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Characterization of RF LDMOS Transistors with Different Layout Structures

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1. Introduction

The conventional LDMOS has to trade off between the on resistance and the breakdown voltage, as well as, between the high drain current and the breakdown voltage. Several researchers have proposed solutions to the trade-off such as the double-doped offset [1], the stacked or step drift region [2], and even the strain structure [3]. In this paper, two types of layout structures, ring and fishbone, were studied for both DC and RF characteristics. We found a superior DC and high-frequency performances with a higher breakdown voltage in the ring structure as compared to the fishbone structure.

2. Experiments

RF LDMOS transistors used in this work were fabricated using a 0.5μm LDMOS process with 13.5-nm-thick gate oxide. The device structure is shown in Fig. 1. The drift length ($L_{Drift}=L_{OV}+L_{FOX}$) had been varied in this investigation. We developed two types of layout structures, fishbone and ring, with the same total channel width 360 μ m (see Fig. 2). For fishbone structure, each cell had 6 fingers with finger width L_F=10 μ m. For ring structure, the width of each ring was 4×10 μ m.

3. Results and Discussion

DC characteristics of the LDMOS with different layout structures were shown in Figs. 3 and 4. In high bias region, the self-heating effect was more serious for device with ring structure due to higher device density. In low bias region, the ring structure showed a higher drain current and transconductance than the fishbone one. It was attributed to the larger equivalent width-to-length ratio (W/L) [4] and lower drain parasitic resistance (R_d). In addition, the breakdown voltage of ring structure was similar to that of fishbone one ($V_{BD}\cong$46 V – 52 V for drift length L_{Drift} =3.0μm – 4.2μm). Fig. 5 shows the extracted drain-source on-resistance R_{ON} plotted against the L_{Drift} at gate voltage V_{GS}=2 V. The R_{ON} was lower in the ring structure. From these results, we noticed that the ring structure had better dc performance than the fishbone one.

The cut-off frequency (f_T) and maximum oscillation frequency (f_{max}) versus the drift length for LDMOS with different structures were compared in Fig. 6. The transistors were measured at V_{GS}=2V and drain voltage V_{DS}=28V for the maximum value of f_T. In Fig. 6, f_T and f_{max} both decreased with increasing L_{Drift}. In addition, we found that the ring structure also improves the high-frequency performance.

We extracted the equivalent circuit parameters of LDMOS, and listed the intrinsic parameters (g_m, C_{gs}, and C_{gd}) in Table I. The intrinsic parameters change slightly when we change device structure and drift length. Therefore, they have minor influence on the geometric dependence of high-frequency characteristics. From the analysis of a MOSFET equivalent circuit [5], f_T and f_{max} are not only dependent on the intrinsic parameters but also dependent on R_d. A reduction of R_d will increase f_T and f_{max}, especially f_{max} [5]. Therefore, the increase of f_T and f_{max} with decreasing L_{Drift} or using ring structure might be attributed to the reduction of drain parasitic resistance.

Figure 7 shows the extracted drain parasitic resistance versus the drift length for LDMOS transistors with different structures. As L_{Drift} increased, the drain parasitic resistance increased. For higher breakdown voltage, L_{Drift} needed to be longer, resulting in a poor R_{ON} , f_T and f_{max}. Nevertheless, the R_{ON} and f_{max} for ring structure appeared superior as compared to the fishbone one. The improvements of DC and RF characteristics were attributed to the minor drain resistance (see Fig. 7). The drain region of the ring structure had extra areas (the shadow region) as compared to the fishbone one, and the extra areas would have lowered the drain parasitic resistance, as shown in the inset of Fig. 7.

4. Conclusions

Two types of layout structures of LDMOS transistors for RF applications were investigated. The ring structure had a better performance than fishbone one, without altering the process flow. The higher drain current and transconductance in LDMOS with ring structure were due to larger equivalent W/L and lower drain parasitic resistance. In addition, the f_T and f_{max} were also enhanced for ring structure due to lower drain parasitic resistance. Using a ring structure, the high breakdown voltage could be achieved by longer L_{Drift} without degrading DC and RF characteristics.

Acknowledgements

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References

[1] M. Shindo et al., Proc. IEEE SISPAD (2001) 107.
[2] G. Cao et al., IEEE Trans. Electron Devices **51** (2004) 1296.
[3] M. Kondo et al., IEEE IEDM Tech. Dig. **5** (2005) 365.
[4] P. L´opez et al., IEEE ISCAS **4** (2005) 3688.
[5] L. Vestling et al., IEEE Trans. Electron Device **49** (2002) 976.

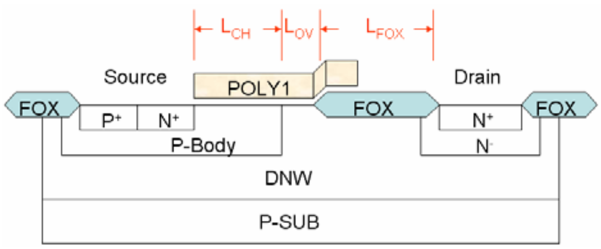
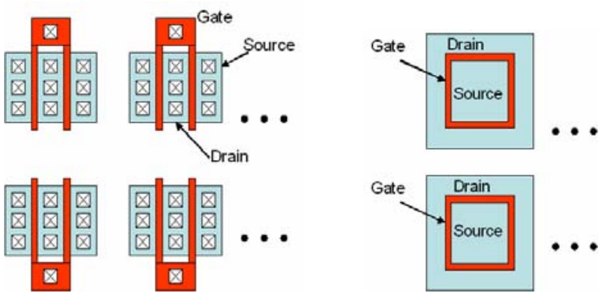


Fig. 1. Cross-section of an LDMOS transistor.



(a) (b)

Fig. 2. LDMOS layout structures: (a) fishbone. (b) ring.

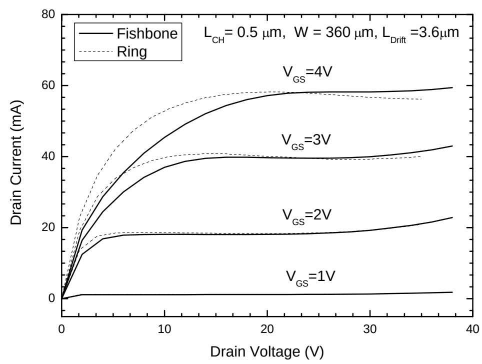


Fig. 3. Output characteristics of LDMOS transistors.

Table I Extracted g_m, C_{gs} and C_{gd} for different layout structures

	Fishbone L_{Drift} =3um	Fishbone L_{Drift} =3.6um	Ring L_{Drift} =3.6um
g_m (mA/V)	29	27	27
C_{gs}(fF)	631.8	651.4	681.5
C_{gd} (fF)	140.4	134.2	119.8

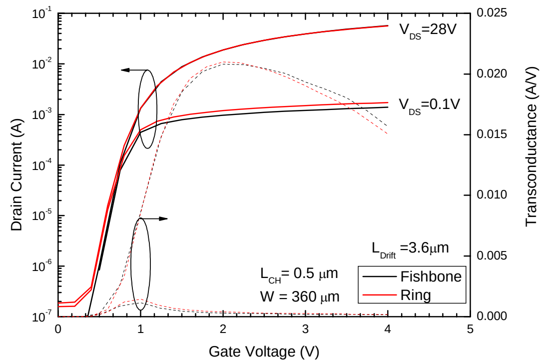


Fig. 4. Drain current versus gate voltage for LDMOS transistors with different structures.

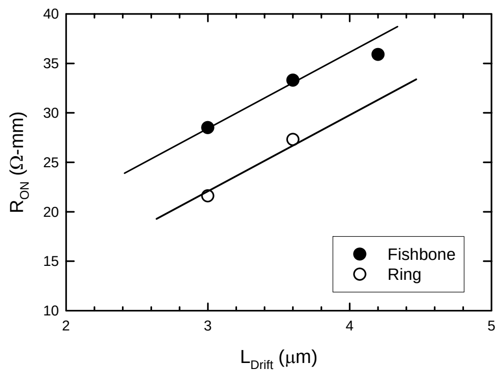


Fig. 5. R_{ON} versus L_{Drift} for different layout structures.

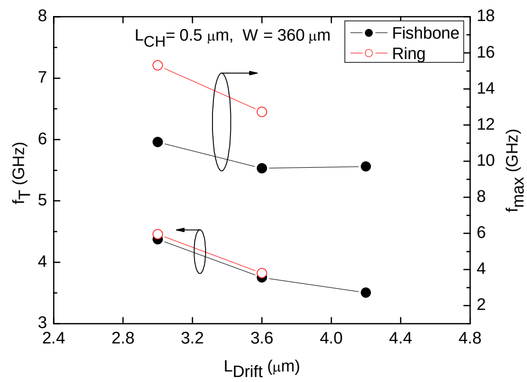


Fig. 6. Cut-off frequency and maximum oscillation frequency versus the drift length.

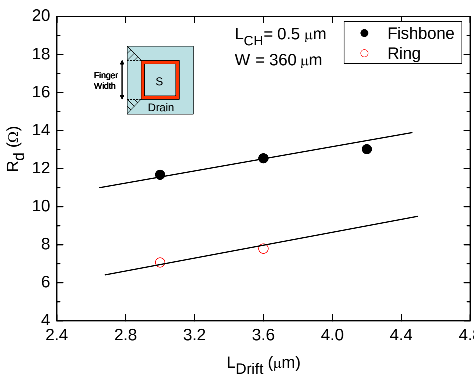


Fig. 7. R_d versus the L_{Drift}. Inset shows the drain region of the ring structure has extra areas (the shadow region) as compared to the fishbone structure.