Impact of passivation treatments on channel mobility for p-channel 4H-SiC MOSFETs

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1. Introduction

Recently, p-channel 4H-SiC MOSFETs have attracted much attention in complementary inverter and CMOS-IC applications [1]. However, their practical use is impeded by the high channel resistance [1]. Therefore, it is necessary to analyze the mechanism of the low channel mobility. However, there are only a few reports on channel mobility for p-channel 4H-SiC MOSFETs [2, 3]. To understand the channel carrier transport mechanisms, the Hall-effect measurement for the channel region of MOSEFTs is effective because the field-effect mobility (μ_{FE}) suffers from the uncertainty in channel carrier concentration [4]. In this work, we evaluated the impact of passivation treatments on both the field-effect mobility and channel Hall mobility for p-channel 4H-SiC MOSFETs.

2. Experimental methods

P-channel MOSFETs were fabricated on (0001) Si face 4H-SiC n-type epitaxial layers on an n-type substrate. The net donor concentration of the nitrogen-doped n-epilayer was 1×10^{16} cm^{-3}. The gate oxide thickness formed by dry oxidation was ~50 nm. Post-oxidation annealing (POA) was performed in nitric oxide (NO) ambient. NO-POA treatments were conducted at 1250 °C for 10, 30, 60, and 120 min. Hall-effect measurements were conducted by using the MOS-gated van-der-Pauw structures [4]. The strength of the applied magnetic field was around 0.5 T.

3. Results and discussion

The μ_{FE} of the four p-channel 4H-SiC MOSFETs with NO-POA is shown in Fig. 1. From Fig. 1, it can be seen that with increasing the NO-POA time, the μ_{FE} decreases. The maximum μ_{FE} was obtained with NO-POA for 10 min. It should be noted that the samples without POA and with wet-POA processes were also fabricated and measured. The sample without POA process did not turn on at the gate voltage of −20V; the wet-POA samples obtained almost the same field-effect mobility with NO10 sample (both not shown here). Figure 2 shows the Hall mobility (μ_H) of the four NO-POA samples. It can be observed that the μ_H was reduced by increasing NO-POA time in the high negative gate voltage regions where channel carrier concentration is high. Figure 3 shows the threshold voltage (V_{th}) as a function of nitridation passivation time. With increasing the NO-POA time, the absolute value of V_{th} decreases first and then increases. The decrease in the absolute value of V_{th} at the initial stage from 10 to 30 min is attributed to the nitridation passivation of interface traps. However, when increasing the NO-POA over 30 min, more nitrogen atoms are incorporated into the channel and they act as donors [5]. The increase in the donor concentration would lead to the increase in the scattering center of holes, thus resulting in the decrease in the Hall mobility.

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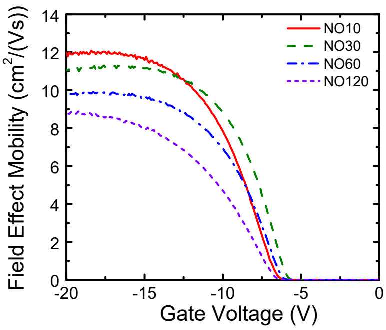

Fig. 1. Field-effect mobility of the p-channel 4H-SiC MOSFETs with NO-POA for different times.

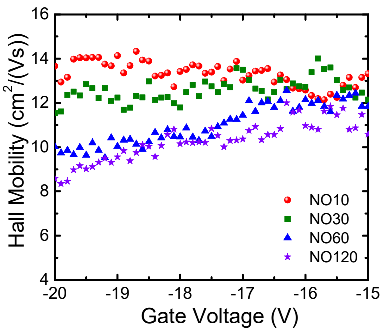

Fig. 2. Hall mobility of 4H-SiC MOSFETs with NO-POA for different times.

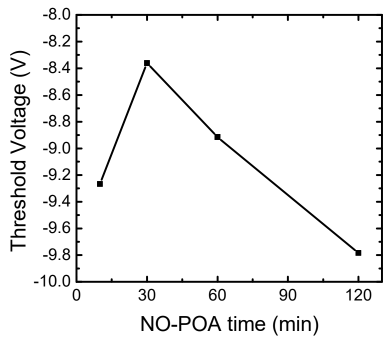

Fig. 3. Threshold voltage of the p-channel 4H-SiC MOSFETs with NO-POA for different times.