산화아연 박막의 고주파 대역 특성 분석
Modulation of high frequency propagation of ZnO film

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1. Introduction

ZnO is an inorganic compound comprised of elements from II-IV groups. ZnO has several merits which are suitable for the applications in variety of fields. ZnO has good transparency, high electron mobility (4000 cm^2/V), wide bandgap (3.37 eV), high carrier concentration (7.5 x 107 cm^{-1}), high current density (>400 mA/mm), strong room-temperature luminescence, piezo-electricity, etc. From such merits, the upcoming applications in transparent electrodes in LCDs, energy saving windows, and the electronic applications in thin-film transistors and light-emitting diodes were feasible.[1, 2, 3]

As the device size gets smaller to nano-meter scale, it is important to investigate characteristics of the intrinsic material by confined quantum effects. This paper conducts experiment regarding transmission properties of ZnO film, the form of micro-rod, and extract data by excluding extrinsic variables. The result also compares the characteristics with ZnO nanowire in nano-meter scale.

2. Experimental details

The device was fabricated on highly doped n-type Si wafer (0.002 Ω/cm) with thermally grown 100 nm SiO_2 for ac parameter characterization. On the wafer, 40nm single crystal ZnO films were grown by CVD method. In order to form ZnO film into a 3-micro-meter-wide thin film rod, SPR3612 and BOE ZnO film wet etchant was used. For the ohmic contact, Ground-Signal-Ground with 10 nm Ti and 400nm Au electrodes were deposited on the top of the ZnO film rod and annealed at 300ºC for 30 minutes. The schematic view of the set-up is shown Fig. 1 (a) with equivalent circuit model for a transmission line shown in Fig. 1 (b). I-V curve is shown in Fig. 2.

The transmission characteristic is measured (S-parameters S_{11}, S_{21}, S_{12}, S_{22}) using with Agilent E8364A network analyzer from 100 kHz to 4.5 GHz. These S-parameters (or scattering matrices), obtained from incident and reflected voltages at each frequency, provides a complete description of the network as seen at two ports.

3. Results and Discussion

S-parameter measured from the network analyzer contains transmission properties not only of ZnO film but also of capacitance effect between two contact pads. Parameters extracted from raw S-parameter may have typical error which seems to have better transmission properties than the intrinsic material in high frequency. In order to subtract the capacitance effect from the raw S-parameter, we introduce Y-parameter de-embedding technique.[4] ZnO film rod S-parameter de-embedded from open data is shown Fig. 3 (a) with comparison of ZnO nanowire and open S-parameters. The S_{21} parameter observed in ZnO film rod seemed to be lower than the ZnO nanowire in lower frequency regime. We also observed the impedance Z according to the frequency as shown in Fig. 3 (b) and found that it decreased as the frequency increased.

Classical RF interconnections are described by the Telegrapher's transmission line model. Telegrapher's transmission line model consists of, R, the series of resistance per unit length, L, the total self-inductance of the two conductors per unit length, G, the shunt conductance, and C, the shunt capacitance per unit length. These RLGC parameters explain the RF signal propagation constant and the characteristic impedance in the frequency domain.[3] The parameters except shunt conductance were decreasing as the frequency is increased up to 4.5 GHz as shown in Fig. 4. The values of all four parameters seemed to be lower than that of the ZnO nanowire's.

4. Conclusion

The data obtained from S-parameter with analysis of Telegrapher's equation showed that although S_{21} parameter is found out to be higher with ZnO nanowire, lower RLGC values were obtained with ZnO film. This phenomenon can be explained by the difference in geometrical properties. ZnO film seemed to be less dependent on the extrinsic factors than ZnO nanowire by its lower surface-to-volme ratio. More researches regarding narrower ZnO film should be investigated in order to analyze the performance of two forms precisely.

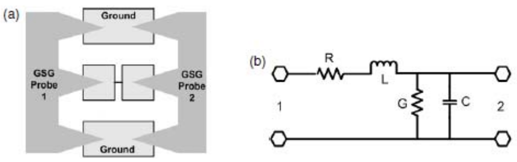

Fig. 1 (a) Two-port measurement of ZnO film (b) Equivalent circuit model for a transmission line

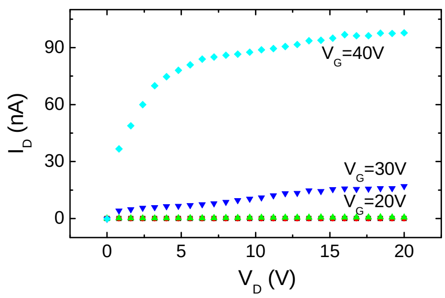

Fig. 2 I-V curve of ZnO film with width of 3μm

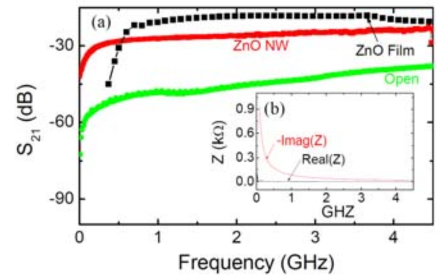

Fig. 3 (a) S_{21} of ZnO film, ZnO NW and open electrodes (b) Real and imaginary impedance

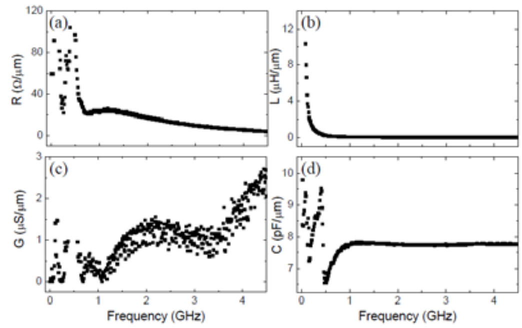

Fig. 4 (a) Series of resistance (b) Total self-inductance (c) Shunt capacitance (d) Shunt capacitance

후기

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