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SOI LNA에서 게이트구조가 핫캐리어에 의한 성능저하에 미치는 영향

(Impact of Gate Structure On Hot-carrier-induced Performance Degradation in SOI low Noise Amplifier)

엄 우 용*, 이 병 진**

(Woo-yong Ohm and Byong-jin Lee)

요 약

본 논문은 SOI 저잡음 증폭기에서 게이트구조가 핫캐리어에 의한 성능저하에 미치는 영향을 조사하였다. 회로 시뮬레이션은 H-게이트와 T-게이트를 가지는 SOI MOSFET에서 측정된 S-파라미터와 Agilent사의 ADS를 사용하여 스트레스 전후의 H-게이트와 T-게이트 저잡음 증폭기의 성능을 비교하였다. 또한 저잡음 증폭기의 장치 열화와 성능 열화 사이의 관계뿐만 아니라 임피던스 매칭(S11), 잡음 지수와 이득에 관한 저잡음 증폭기의 성능 지수 등을 논의하였다.

Abstract

This paper presents new results of the impact of gate structure on hot-carrier-induced performance degradation in SOI low noise amplifier. Circuit simulations were carried out using the measured S-parameters of H-gate and T-gate SOI MOSFETs and Agilent's Advanced Design System (ADS) to compare the performance of H-gate LNA and T-gate LNA before and after stress. We will discuss the figure of merit for the characterization of low noise amplifier in terms of impedance matching (S11), noise figure, and gain as well as the relation between device degradation and performance degradation of LNA.

Keywords : gate structure, hot-carrier, SOI MOSFET, LNA, H-gate, T-gate

Ⅰ. Introduction

The SOI(Silicon-on-Insulator) MOS technology is gaining more popularity as a good candidate for low-power microwave circuits due to its excellent RF performance in terms of gain, speed, and cut off frequency (f_T). Many studies showed that the noise figure and the gain of a CMOS low noise amplifier have been degraded after DC hot carrier stress[1~4]. The millimeter-wave amplifiers with low noise and high gain could be realized by using SOI CMOS technology[5]. The body contact structures such as T-gate and H-gate SOI MOSFETs have been proposed to suppress the kink effects as well as parasitic lateral bipolar transistor effects. The previous results show that H-gate devices have higher driving current than T-gate due to the gate extension induced inversion charges[6]. However, DC and RF performance degradation of H-gate are more significant than that of the T-gate device due to the higher drain current[7].

In this work, we expand our recent studies of hot

* 평생회원, 인하공업전문대학 디지털전자과
(Dept. of Digital Electronics., Inha Tech. College)
** 정회원, 인천대학교 전자공학과
(Dept. of Electronic Engineering, Univ. of Incheon)
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carrier effects with gate structures in SOI MOSFETs, and present new results of the impact of gate structure on hot-carrier-induced performance degradation in SOI low noise amplifier. We discuss the figure of merit for the characterization of low noise amplifier in terms of impedance matching (S11), noise figure, and gain.

II. Device Fabrication and Measurement

Fig. 1 shows the top view of multi-finger type devices in T-gate and H-gate shapes. The devices are fabricated on SIMOX wafers with t_{BOX}=100㎚. The final silicon and the gate oxide thickness are 100 ㎚ and 3.8㎚, respectively. Also, both devices have the four-finger structure with unit width W_f=20㎛, and gate length 0.25㎛. S-parameters are measured from the SOI devices using an on-wafer RF probe of Cascade Microtech and an HP 8510C network analyzer, and converted into Y-parameters together

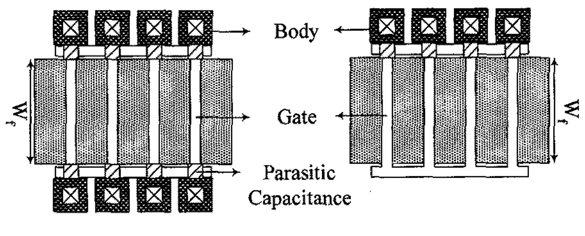

그림 1. H-게이트와 T-게이트 장치의 상면도
Fig. 1. Top view of H-gate and T-gate devices.

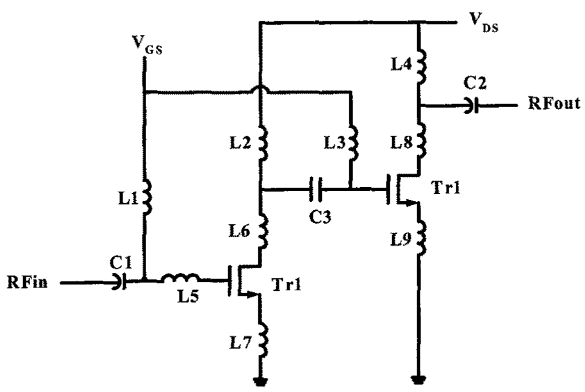

그림 2. 5㎓ CMOS 트랜시버를 위한 저잡음증폭기
Fig. 2. Low noise amplifier schematic for 5㎓ CMOS transceiver.

표 1. LNA를 위한 인덕터와 커패시터 파라미터값
Table 1. Parameter values of inductors and capacitors for both types LNA.

	H-gate	T-gate
C1(fF)	434.7	395.5
C2(fF)	185.8	441.8
C3(pF)	50	50
L1(nH)	3.7	3.7
L2(nH)	8	8
L3(nH)	3.7	3.7
L4(nH)	8.7	8.7
L5(nH)	2.3	2.7
L6(nH)	10	8.7
L7(nH)	1.2	0.5
L8(nH)	2.4	2.4
L9(nH)	3.2	1.0

with the open/short test pattern. The SLOT method is used for the calibration. The minimum noise figure (F_{min}) is measured at the frequency range of 0.5~6㎓ using an ATN setup. The hot carrier stress is applied with V_{GS}=0.7V and V_{DS}=3.1V.

To investigate the impact of gate structure on hot-carrier-induced performance degradation in low noise amplifier, a two-stage amplifier topology with inductive degeneration at the source, as illustrated in Fig. 2, was used. Table 1 shows the parameter values of inductors and capacitors in both gate structures used to provide circuit matching and to optimize noise figure. Circuit simulations were carried out using ADS to compare the performance of LNA before and after stress. To evaluate hot carrier effects on LNA, we apply the measured fresh and degraded S-parameters of both devices to ADS and obtain the degraded performance of LNA.

III. Results and Discussion

Fig. 3 compares minimum noise figure(F_{min}) and associated gains (G_{ass}) of the two devices, each as a function of the drain current before and after stress.

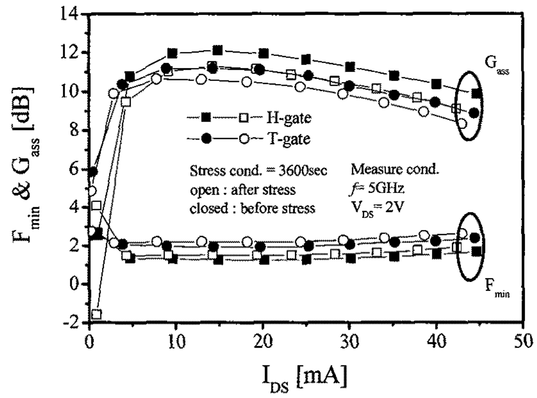

그림 3. 스트레스 전·후의 드레인전류에 따른 F_{min}과 G_{ass}

Fig. 3. F_{min} and G_{ass} of the two devices as a function of the drain current before and after stress.

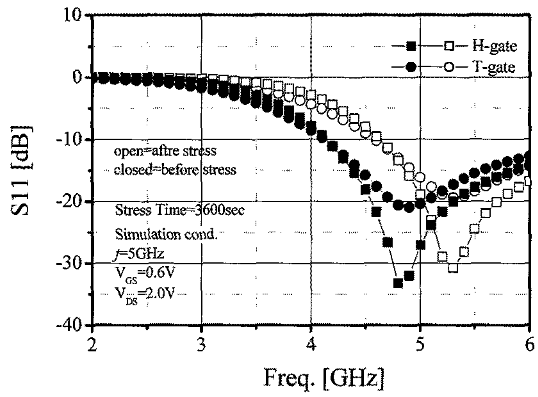

그림 4. 스트레스 전·후의 LAN S11 파라미터

Fig. 4. S11 parameters of LNA before and after stress.

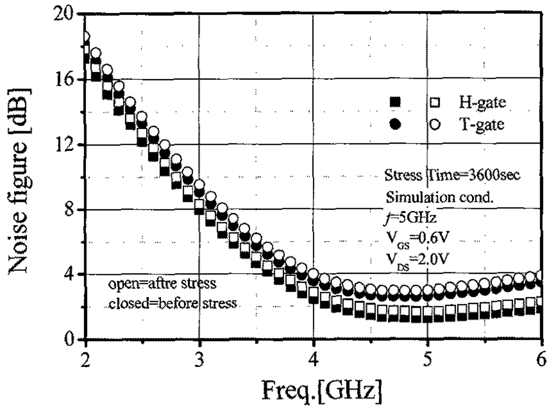

그림 5. 스트레스 전·후의 LNA 잡음지수

Fig. 5. Noise figures of LNA before and after stress.

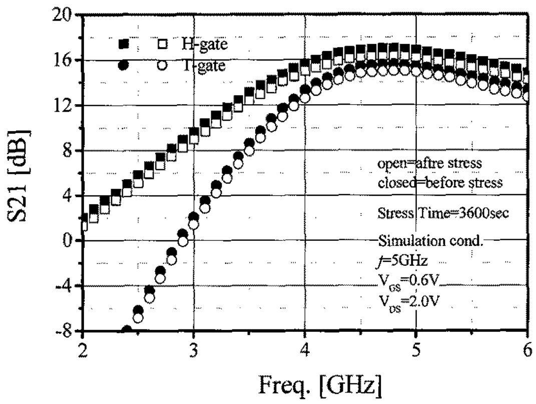

그림 6. 스트레스 전·후의 LNA S21 파라미터

Fig. 6. S21 parameters of LNA before and after stress.

The degradation of F_{min} and G_{ass} of the H-gate device are more significant than those of the T-gate device due to the higher drain current.

The simulation, as shown in Fig. 4 shows that S11 of H-gate LNA is more deteriorated than that of T-gate LNA. The degradation of S11 is due to the degradation of transconductance and gate-source capacitance.

Fig. 5 compares the noise figure degradation of both types of LNA due to hot carrier stress. Although the noise figure of H-gate LNA is smaller than T-gate LNA before stress, the degradation of noise figure is more significant in H-gate LNA than that in T-gate LNA after stress. The reason of noise figure degradation is because the increase in the channel noise of transistors together with the decrease of the gain of the circuit.

Fig. 6 also compares the S21 degradation of both types of LNA due to hot carrier stress. Although the S21 of H-gate LNA is larger than T-gate LNA before stress, the degradation of the gain in H-gate LNA is more significant than that in T-gate LNA after stress. It is believed that the variation of transconductance and output conductance cause the degradation of the gain.

Fig.7 shows the degradation of noise figure and gain for both types of LNA with stress time. Clearly it can be observed that the degradation of figures of merit of H-gate LNA is more significant than those of T-gate LNA. This result is due to the more significant degradation of H-gate than T-gate

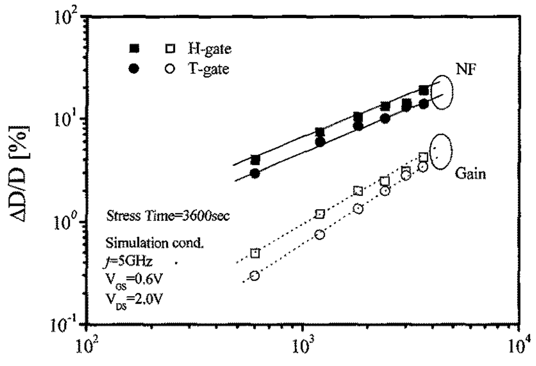

그림 7. 스트레스 시간에 따른 잡음지수와 이득 감소
Fig. 7. Degradation of noise figure and gain of LNA with stress time.

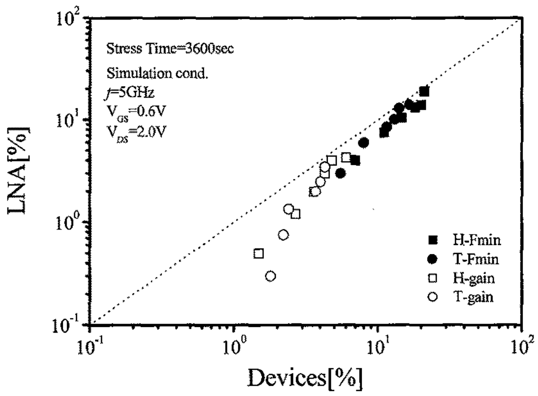

그림 8. LNA 디바이스 감소와 성능 관계
Fig. 8. Relation between device degradation and performance degradation of LNA.

structure after stress.

Fig. 8 shows the relation between device degradation and performance degradation of LNA. The performance degradation is directly proportional to the device degradation.

Ⅳ. Conclusions

The simulation results show that the degradation of figures of merit of H-gate LNA is more significant than those of T-gate LNA. This result is due to the more significant degradation of H-gate than T-gate structure after stress. Although the H-gate structure is superior to the T-gate structure for the design of LNA due to the low F_{min} and high G_{ass}, one should take care of the hot carrier effects in the design of LNA using the H-gate structure.

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저 자 소 개

엄 우 용(평생회원)
대한전자공학회 논문지
제43권 IE편 2호 참조

이 병 진(정회원)
대한전자공학회 논문지
제42권 SD편 2호 참조