Wireless Interconnects for UWB Signal Transmission in ULSI s

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1. Introduction

In order to realize 3D-intergration of ULSI, global wireless interconnection will be a key technology which utilizes electromagnetic wave transmission by using ultra wideband (UWB) transceiver system. Figures 1 and 2 show concepts of wireless interconnects using integrated antennas fabricated in Si ULSIs and a 3D integration of ULSIs with wireless interconnects. Issues for on-chip Si integrated antennas are transient response of the transmitting and receiving antennas fabricated on Si substrates and signal interference for UWB communication between chips. In this study, the transient response, bit error rate (BER) and interference in UWB communication in and among Si chips are investigated. UWB transmitter and receiver are designed and fabricated for evaluation.

2. Experimental

P-type (100) Si wafers were prepared. The surface of Si was oxidized to form 0.3 μm thick field SiO_2. 1.0 μm thick aluminum was deposited on the SiO_2 layer and 10 μm wide and 6 mm long linear dipole antennas were fabricated on SiO_2.

Figure 3 shows a measurement set-up for BER of UWB signal transmission using integrated linear dipole antennas. Pseudo random binary signals generated by serial BERT were transformed to Gaussian monocycle pulse (GMP) trains by two impulse forming networks (IFN). 180º hybrid couplers were inserted between the dipole antenna and the IFN. The GMPs were transmitted and received by linear dipole antennas and recorded by the sampling oscilloscope. The received signals were recovered as binary data and compared with the generated signal to obtain the BER. The antenna measurement set-up for interference is shown in Figs. 4.

3. Results and Discussion

Figures 5(a) and 5(b) show the effect of Si substrate resistivity on the BER for 5 Gbps and 13.5 Gbps, respectively. The lowest BERs were achieved as 4×10^{-3} and 1.6×10^{-2} for data rates of 5 Gbps and 13.5 Gbps, respectively. The BER increased with increasing the distance between transmitting and receiving antennas. Figure 6 shows the effect of horizontal distance on the BER. The BER of 32,767 bit pseudo random binary sequence (PRBS) was 3.1×10^{-5} for 1 mm distance between antennas on 10 Ω·cm resistivity Si substrate, when data rate was 7 Gbps. Interference of 5 Gbps digital noise was observed. UWB signals were interfered by high-data-rate digital noise from a transmission line in a different chip. It is found that differential mode signal with 5.1 GHz high-pass filter could recover Gaussian monocycle pulses as shown in Fig. 7.

A schematic block diagram of the UWB transmitter is shown in Fig. 8. The circuit is implemented in 0.18 μm CMOS process. The differential voltage controlled ring oscillator (VCO) generates rectangular shaped clock pulse and the differential clock pulse is digitally mixed with the non-return-zero (NRZ) data by using 'AND' gate to generate on-off keying (OOK) modulated signal. To reduce the common mode noise and transmit the GMP by integrated dipole antenna, single ended GMP is converted to differential GMP by using single input differential output amplifier. The Output amplifier has a voltage gain of 7.28 dB at the center frequency of GMP (2.4 GHz) and wide bandwidth. A source follower circuit is used to avoid reflection due to impedance mismatch between the transmitter circuit and antenna. The transmission of OOK data modulated signal in interchip communication by integrated antennas on silicon was simulated as shown in Fig. 9. The received signal is the derivative of the transmitted signal and the transmission and reception were achieved at the rate of 1.4 GHz.

4. Conclusion

Inter-/intra-chip wireless interconnection in Si using integrated dipole antennas for UWB signal transmission was developed and characterized. UWB transceiver circuits were developed.

Acknowledgment

This work is supported by the Ministry of Education, Culture, Sports, Science and Technology, Japan under the 21st Century COE program and the Grant-in-Aid for Scientific Research.

References

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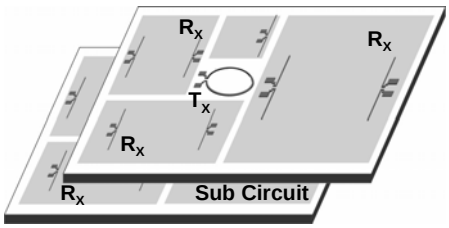

Fig. 1. Concept of wireless interconnect using integrated antennas in multiple Si ULSI chips.

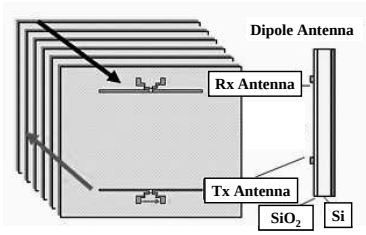

Fig.2 Iinterchip wireless interconnect system for future 3D integration of ULSIs.

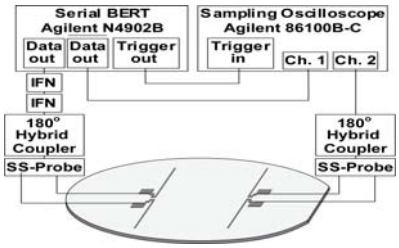

Fig. 3. Measurement set-up for bit error rate of ultra-wideband signal transmission in time domain.

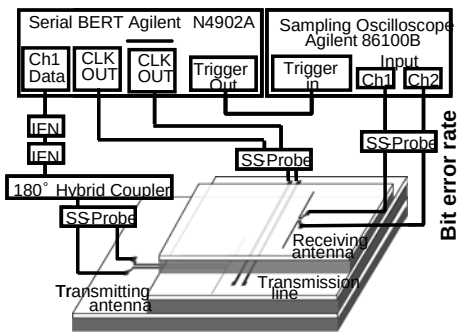

Fig.4. Wafer level measurement set-up for interference of UWB signals in stacked chips.

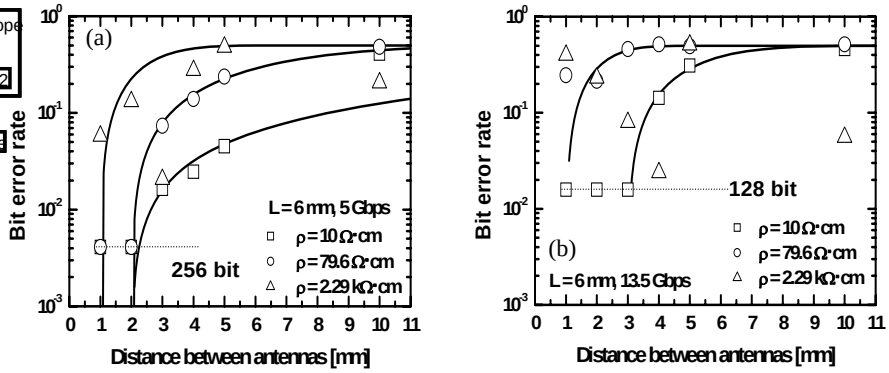

Fig. 5. Effect of Si substrate resistivities on bit error rates of 128 bit pseudo random binary signals. (a) Bit rate = 5 Gbps, (b) Bit rate = 13.5 Gbps.

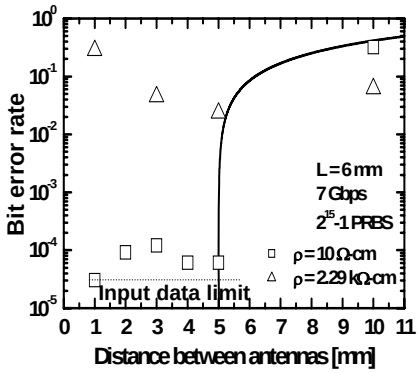

Fig. 6. Effect of distance between antennas on bit error rates of 32,767 bit pseudo random binary signals.

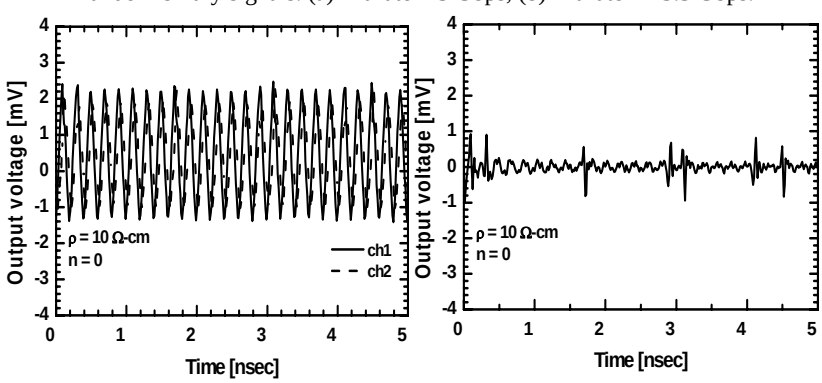

Fig.7. Waveforms of data transmission with interference. (a) Received signal interfered by 5GHz digital noise. (b) Differential GMP signal recovered by 5.1 GHz high-pass filter.

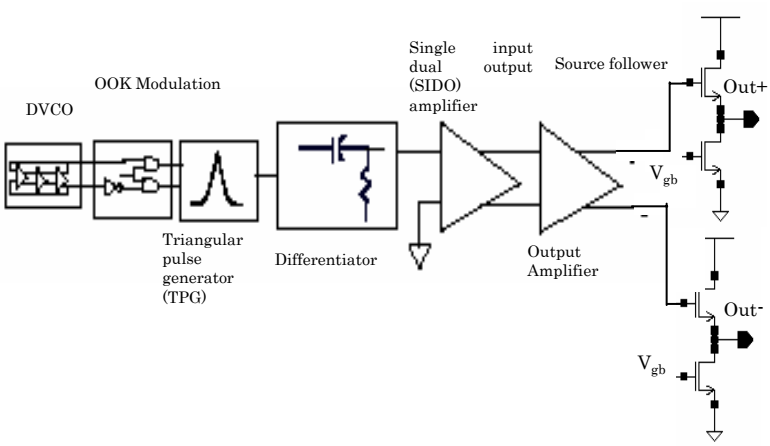

Fig.8. Schematic block diagram of impulse based UWB transmitter.

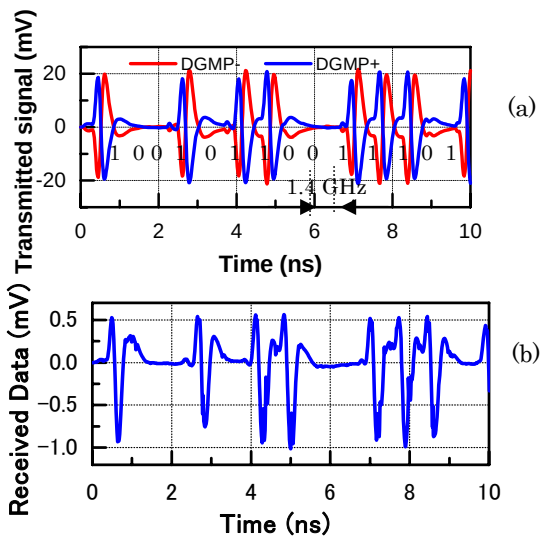

Fig. 9. Interchip transmission of On-Off-Keying modulated data using integrated dipole antenna in Si. (a) Transmitted signal. (b) Received signal at 3 mm distance.