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Study of Drain Contact Structure Dependent Deep Submicron MOSFET Reliability by Photon Emission Analysis

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1. Introduction

It is known that photons are emitted from silicon MOSFETs due to recombination of electron hole pairs generated by impact ionization[1)]. Many researchers reported that the photon current dependence on gate voltage follows the same trend as the substrate current[2-3)]. Therefore, the photon emission spectrum or intensity can be used to characterize hot carrier immunity of a given device.

For many years, hot carrier induced degradation has been investigated for submicron devices in terms of device structure and almost no attention has been paid to source/drain contacts. The best contact design is to put maximum number of contacts to reduce series resistance.

In this work, for the first time, we have analyzed the photon emission for different contact structures and found that the device lifetime can be significantly enhanced by reducing number of drain contacts.

2. Experiments and Results

Devices used in this work have been fabricated by 0.25 micron CMOS process. Fig. 1 shows contact structures used in this work for nMOSFET's with W/L = 20/0.25 μm. We repeatedly observed that the drain current is the largest and smallest in the 20 contacts and the opposite single contact, respectively. We believe that voltage drop along the drain diffusion layer causes less current in single contact structures. Fig. 2 is the spectrum of photons emitted from drain edges. It is clear that the single contact has much less emitted photons due to less impact ionization. Therefore, we think that the single contact structure generates much less hot carriers and by optimizing the contact structure, one can enhance the device lifetime. However, the increase of device lifetime can only be realized at the price of the decrease of drain current. Fig. 3 shows the drain currents and the maximum substrate currents of 20, 3, and single contact structures. The maximum substrate current of the single contact structure is 0.1 mA while that of the 20 contacts structure is 0.199 mA. In the meantime, drain current of the single and 20 contacts structures are 9.1 and 10.6 mA, respectively. From this result, the 10% sacrifice in drain current is worth while because it results 100 % decrease in the substrate current. To study further, we compare the photon emission of 3 contacts and various single contact structures in Fig. 1. Fig. 4 shows that all single contact structures emit less photons than the 3 contacts structure. Also, it is found that structures with less photon emission have less substrate currents and saturation drain currents as shown in Table 1. In order to confirm the lifetime dependence on contact structure, we have measured drain current degradation after stress. Fig. 5 clearly shows that the single contact structure has much less degradation than the 3 contact structure in both linear and saturation current. From the results listed above, we suggest that device reliability can be significantly improved with properly designed contact structure.

3. Conclusion

From the experiment, we conclude that the device lifetime can be improved by changing source/drain contact structure. Therefore, simple, conventional approach for the contact design which tries to put more contacts needs to be modified with regard to hot carrier immunity. In general, the lifetime increases with less number of contacts. And it is desirable to find optimum number of contacts because there is trade off between the current drive capability and lifetime. Currently, we are developing a methodology for optimum contact structure design.

References

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Table 1. Saturation drain current and the maximum substrate current for different contact structures. (Vds=4V, Vgs=2V)

	Center Contact device	Same End Contact Device	Opposite Contact Device	3-Contacts Device
IDsat(A)	9.20E-03	7.91E-03	7.73E-03	9.56E-03
Isub(A)	-3.01E-04	-1.66E-04	-1.46E-04	-3.74E-04

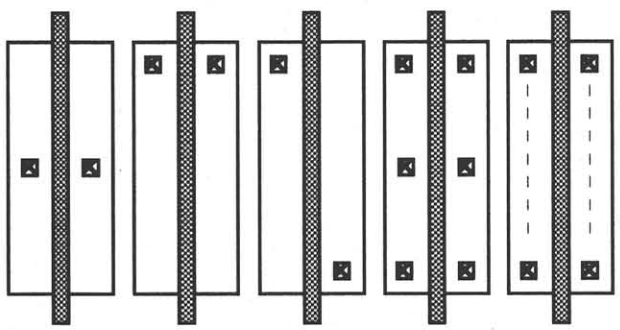

Fig. 1 Different source/drain contact structures tested.

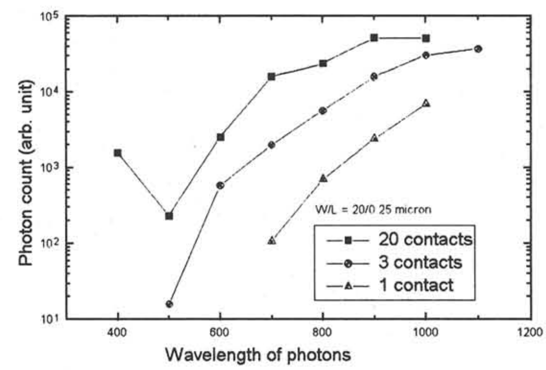

Fig. 2 Spectral analysis of emitted photons from different contact geometries. Bias condition was Vds=4V, Vgs=3V.

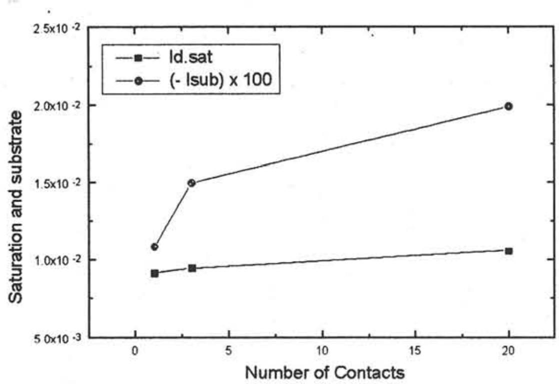

Fig. 3 Saturation current and substrate current for diffenent contact geometries. (Vds=4V, Vgs=3V)

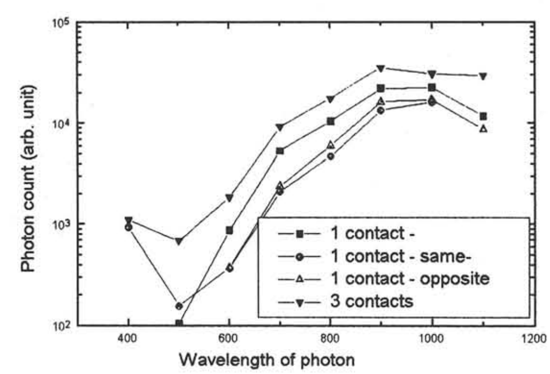

Fig. 4 Spectral analysis of the emitted photons for diffenent single drain contact geometries in comparison with 3-contacts case. (Vds=4V, Vgs=2V)

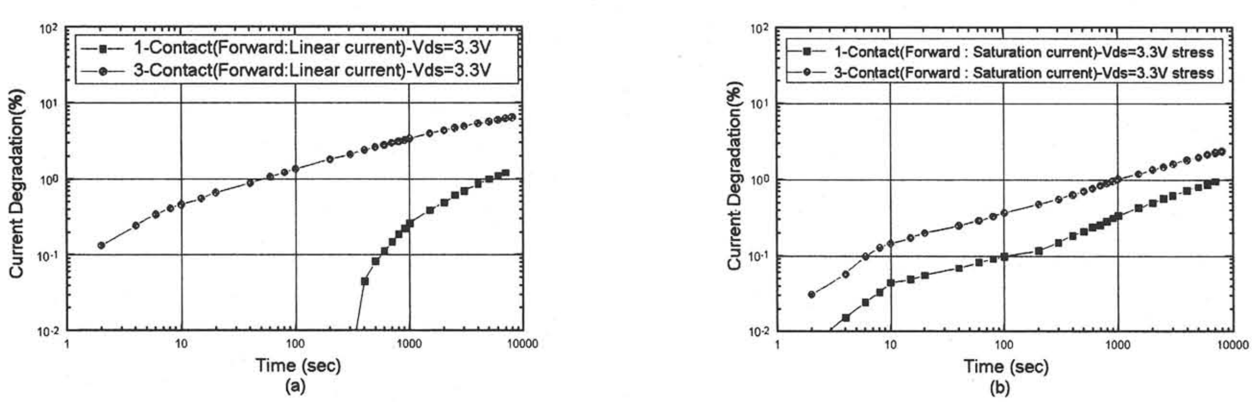

Fig. 5 Drain current degradation measurement results for the 3-contacts and single contact at center structures.

(a) forward linear current degradation. (b) forward saturation current degradation.