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Electrical Analysis of High Mobility Poly-Si TFTs Made from Laser Irradiated Sputtered Si Films

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High mobility poly-Si TFTs fabricated from laser irradiated sputtered Si films are electrically analyzed from Hall effect and potential profile in the channel. It is found that carrier velocity increases as carrier trap state density N_{st} is decreased, but that carrier concentration is nearly independent of N_{st}. Moreover, plateau regions of zero electric field are observed in poly-Si TFTs with high N_{st}. Therefore, it is concluded that high mobility occurs as a result of increasings carrier velocity and electric field by reducing N_{st}.

1. Introduction

Polycrystalline silicon thin-film transistors (poly-Si TFTs) are of interest for use in flat-panel display devices.[1,2] and integrated circuits in three-dimensional LSIs.[3] They may also be applicable to noncrystalline substrates.[4] Various approaches have been tried to fabricate high-quality poly-Si TFTs.[5] We have previously described a new process for high-mobility poly-Si TFTs, in which sputter-deposited Si films are subjected to laser irradiation.[6]

There are many carrier trap states at the garin boundaries, resulting in the formation of a potential barrier which affects the electrical characteristics of poly-Si TFTs. These characteristics were analyzed on the basis of the potential barrier, using carrier trap state density N_{st}.[7,8,9] Poly-Si TFT characteristics are also influenced by such factors as the number of mobile carriers, their velocity, and the electric field acting on the carrier. However, it is not clearly understood which of the factors more strongly influences on these characteristics.

This paper describes measurements of Hall effect and potential profiles in the channel for poly-Si TFTs with various N_{st} levels. The relationships of carrier concentration, Hall mobility and potential profiles to carrier trap state density N_{st} are presented.

2. Poly-SiTFT Fabrication and Measurements

Coplanar structure, N-channel poly-Si TFTs were fabricated on a noncrystalline substrate. These poly-Si TFTs, which had various levels of mobility, were fabricated from laser-irradiated sputtered Si films and sputtered gate SiO_2 films. The details of the fabriction process were described in ref(6). The mobility levels were controlled by process conditions such as laser power. Carrier trap state density N_{st} was measured for poly-Si TFTs. Hall effect and potential profiles in the channel were measured for the poly-Si TFT shown in Fig.1. The poly-Si TFTs have Hall electrodes (U1,U2,...,U6 and D1,D2,...,D4) in addition to gate, source

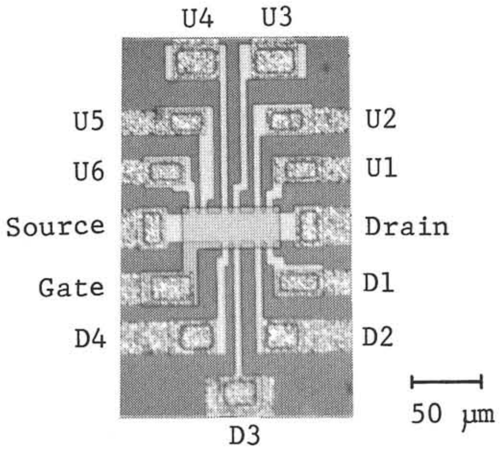

Fig.1 A photograph of poly-Si TFT with Hall electrodes.

and drain electrodes. Channel length is 69 μm and channel width is 20 μm. Hall voltage was measured as the induced voltage between two electrodes opposite each other. The Hall effect was measured under a drain current of 10 - 50 μA and an applied magnetic field of 0.71T. Carrier concentration n_e and Hall mobility μ_H and their profiles in the channel were calculated from Hall voltage, drain voltage, and the channel length and width of poly-Si TFTs. The potential profiles in the channel were also obtained by measuring the voltage in electrodes U1 to U6 against the source electrode. All measurements were done at room temperature.

3. Results and Discussion

Changes in field effect mobility μ_e and activation energy E_a as a function of carrier trap state density N_{st} are shown in Fig.2. Activation Energy E_a was calculated from the temperature dependence of the drain current. μ_e increases to a value near single crystal mobility with a decrease in N_{st}. Moreover, Ea changes from positive to negative as N_{st} is decreased. This means that the potential barrier becomes lower with decreasing N_{st}.

Figure 3 shows the profiles of Hall mobility μ_H in the channel for poly-Si TFTs

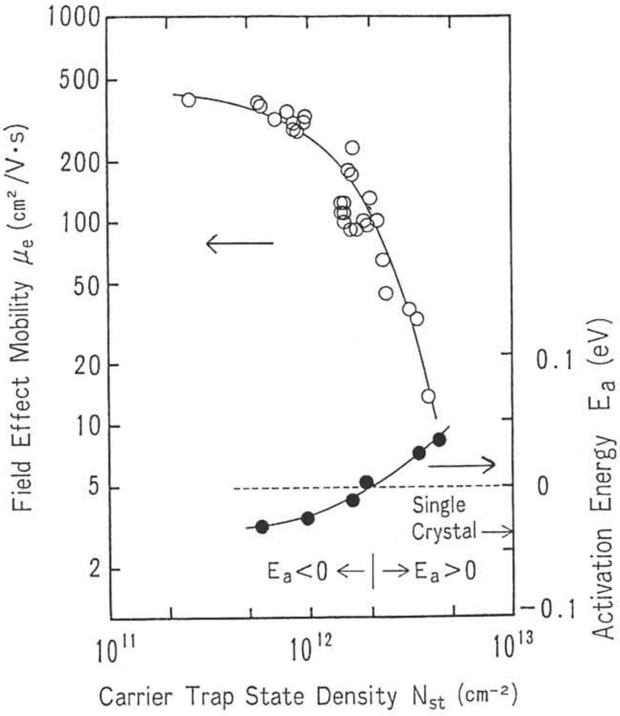

Fig.2 Carrier trap state density dependence of field effect mobility μ_e and activation energy E_a.

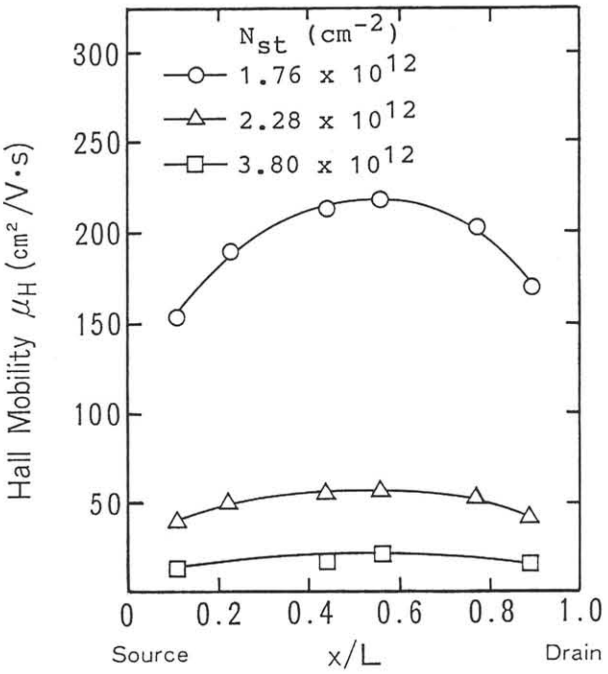

Fig.3 Profiles of Hall mobility μ_H in the channel for low and high N_{st} poly-Si TFTs. (V_g - V_t ≃ 18.6 V)

with N_{st} of 1.76×10^{12}, 2.28×10^{12} and 3.80×10^{12} cm^{-2}, which correspond to $E_a < 0$, $E_a \simeq 0$ and $E_a > 0$, respectively. Hall mobility, that is, carrier velocity itself, increases with decreasing N_{st}. Hall mobility μ_H decreases slightly near both source and drain electrodes, and the μ_H profiles in the channel are not greatly different from each other. Figure 4 shows the profiles of carrier concentration n_e in the channel for the same poly-Si TFTs as in Fig. 3. In contrast to μ_H, the n_e values for high N_{st} and low N_{st} poly-Si TFTs are nearly the same. The findings shown in Figs.3 and 4 lead to the conclusion that field effect mobility is mainly determined by carrier velocity rather than by carrier concentration.

Figures 5 (a), (b) and (c) show changes in potential profiles as a function of drain voltage for the same poly-Si TFTs as in Figs.3 and 4. As these figures show, the potential profiles are very different for carrier trap state density N_{st}. For the poly-Si TFTs with high N_{st} of Fig.5 (a), a plateau area with low or zero electric field is formed in the middle channel region. This plateau area formation is apparently due to

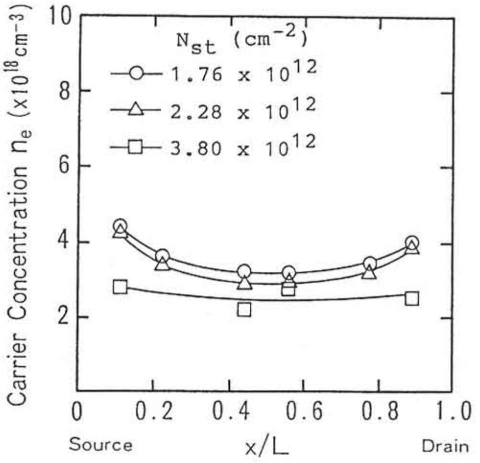

Fig.4 Profiles of carrier concentration n_e in the channel for low and high N_{st} poly-Si TFTs. ($V_g - V_t \simeq 18.6$ V)

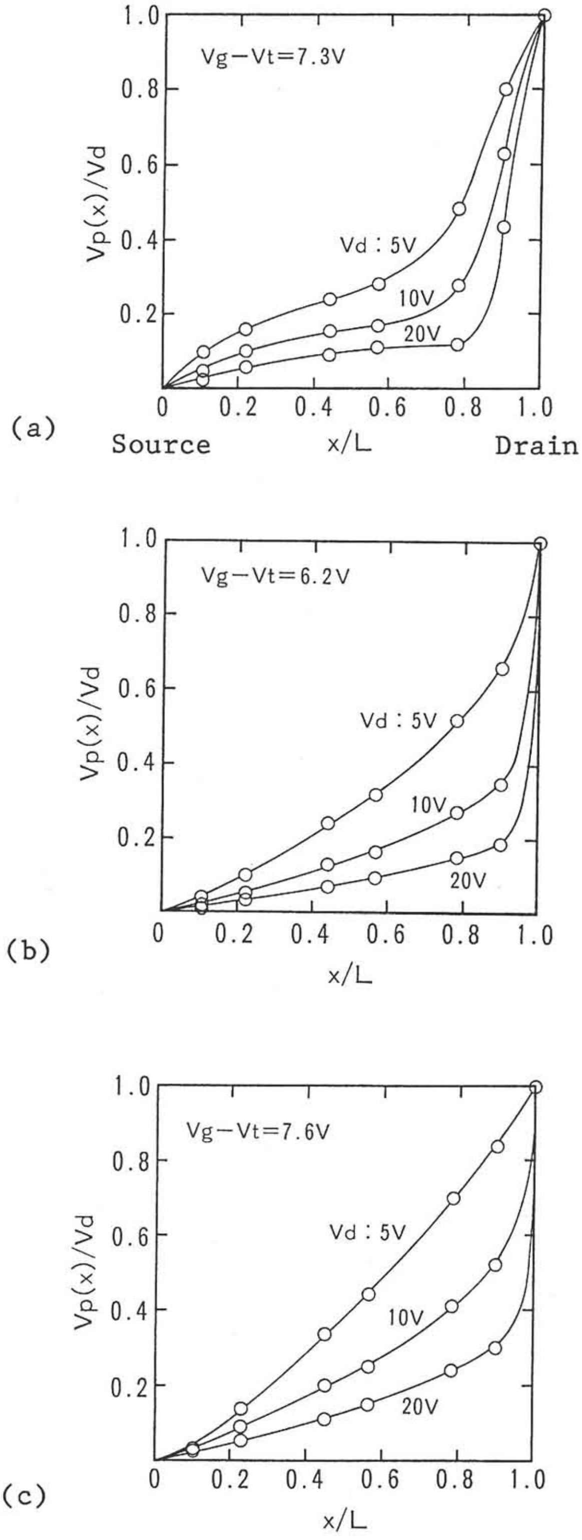

Fig.5 Potential profiles for poly-Si TFTs with different levels of N_{st},
(a) N_{st} : 3.80×10^{12} cm^{-2},
(b) N_{st} : 2.28×10^{12} cm^{-2},
(c) N_{st} : 1.76×10^{12} cm^{-2}.

a high potential barrier at the grain boundaries. However, for the low N_{st} of Figs.5 (b) and (c), poly-Si TFTs show no plateau area and have the same profiles as single crystal MOSFETs.[10)] The difference in potential profiles means that the electric field more effectively accelerates carriers in the middle channel region for low N_{st} poly-Si TFTs than for the high N_{st} poly-Si TFT.

Reducing carrier trap state density leads to increasing carrier velocity and effective carrier acceleration, resulting in high field effect mobility μ_e.

4. Conclusion

Hall effect and potential profile were measured for poly-Si TFTs with varying levels of carrier trap state density N_{st}. Carrier velocity increases as N_{st} decreases, but carrier concentration is nearly independent of N_{st}. Moreover, plateau regions were observed in high N_{st} poly-Si TFT. Thus, it is concluded that high mobility occurs as a result of increasing the carrier velocity and electric field by reducing N_{st}.

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