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Tunable Surface-Acoustic-Wave Generator on a Monolithic MIS Structure

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Recently, we have proposed and experimentally demonstrated a new parametric amplifier and a generator of SAW on a monolithic MIS structure with a uniform pump electrode as shown in Fig.1.

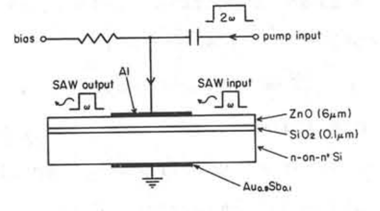

Fig.1 A schematic configuration of SAW amplifier and generator on an Al/ZnO/SiO_2/Si (MIS) structure.

In the MIS structure, the parametric interaction occurs between a propagating potential of SAW (ω) generated by an interdigital transducer and the uniform pump potential (2ω) applied to the center electrode by the capacitance of the space-charge layer in Si[1]. We have already shown that the forward wave was amplified and simultaneously the backward wave was generated as an idler wave. We have also shown that if the pump power was larger than a threshold value, the generation of SAW propagating in the right and left direction occurred, even if there was no signal input[2),3)].

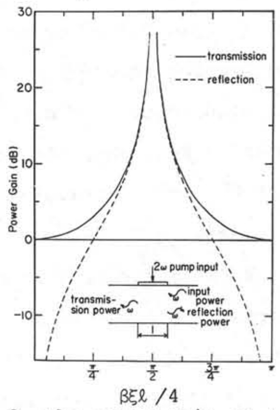

Fig.2 The power gain as a function of $\beta\xi\ell/4$.

In Fig.2, theoretical curves of the power gain are plotted as a function of $\beta\xi\ell/4$, where β is the propagation constant of SAW, ℓ is the length of the pump electrode, and ξ is the value of the nonlinear capacitance which is proportional to the pumping power. If the condition, $\beta\xi\ell/4 = \pi/2$, is satisfied, the parametric generation of SAW occurs. For example, when the modulation of capacitance by pumping is 1%, i.e., $\xi=0.01$ and the wavelength of SAW is $\lambda=2\pi/\beta=100\mu m$, we get $\ell=$ 10mm, which is experimentally realizable[2)].

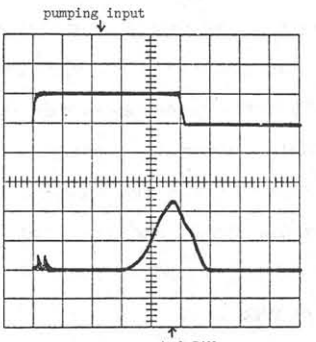

Fig.3 SAW parametric generation by the uniform pumping of center electrode without SAW signal input. Upper trace; pumping power (f= 444MHz, 39 dBm). Lower trace; SAW signal at the input transducer (f_{saw} = 222MHz). Horizontal scale; 5μs/div..

We used the sample which consists of a thermally oxidized (in dry O_2) epitaxial n-on-n^+ Si (thickness and resistivity of the epitaxial layer are 9 μm and 90 Ω-cm, respectively, thickness of the oxide layer = 1000 Å) and a dc sputtered layer of ZnO(thickness = 6μm). The dimension of the pump electrode was 2 x 15 mm^2. We have shown, for the first time, the experimental results of parametric generation of SAW (222 MHz) observed after build up time of 15 μsec at the input transducer by the uniform pumping of center electrode (444 MHz, r.f. pulse)[3], (see Fig.3)

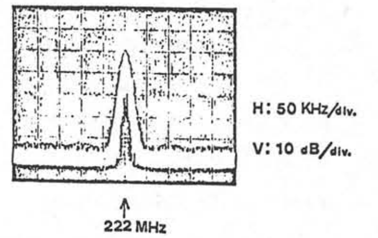

Fig.4 Frequency spectrum of generated SAW with cw pumping (37.5 dBm).

However, the above experimental results was preliminary. In this paper, we show the experimental results on the frequency spectrum of the generated SAW, the conversion efficiency from the pumping to the SAW power, and the tunability of the center frequency of the SAW in our device. In Fig.4, the frequency spectrum of generated SAW is shown when the cw pumping power of 37.5 dBm is applied to the center electrode. The band width of generated SAW is about 20 kHz, which is very narrow compared with that of the input interdigital transducer (about 11 MHz). Next, in Fig.5, the cw-pumping-power dependence of SAW generation is shown, where the electrical output was detected at the input IDT (transduction loss is about 38 dB at 222 MHz). We estimate from Fig.5 that the conversion efficiency from the pumping to the SAW is about -22 dB at the pumping power of 40 dBm. In order to confirm the tunability of the generated SAW frequency, the generated SAW was detected by the laser-probing method[4], when the pumping power is constant (power= 50 dBm, pulse width = 20 μsec) and the pumping frequency is varied, (see Fig.6). The generated SAW frequency is widely variable, (mid- frequency ≃ 200 MHz, variable range ≃ 80 MHz).

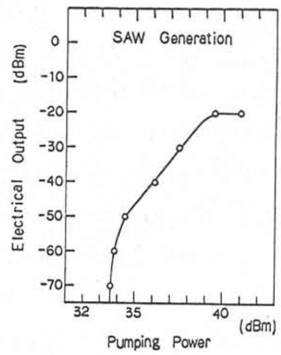

Fig.5 Cw-pumping-power dependence of generated SAW output.

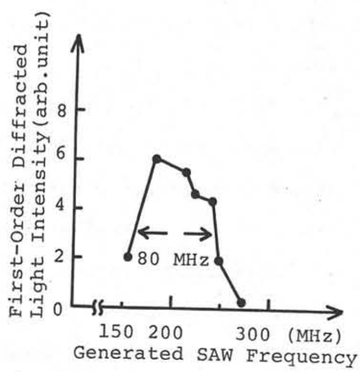

Fig.6 Tunability of the generated SAW center frequency.

In conclusion, our device can be used as a really tunable, wide-band center-frequency, and high Q generator of SAW without micro-fabrication.

References
1) K. Tsubouchi, S. Minagawa and N. Mikoshiba, J. Appl. Phys., 47 (1976) 5187.
2) S. Minagawa, T. Kugaya, K. Tsubouchi and N. Mikoshiba, 1977 Ultrasonics Symposium Proceedings, Phoenix, IEEE 77CH1264-1SU(IEEE,New York,1977) p.629.
3) S. Minagawa, T. Kugaya, K. Tsubouchi and N. Mikoshiba, Appl. Phys. Lett., 33 (1978) 687.
4) E.G.H. Lean and C.G. Powell, Proc. IEEE, 58 (1970) 1939.