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THE ANALYSIS OF TECHNOLOGICAL METHODS FOR PREPARATION OF REFLECTING GRADING FOR DEVICES BASED ON SURFACE ACOUSTIC WAVES

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The formation methods for reflecting grooves with vertical walls and depth of up to 7 μm are analyzed and optimized at the paper.

The devices based on surface acoustic waves (SAW) find wide applications in UHF radioelectronics equipment. The increase of operation frequency up to 500 MHz leads to increase of device dimensions to micron and submicron range.

Two ways can be used to obtain high parameter value for devices based on SAW. The first way compensates repeated and secondary effects by their consideration in algorithm of structure synthesis for interdigital transducers. It requires use of complicated models which describe their operation and it leads to complication of problem of construction optimisation.

Second way which we present in this paper is oriented on design of new technological&construction solutions for SAW processing elements and SAW devices as a whole. These solutions should minimize the influence of repeated and secondary effects and these solutions should be easily described by simple models [1].

The typical solution for SAW devices is using of reflecting grating. The wide use find reflecting gratings which have groove forms and are formed in piezoelectric substrate. The level of repeated and secondary effects is rather low in comparison to similar SAW devices.

Periodical gratings which use grooves for SAW reflection find wide use in stripline filters, delay lines, dispersive delay lines, matched filters for phase-shift keyed signal, resonators, non-linear processor etc. Simple and efficient description of reflecting process can be obtained for conditions of low reflectance which is realized in filters with reflecting grooves. At these conditions every groove reflects just only small part of surface wave energy. Comparatively high reflectivity factors are observed as a results of reflections on many grooves.

Simple geometrical relations allow to obtain functional dependence of reflectivity factor on groove depth. The important parameters are just only wavelength λ and groove depth h. Thus reflectivity factor r should be function of h/λ [2]:

$$r = C(h/\lambda), \tag{1}$$

where C is constant.

Changing groove depth *h*, reflectivity factor can be adjusted according to linear law at defined frequency. This aspect which allows to simple change the reflecting ability is important for SAW devices. The simple periodical grating formed by system of N grooves is shown in Fig. 1 (h is groove depth, W is groove width, d is grating spacing).

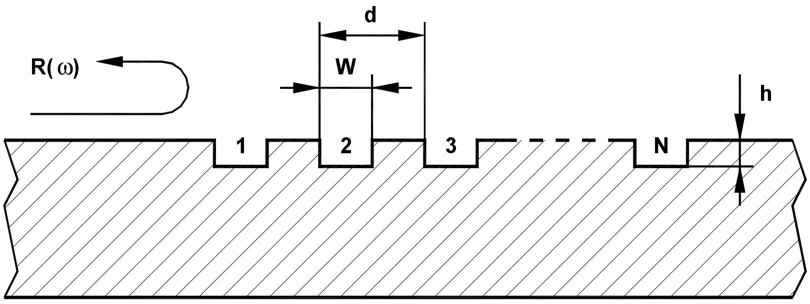

Fig. 1. Simple periodical grating formed by system of N grooves (1, 2, 3, ... , N)

The next conclusions emerge after analyzing the interaction between SAW and reflecting structure:

– the basic characteristics of SAW devices with reflecting gratings are defined by geometrical dimensions of etched grooves;

– high precision of reflecting structure manufacturing is required to ensure tolerable limits for electric parameters because of low speed of SAW propagation.

Above-mentioned aspects allow to formulate main criterions for technological process of reflecting groove manufacturing. Firstly, technological process should allow high resolution i.e. it ensures elements with small dimensions (~ 1 μm). Secondly, technological process should be highly anisotropic, i.e. it ensures grooves with vertical walls. Process anisotropy is caused by need of to repeat elements with micron width and by rectangular groove profile which is the easy one to reproduce and to calculate. Thirdly, groove depth should be controlled during manufacturing process because this depth defines reflecting ability and grating phase characteristics. Fourthly, technological process should be highly selective, i.e. it ensures selective etching without damage of mask or lower layer.

Modern state of SAW devices requires design of technology which allows to form reflecting grooves with vertical walls in piezoelectric substrate with depth of up to 7 μm.

Liquid chemical etching does not fit because of isotropic character and complication to control material removal. Dry etching method using directed flow of charge carriers allow to ensure high anisotropy and processing uniformity but necessity of deep etching in piezoelectric materials which possess low ion etching speed requires improved productivity and precision of manufacturing process and it limits using of technological processes developed for semiconductor and IC technologies. Thus, design and study of new technology for ion-stimulated etching of reflecting grooves is actual problem.

The grooves are produced by ion etching using УРМ3.279.029 apparatus with self-contained ion source ИИ-3-01 at next mode:

– argon pressure - $4x10^{-1}$ Pa;

– electromagnet current – 0.22 A;

– cathode current - 85-90 A;

– anode voltage - 48 V;

– discharge rate – 14.5 A;

– accelerating voltage – 2.5 kV;

– ray current – 0.07 A.

At groove etching up to 1 μm the photoresistive mask can be used with thin aluminium layer (d = 0.3 μm) and this mask is used further to form interdigital transducers (IT). Photoresist ФП-383 forms stable photoresistive mask. To form groove image photoresist was thermal treated: at 373 K for 30 min. at 423 K for 15 min. and at 443 K for 30 min. Photoresist removal after ion etching occurs in heated triethanolamine. IT image was formed by known photolithography methods.

The new achievement in formation of microelectronic device structure is chemical etching stimulated by laser irradiation [6]. This technology allows to realize one-step mask-free process of formation of reflecting structure and to reduce production work content. Laser etching allows to simplify process by elimination of repeated operations of photolithography Besides, high process locality allows to correct topology of manufactured devices to adjust parameters and reduce defect influence.

Laser etching process similarly to plasma etching using directed flow of charge carrier allow to achieve micron and submicron values but laser etching does not make any radiation damage in processed material.

Minimum dimension of element is determined by equation

$$l_{min}= d+2\lambda_c, \qquad (2)$$

where d is dimension of laser beam on the processed surface;

λ_c is average free path for photogenerated particles.

Etching speed increases in inverse proportion to laser beam radius. Laser etching speed (up to 20 μm/sec) exceed speed values for liquid and plasma etching methods. Etching depth possesses hyperbolic dependence on laser beam scanning speed.

We manufactured series of stripline filters, rezonators and dispersive delay line based on SAW with reflecting grooves using laser etching method. For example we designed filter on frequency of 471 MHz and relative bandwidth of 1 %. SAW is actuated by ITs and SAW double reflects on identical gratings and finally SAW comes to output IT. (Fig. 2). Reflecting structures with 100 grooves installed under angle of θ = 39,67° to Z axis [2]. Groove depth was calculated according [2] and is 0.3 μm. Gain-frequency characteristic was studied using X1-39 apparatus in unmatched mode. The change in groove depth in limits from 0.3 to 0.7 μm leads to dissipation in a range of 30-36 dB. Devices with groove depth more than 0.4 μm show gain-frequency characteristic activity dip in the middle frequency (rejection) which is caused by secondary SAW reflecting inside grating. It allows to make conclusion that reflecting factor for every groove can not exceed 0.003, and total grating reflecting factor can not exceed – 0.53.

Reflecting grooves were also used in dispersive delay line based on lithium niobate YZ using fir-type topology. The calculation method is elaborated on the basis of analysis and measuring data shown in [2]. The device is calculated for central frequency of 360 MHz, processed signal duration of 10 μm and frequency deviation of 120 MHz. The slope of dispersion characteristic is positive. Every reflecting grating has 300 grooves which is situated under angle of 43,18° to X crystal axis [2]. Estimated groove depth is 3.0-3.6 μm. Dissipation is in range of 40-43 dB.

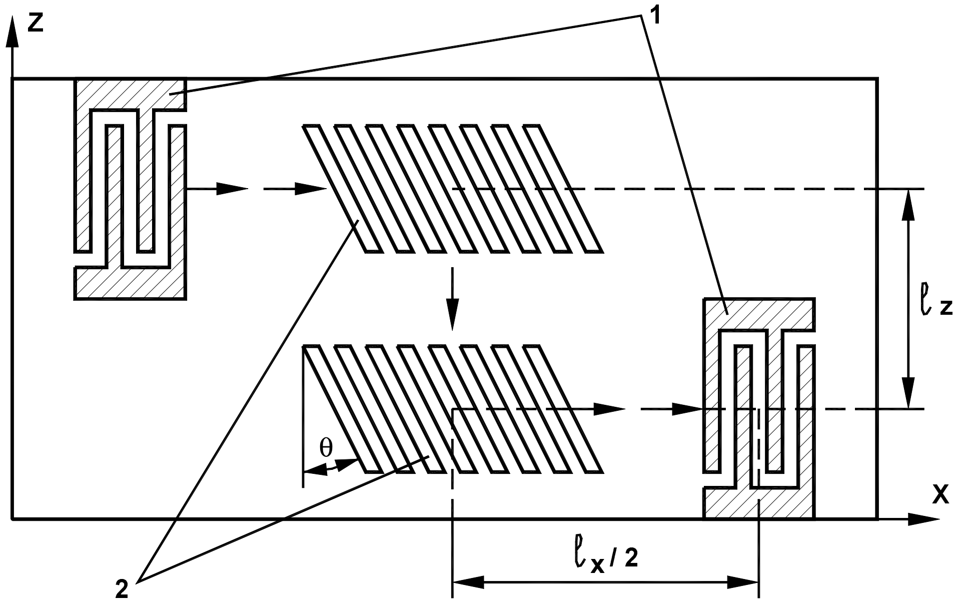

Fig. 2. The topology of stripline filter with reflecting grating as periodical grooves
1 – interdigital transducer; 2 – reflecting grating

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