitions according to mass. Thus the predicted damage dependence is $3.9 / \sqrt{m_{atom}}$ times m_{atom}/m_{ion}. For any given molecular ion, the heaviest atom will be responsible for the damage because it will receive the largest share of the energy upon impact and fragmentation. The predicted values for damage dependence according to this model are listed in table 1.

From table 1 we find that in CCl_2F_2 plasma, both F from CF^+ (0.54 A/V) and Cl^+ (0.66 A/V) are a better match to the measured value (0.59 A/V) than the value for CF^+ (0.70 A/V) from the molecular ion model. Since Cl^+ has a deeper effect, it is expected to be the species causing the damage. For SF_6 plasma, the value for the fragmentation model (0.43 A/V) matches the measured value (0.35 A/V) better than the value from the molecular ion model (0.55 A/V). As well, for CF_4 plasma, the value for the fragmentation model is closer to the measured value than was the case for the molecular ion model. According to the fragmentation model, the fragment of CF^+ responsible for the damage is fluorine. In a study of damage to sulfur-doped GaAs by Shingu and coworkers,[28] both low temperature photoluminescence and

Table 1. Correlation of measured to predicted damage dependence for ion species in the plasma

plasma feed gas	measured damage dependence	predicted damage dependence molecular ion model	 fragment'n model	species
He	1.8 A/V	2.0 A/V	2.0 A/V	He^+
Ar	0.65 A/V	0.62 A/V	0.62 A/V	Ar^+
Xe	0.38 A/V	0.34 A/V	0.34 A/V	Xe^+
CCl_2F_2:He	0.59 A/V	0.66 A/V	0.66 A/V	Cl^+
		0.70 A/V	0.54 A/V	CF^+
SF_6	0.35 A/V	0.55 A/V	0.43 A/V	SF^+
CF_4	0.49 A/V	0.70 A/V	0.54 A/V	CF^+
O_2	0.17 A/V	0.69 A/V	0.34 A/V	O_2^+

Secondary Ion Mass Spectrometry were used to detect carbon contamination after CF_4 plasma exposure. The quantity of carbon increased as RIE power was increased and as sheet carrier concentration decreased. The implication was that the acceptor levels responsible for sheet carrier loss were related to the carbon contamination. The fragmentation model does not imply that C from CF^+ does not produce damage; it implies that F from CF^+ produces the deepest damage (because F gets 61% of the energy) and this is the damage measured with our MBE structure. Referring back to table 1, the damage dependence of O_2 plasma is very low and does not fit the fragmentation model but is not as far off as the molecular ion model. Overall, the fragmentation model fits the data better than the molecular ion model.

5 Optical Emission Studies

We decided to look closely at He optical emission from CCl_2F_2:He plasma because the damage dependence for $CCl_2F_{2:He}$ plasma is much lower than that for He plasma. This suggests that He ions may not be present in CCl_2F_2:He plasma and this was observed to be the case by Optical Emission Spectroscopy.

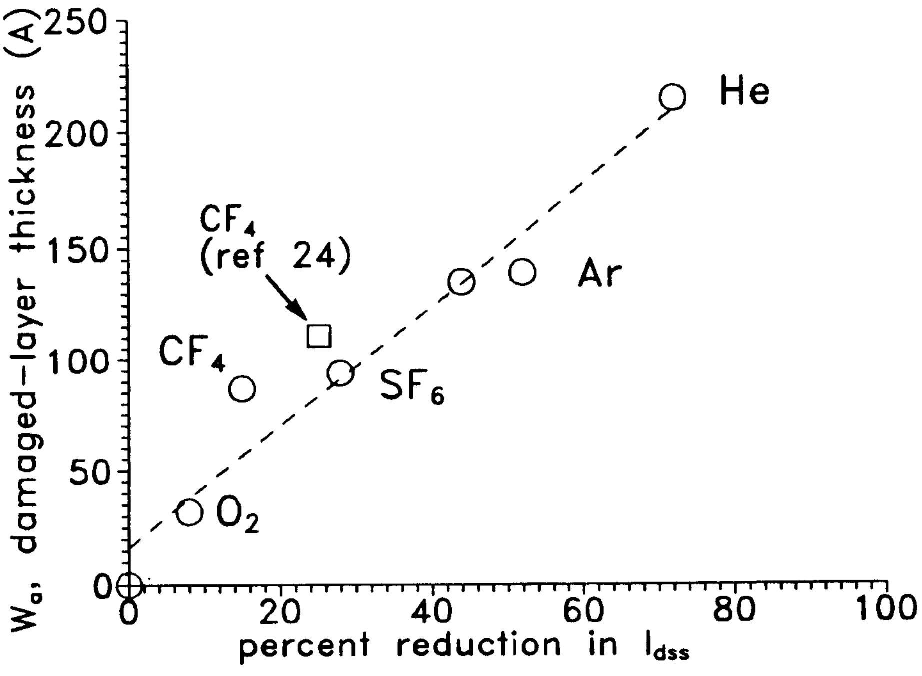

Figure 4. Correlation between damaged-layer thickness, W_a, and percent reduction in I_{dss} for 100-micrometer MESFETs.

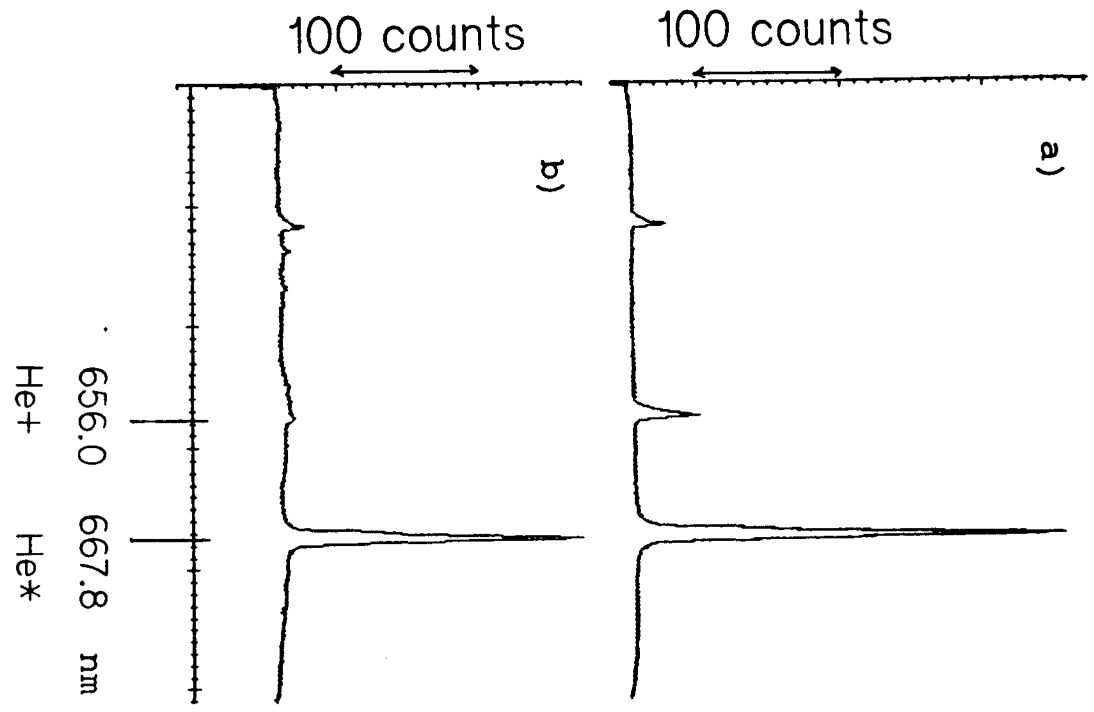

Figure 5. Optical Emission spectra of (a) a 20 V He plasma and (b) the same plasma with 0.1 sccm CCl_2F_2 added and the dc bias increased to 250V to enhance detection of He^+ and He^*.

In figure 5, spectra are shown of a He plasma at a dc bias of 20 V and the same plasma after addition of a very small quantity of CCl_2F_2, this time at a bias of 250 V. After CCl_2F_2 addition, the emission from He^+ is essentially gone. Quenching of He^+ emission was also found when Xe was added and when $SiCl_4$ was added to a He plasma. However, quenching of Ar^+ was not observed when SF_6, Cl_2, $SiCl_4$, or Xe were added to an argon plasma. These results, along with data of Sugimoto and Miyake,[29] are summarized in table 2. When there is a large enough difference in ionization potential (I.P.), the gas with the high ionization potential does not ionize. This principle is used in commercial fluorescent lighting which typically consists of Ar (I.P. of 15.8 eV) and Hg (I.P. of 10.4 eV) in a ratio of 100 to 1 at 100 Torr. Under steady-state lamp operation, mercury is ionized but argon is not.[30] The conclusion is that plasmas consisting of mixtures of He (or Ne) and the molecular gases used in semiconductor plasma etching do not contain He (or Ne) ions.

Table 2. Quenching of inert gas ions by addition of molecular or inert gas to the plasma

inert gas ion(I.P.)[1]		added molecular or inert gas (I.P.)[2]		quenching of inert gas ion
He^+	(24.6 eV)	$SiCl_4$	(≤13 eV)	yes[3]
"		CF_3Cl	(~13 eV)	yes[4]
"		CCl_2F_2	(12.3 eV)	yes
"		Xe	(12.1 eV)	yes
Ne^+	(21.6 eV)	CF_3Cl	(~13 eV)	yes[4]
Ar^+	(15.8 eV)	SF_6	(15.8 eV)	no
"		Cl_2	(~13 eV)	no[3]
"		$SiCl_4$	(≤13 eV)	no[3]
"		CF_3Cl	(~13 eV)	no[4]
"		Xe	(12.1 eV)	no
Kr^+	(14.0 eV)	CF_3Cl	(~13 eV)	no[4]
Xe^+	(12.1 eV)	CF_3Cl	(~13 eV)	no[4]

[1] Handbook of Chemistry and Physics, 66th edition, (CRC Press, Boca Raton, Florida, 1985) page E-74.

[2] F.H. Field and J.L. Franklin, *Electron Impact Phenomena*, (Academic, New York, 1957).

[3] This work was performed at Varian Associates in Palo Alto on a Zylin-20 RIE system with S. (Mak) Salimian.

[4] Iwao Sugimoto and Shojiro Miyake, J. Appl. Phys. **65** 4639 (1989).

6 Summary and Conclusions

Changes in the sheet conductivity of thin, highly-doped GaAs layers have been used to establish a depth scale of the relative amount of ion damage from inert gas plasmas (He, Ar, and Xe) and molecular gas plasmas (CCl_2F_2, SF_6, CF_4, and O_2). An inverse-square root of mass relationship was derived for the damage dependence on dc bias after He, Ar, and Xe plasma exposures; the equation predicts these data to about 10%. For the molecular gas plasmas, two models were tested for their ability to predict the measured damage effect: one in which the molecular ions causing damage were intact upon impact and one in which the ions fragmented upon impact. The fragmentation model was fairly successful (within 15%) at predicting the damage effects from CCl_2F_2, SF_6, and CF_4 plasma exposures. This interpretation indicated that F from CF^+ or Cl^+ causes damage during exposure to

CCl_2F_2 plasma, that F from CF^+ is responsible in CF_4 plasma, and that S from SF^+ is responsible for damage in SF_6 plasma. The molecular ion model was less successful (within 30%) at predicting the measured damage dependence of CCl_2F_2, SF_6, and CF_4 plasma exposures.

Neither of the models fits the data for O_2 plasma. One possible explanation for this is that the assumption does not hold that dc bias and ion potential are related in O_2 plasma the same way that they are for the other plasmas. Since O_2 plasma is electronegative, the ion potential could be less than the dc bias if the plasma potential is negative. This would increase the value for the damage dependence if it were measured with respect to ion potential.

In this work, we used CCl_2F_2 plasma mixed 1:1 with He as a practical matter: the GaAs test sample would not etch at dc biases from -50 to -150 V in this gas mixture. Additional understanding of the ions present in mixtures of inert and molecular gases was gained by noting that the damage dependence with dc bias was much lower for CCl_2F_2:He plasma than it was for He plasma. This led to the observation, by Optical Emission Spectroscopy, that He^+ ions were not present in CCl_2F_2:He plasma. A number of mixtures of inert and molecular gas plasmas was investigated and it can be concluded that species with ionization potentials on the order of 50% higher than other species in the plasma will not be ionized.

In this study, a Si-doped GaAs layer has been used as a vehicle through which to study the effects of exposure to different gas plasmas. The test structure is not affected by thin surface layers like native oxides or even the 30 A surface films that are formed from CF_4 or SF_6 plasma exposure.[21] Pinning of the GaAs surface enables the test structure to be immune to surface films. This suggests that the results of the study, in a relative sense, might apply to GaAs with dopants other than silicon, and might apply to other semiconductors. We have already used the test structure to compare damage caused by different RIE systems as well as damage induced by systems for plasma deposition.

7 Acknowledgments

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