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Lateral Carrier Profile Measurement under Quarter-Micron MOS Devices Using Chemical Etch/AFM Method

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Lateral carrier profile measurement under quarter-micron MOS devices has been investigated by using chemical etch/AFM(Atomic Force Microscopy) method. From the experimental results, 2-dimensional carrier profiles can be measured in the source/drain region under quarter-micron MOS devices and good correlation is obtained between the effective channel length and the length obtained by the chemical etch/AFM method. These results suggest that the chemical etch/AFM method is very useful for the measurement of lateral carrier profiles.

1. Introduction

In order to design devices under quarter-micron, using TCAD(technology computer aided design) simulator, not only vertical but also lateral profile measurement is very important. In vertical profile measurement, SIMS(secondary ion mass spectrometry) and SRP(spreading resistance probe) methods have been used. On the other hand, in lateral profile measurement, a few reports have been published recently. Chemical etch method[1], SCM(Scanning Capacitance Microscopy)[2] and SIMS method[3] have been reported as direct methods to measure the lateral profile. However, few papers have been reported on the actual device application of these methods. In this paper, we have demonstrated 2-dimensional carrier profile and the electrical channel length measurement under quarter-micron devices, using the chemical etch/AFM method.

2. Experimental

In order to obtain the relationship between the chemical etch depth and carrier concentration, two kinds of samples were fabricated; BF_2^+ implanted and B^+ implanted samples. In BF_2^+ implanted samples, BF_2^+ was implanted at 20keV with a dose of 3×10^{15} cm^{-2}, followed by annealing at 850°C for 50 minutes. In B^+ implanted samples, B^+ was implanted at 70keV with a dose of 5×10^{15} cm^{-2}, followed by annealing at 1200°C for 1 hour. Cross-sections of these samples were polished and etched by a mixture of HF/HNO_3 solution. Etch depths were measured by AFM and carrier concentrations were measured by SRP. From these results, the relationship between the etch depth and carrier concentration was obtained.

By using this relationship, we measured 2-dimensional carrier profiles, and then the electrical channel length in MOS devices. Single drain P-type MOS devices were fabricated with gate lengths of 0.2-1.0 μm, as shown in Fig.1. The gate oxide thickness was 6.5nm and source/drain region was formed by BF_2^+ implantation (20KeV,$3\times10^{15}$$cm^{-2}$), followed by annealing at 850℃ for 50 minutes. After polishing the cross-sections of MOS devices, these samples were chemically etched and the etch depth was measured by AFM.

3.Results and Discussion

Figure 2 shows the dependence of chemical etch depth on carrier concentration in BF_2^+ implanted samples. The relationship was obtained at carrier concentrations below 1×10^{20} cm^{-3}. In this region, defects such as implantation damage and boron segregation did not affect the measurement. Etch depth has a strong relationship with carrier concentration and the minimum detection limit of carrier concentration was approximately 1×10^{18} cm^{-3}. When we used another etchant such as a different ratio of mixture or a different solution, carrier concentration below 1×10^{16} cm^{-3} was detected. The boundary of the junction can be easily detected, however, a poor relationship between etch depth and carrier concentration was obtained. Thus, etchant should be improved for detailed measurement. In Fig.3, the relation of etch depth against the carrier concentration is shown in B^+ implanted samples. The same relation as BF_2^+ implanted samples , as shown in Fig.2, was obtained. Therefore, these results indicate that etch depth is determined only by carrier concentration.

2-dimensional carrier profiles were measured in single-drain P-MOS devices, using the relation of etch depth versus carrier concentration. Etch depth was measured by AFM after etching the cross-section in P-MOS device with a gate length of 0.2 um. From the result of etch depth, a 2-dimensional carrier profile was obtained. The result is shown in Fig.4. Electrical channel length was about 140nm in this case. Vertical and lateral carrier profiles in the source/drain region are shown in Fig.5. In the lateral carrier profile, carrier concentration was plotted from the gate edge. Although the detection limit of carrier concentration in our experiment was approximately 1×10^{18} cm^{-3} and the electrical channel length was determined at the channel concentration, the measurement error is very low, because the lateral profile is very abrupt at concentrations below $1\times10^{18}cm^{-3}$, as shown in Fig.5. In order to demonstrate the validity of electrical channel length measured by chemical etch/AFM method, effective channel length was measured electrically. The series resistance between source and drain was measured by changing the gate voltage for devices with different gate length, when the voltage of 0.1 V was applied between source and drain. The result is shown in Fig.6. From this figure, the effective channel length was found to be 0.1um smaller than the actual gate length. Figure 7 shows the relation between the effective channel length and the length obtained by chemical etch/AFM method. Good correlation was obtained by both methods. These results suggest that the chemical etch/AFM method is very useful to evaluate the 2-dimensional carrier profile, and then the electrical channel length.

4. Conclusion

We demonstrated the lateral carrier profile and the electrical channel length measurement under quarter-micron devices, using chemical etch/AFM method. This method is very simple and useful for the development of sub-quarter-micron devices. By combining this method with a TCAD simulator, the design of quarter-micron and sub-quarter-micron devices will progress with higher accuracy.

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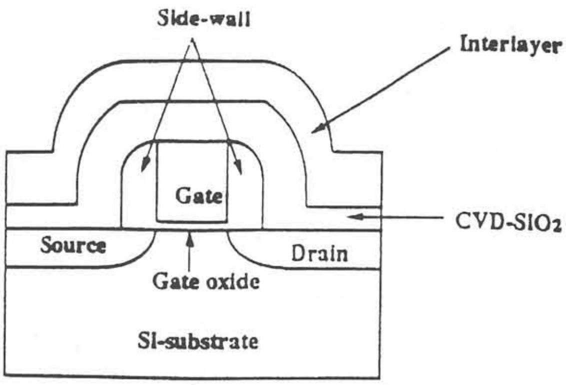

Fig.1 Schematic cross-section of PMOSFET structure

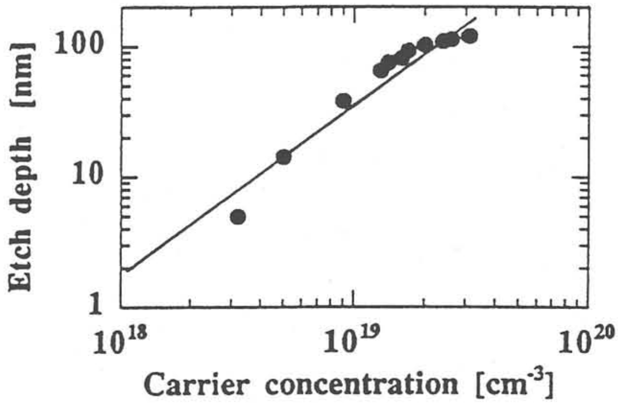

Fig.2 The relationship between etch depth and carrier concentration for a BF_2^+ implanted sample

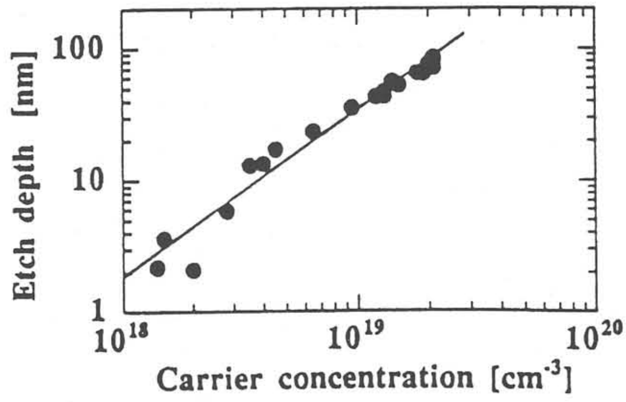

Fig.3 The relationship between etch depth and carrier concentration for a B^+ implanted sample

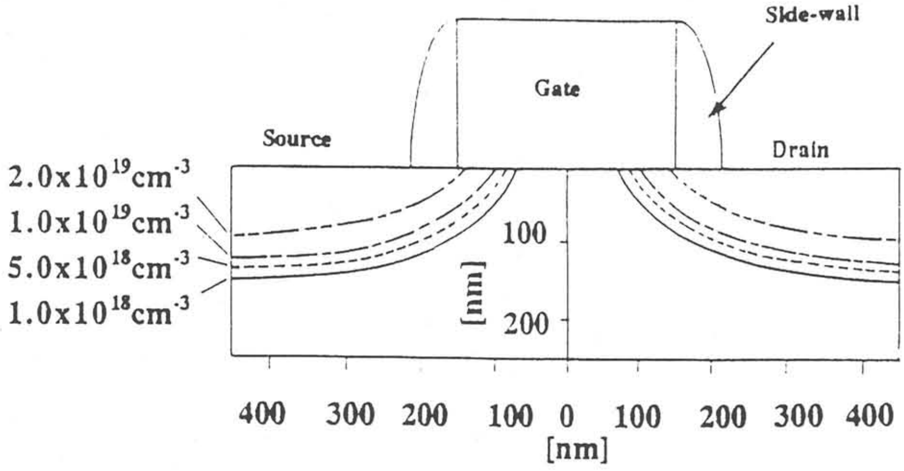

Fig.4 2-dimensional carrier profile obtained by the chemical etch/AFM method

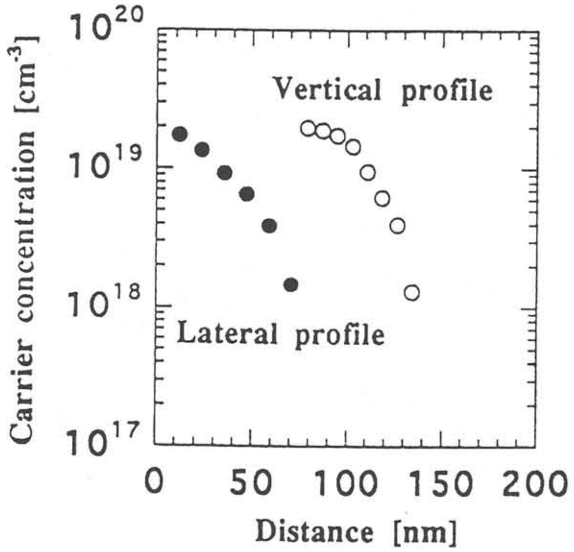

Fig.5 Vertical and lateral carrier profiles

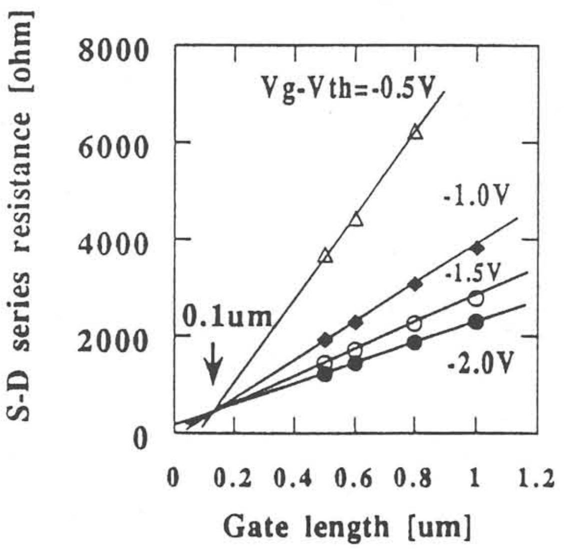

Fig.6 Effective gate length measurement

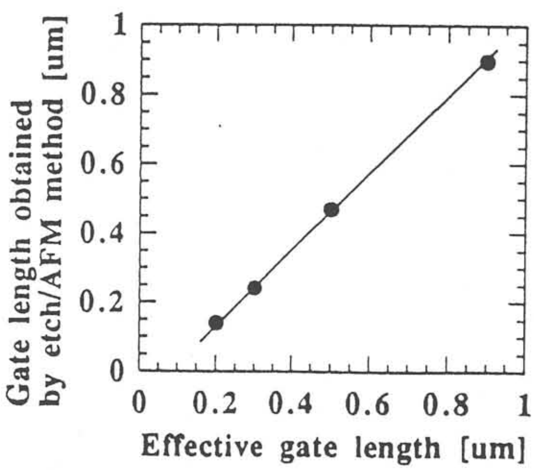

Fig.7 Relationship between the effective channel length and the length obtained by the chemical etch/AFM method