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SURFACE ACOUSTIC WAVES ON SEMICONDUCTORS

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ABSTRACT. The paper is concerned with a discussion of SAW properties on semiconductor substrates. Some applications are briefly highlighted.

1. INTRODUCTION

With the continuous advancement of the technology level of integrated circuits, completely new prospects have emerged also for other fields of the production of electronic solid-state devices.

One field whose theoretical fundamentals have long been known [1] and which has been opened up for the production of signal processing devices only by the application of technological steps of microelectronics, is that of acoustoelectronics. Here, electric signals are converted into acoustic surface waves. These waves propagate along the surface of a solid delaying (storing) the signal because of the relatively slow propagation velocity, and will thereupon be reconverted. At present, some millions of solid-state filters presenting the most various filter characteristics are being produced according to this principle in some countries of the world and used as discrete components.

Since both microacoustic and microelectronic devices represent solid-state components manufactured by applying procedural steps of microelectronics technology and since, furthermore, there is a tendency towards still higher degrees of integration, the idea of connecting both techniques suggests itself [2].

2. MATERIALS

Discrete acoustoelectronic devices are produced almost exclusively from piezoelectric insulators (lithium niobate $LiNbO_3$, quartz SiO_2) in monocrystalline form, while in microelectronics silicon plays, now as before, an outstanding role as substrate material. In practice, the excitation of acoustic surface waves is brought about exclusively by utilizing the piezoelectric effect. Silicon not being piezoelectric, a layer consisting of a piezoelectric material must be deposited in the case of monolithic integration. The layer materials preferred at present for this purpose are zinc oxide (ZnO) and aluminium nitride (AlN). The increasing use of new semiconductor materials has also led to an increase in the possibilities of linking these two techniques. This concerns especially gallium arsenide (GaAs) which is particularly well suitable to serve as piezoelectric semiconductor [3].

3. COMPONENT PRINCIPLES

There have become known some solutions in the form of hybrid circuits on a ceramic substrate, for example, as integrated oscillators [4]. In the case of another device, $LiNbO_3$ is used as piezoelectric material for the excitation and propagation of the acoustic surface waves, and the signal is coupled into an integrated circuit on the basis of field effect transistors *via* an air gap of a width of 300 nm and metal electrodes [5].

A further step consists in the monolithic integration with direct interaction between the acoustic surface waves and the electronic devices. For this, there have been developed in particular various types of programmable coding and decoding devices [6, 7, 8]. Here, the acoustic surface waves can interact with the charge carriers in the channel of an FET either by utilizing the mechanical stress in the piezoresistive FET or by utilizing the electric field which accompanies the wave during its propagation in a piezoelectric substance or in the piezoelectric layer system. The principle of such filter arrangements is based on the fact that the electric signal has practically propagated in the form of an acoustic surface wave along the surface of the solid during its travel time and can be sampled *via* taps. In an integrated monolithic circuit, these taps may either be fixed-programmed or provided with a program function varying with time. Comparable results can also be obtained by appying other circuit-engineering solutions, but only at considerable expenditure.

Acoustoelectronics is particularly well suited for sensor technology as it is possible to couple the measuring signal representing a frequency change directly to the computer engineering means. In this case, too, integrated monolithic components connecting the sensor part with a microelectronic part offer some special advantages [9, 10].

Completely new solutions for devices will result by consistently advancing the concept of integration and by utilizing the interaction of the acoustic surface wave with the charge carriers in the semiconductor directly for signal processing. The original idea of transferring energy from drifting electrons to acoustic surface waves in order to realize in this way acoustoelectronic amplifier components [12] has turned out to be right from the physical point of view; however, it failed to find a wider application. In comparison, other principles of microelectronics are more and more often transferred to the field of acoustoelectronics. Thus, for example, tapped delay lines serving as coding devices have been proposed in the case of which the transport of charge carriers is realized *via* acoustic surface waves (Acoustic Charge Transport – ACT), similarly to the CCD principle [13]. An important group of devices has emerged from the utilization of nonlinear effects in the interaction between acoustic surface waves and electric charge carriers. Such devices (convolvers) are able to realize a number of signal processing functions as, for example, the convolution of two signals, the correlation of signals, signal compression and inversion, selection by variable filter functions, as well as the coding and decoding of signals [14].

Further possibilities will probably emerge when storage correlators are constructed including storage effects in semiconductor devices [15].

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