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Bulk Charge Transfer Device

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A new type charge transfer device based on the transport of majority carriers through a thin semiconductor layer is proposed and successfully experimented. In this Bulk Charge Transfer Device (BCD), the main role to isolate and transfer a charge packet is carried out by applying to the transfer electrode the clock voltage of such polarity that repels the majority carriers. The polarity of this voltage is opposite to that for the burried channel CCD.[1] This mode of operation makes possible the BCD with an electrode-gap of loosed toleranse, e.g. 6 μm, to operate over the frequency range of 10 kHz to 15 MHz with a low clock voltage of 4 volts and with sufficient signal charges of above 10^{12} cm^{-2}.

The principle of the BCD is illustrated in Fig.1, showing the situation as the charge packet of electrons, i.e. the majority carriers of the n-type layer, is being transfered from the region under electrode 2 to that under electrode 3. Those regions are electrically isolated by a sufficiently large and negative voltage; -Vc, applied to the electrode pairs 1 and 1'. When the voltage applied to electrode 2 goes down from 0 to -Vc, and that applied to electrode 3 goes up from -Vc to 0, the charge packet is pushed deep into the n-type layer and, pulled by the ionized donors under electrode 3, it is transfered through inside the n-type layer apart from the Si-SiO_2 interface.

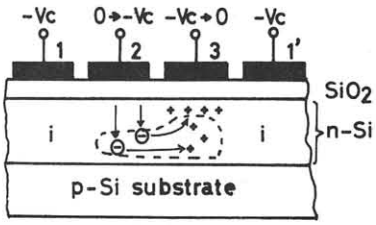

Fig.1 Schematic of part of a 3 phase BCD to show the transfer of the charges
⊖ : charge to be transfered
+ : ionized donor in a state of non-equilibrium

Fig.2 shows the equipotential curves in the device computed with the depletion approximation. The charge packet should be transfered as indicated by an arrow along the potential valley inside the n-type layer.

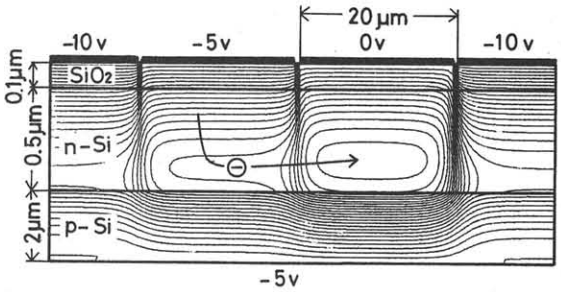

Fig.2 Equipotential curves around the channel computed with the depletion approximation solving two dimensional Poisson's equation by relaxation method
N_D: $3x10^{16}$ cm^{-3}
N_A: $1x10^{15}$ cm^{-3}

The principle of the device operation allows to use either reverse biased p-n junctions or schottky junctions for the transfer

electrodes and sapphire or spinel for the substrate.

Two types of 8 bit - 3 phase BCD with electrode-gaps of 2 μm and 6 μm were prepared. The cross-sectional view is schematically shown in Fig.3. The impurity of the n-type layer was accurately controlled to be a density of 1.5×10^{12} cm^{-2} by ion implantation of phospher, and was diffused to the depth of about 0.5 μm during the gate-oxidation to get the gate oxide of 0.1 μm thick.

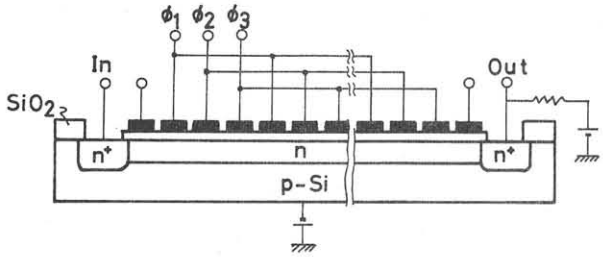

Fig.3 Cross-sectional view of 3 phase BCD. The specifications of the prepared 8-bit BCD was as follows;
depth of the n-type layer: 0.6 μm
width of the layer (channel width): 100 μm
impurity density of the layer : 1.5×10^{12} cm^{-2}
length per bit : 60 μm

Fig4 shows measured curves of the transfer inefficiency vs.the transfer frequency. Constant transfer inefficiency due to the electrons under the electrode-gap was observed. High frequency performance exeeds over that of CCD due to the device operation with bulk mobility which was measured as much as 800-900 $cm^2 sec^{-1} v^{-1}$.

Fig.5 demonstrates the transfer of video signal through the device with clock frequency of 10 MHz.

The authors are grateful to Dr. Y. Ohya, Mr. M. Ashikawa and Mr. M. Ozawa for their encouragements and co-operation.

Reference

1) R. H. Walden et al : Bell Syst. Tech. J. Brief, 51, (1972) 1635.

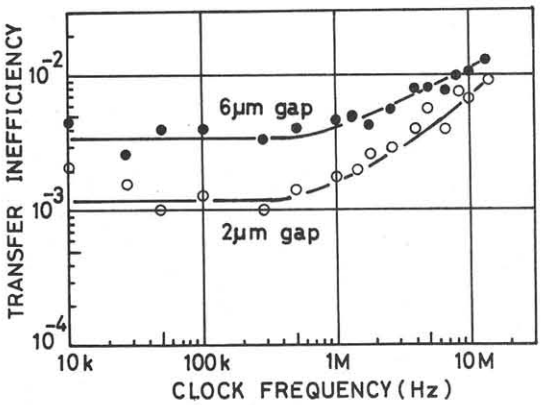

Fig.4 Transfer frequency dependancy of the transfer inefficiency of BCD fablicated

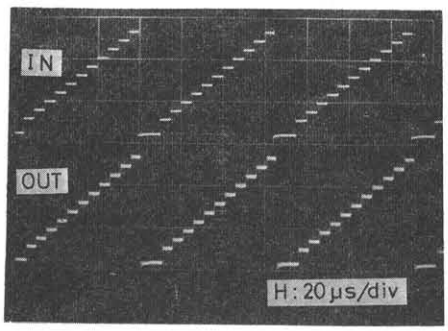

Fig.5 Transfer of video signal through 8 bit BCD