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Monolithic Surface Wave Memory with Long Storage Time

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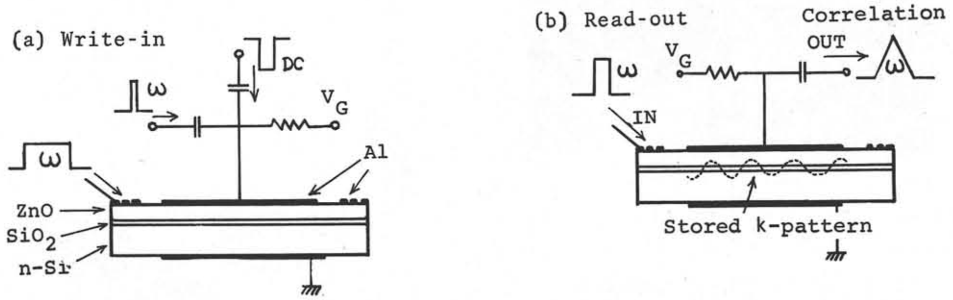
Several experiments on the storage of phase and amplitude of surface acoustic waves have been made using the airgap-coupled semiconductor-piezoelectric structure in which signals were stored in surface states of Si[1], in a Schottky diode matrix[2], and in a p-n diode matrix[3]. Storage times of these devices are of the order of 10^{-2} -10 sec. We report here a new type surface wave storage device with a storage time of more than 10 hours using a $ZnO/SiO_2/Si$ monolithic structure.

The device we used is the same as ordinary monolithic convolvers[4-7] whose structure is shown in Fig.1(a). An rf sputtered ZnO film with the thickness of 2 μm was grown on the (111) surface of n-Si(resistivity:100 Ωcm) covered with 0.1 μm thick thermally grown SiO_2. Two port insertion loss at the frequency of 130 MHz is 27 dB. The convolution signal is sensitively controlled by the dc voltage applied to the gate electrode(length:2 cm). A maximum convolution efficiency is -60 dBm when the gate voltage is -8.5 V at which the Si surface is found to be depleted from the C-V measurement.

In order to store the signal, as shown in Fig.1(a), a surface wave was launched by applying to the transducer an rf pulse whose amplitude and duration were 55 V_{pp} and 8 μs respectively. An rf pulse of 1.4 V_{pp} and 8 μs was applied to the gate at the time when the surface wave was propagating under the gate, and simultaneously, a negative dc pulse with the height and duration of -50 V and 3 μs respectively was superposed to the gate. To read out the stored signal, a surface wave with the duration of 1 μs was launched and the output correlation signal was detected from the gate as shown in Fig.1(b). Fig.2 shows the signal read out 30 min after write-in. As shown in Fig.3, nearly 1/4 of the initial

Fig. 1 Experimental Setup



signal remains after 10 hours. Without the negative pulse in the write-in process, the storage time decreased to the order of milliseconds. We interpret these results as follows.

During write-in, the surface wave and the rf gate pulse couple via space-charge nonlinearity of electrons in Si, resulting in the creation of a charge grating(k-pattern) whose period is the same as the wavelength of the surface wave. This charge grating is trapped in some localized states. In the read-out process, the reading surface wave couples with the charge grating and generates the correlation output at the gate. When the negative pulse is not applied in write-in, the trapping centers for the k-pattern are surface states at SiO_2/Si interface which give a storage time of several milliseconds[8]. When the negative pulse is applied, electrons are injected from the gate electrode into the ZnO film and are trapped at ZnO/SiO_2 interface in the form of the k-pattern. These trapping centers have much greater detrapping time constant than that of the surface states at SiO_2/Si interface. Therefore much longer storage time is obtained. We ascertained that these charges can be erased by illuminating the sample with white light.

In conclusion, we have demonstrated an acoustic surface wave memory with the storage time longer than 10 hours based on a new mechanism. This monolithic device is expected to be useful in various applications in signal processings.

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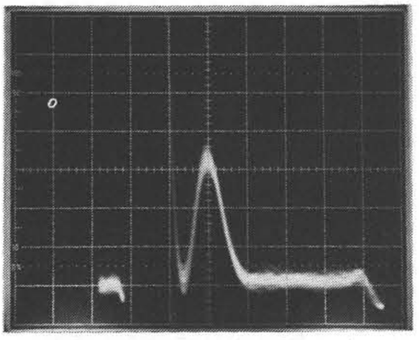

Fig. 2 Read-out of a Stored Signal
30 min after write-in
Time Scale: 1 μs/div.

Fig.3
Stored Signal Amplitude vs Time