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Detection of Acoustic Waves with a PI-DMOS Transducer

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This paper describes the application of a new type of fast and sensitive pressure transducer as an acoustic wave detector. The device, a piezoelectric DMOS transducer was made with a gauge factor in excess of 10,000 and a response time to a shock input of less than 400ns. A small sensing area of less than 800 $(\mu m)^2$ is readily achievable. The limiting frequency of operation is expected to be in the GHz range. As a bulk acoustic wave detector, the PIDMOS exhibits a constant gain over a wide frequency range. Surface acoustic waves at 28 MHz have also been detected.

The device structure is basically that of a DMOS transistor except that the gate insulator is made of a thin piezoelectric film sandwiched between two SiO_2 layers. The strain signal induces a polarization potential in the ZnO layer and is electrically detected and amplified as changes in the drain current. Transconductance and operation frequency are superior to those of conventional MOSFET structures as a result of the short channel length and the small output capacitance.

Device response to static strain and to an ac strain at 600 Hz are demonstrated in Fig. 1 and Fig. 2. Detection of bulk acoustic waves at 6.7 MHz and surface acoustic wave at 28 MHz are shown in Fig. 3 and Fig. 4. Theory of the device response to the amplitude and frequence of the strain signal has been formulated and matched to experiment. This device should be extremely valuable for applications to the Non Destructive Evaluation (NDE) of materials and in Surface-acoustic-wave communication systems. It may also be attractive for applications in the medical fields and in the geosciences.

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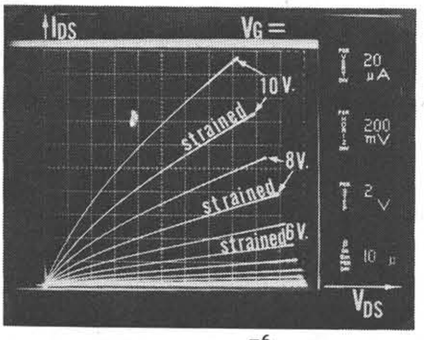
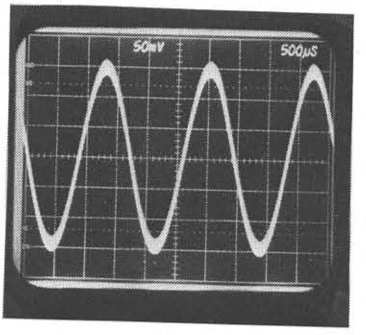


Strain(s) = 1.8×10^{-6}

Gauge Factor $\equiv \dfrac{\Delta I_D/I_{D0}}{S} = 1.6\times10^{5} (V_{GS}=8V.)$

Fig. 1. PI-DMOS response to static strain.



V_{DD} = 10V., V_{GS} = 13V.

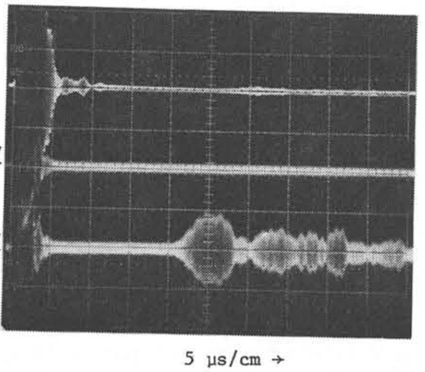
R_L = 33 kΩ, I_{D0} = 120 µA

Fig. 2. PI-DMOS response to ac strain at 600 Hz.

↑ 5V/cm

50mV/cm

50mV/cm



5 µs/cm →

Top trace : Input, V_{RF}(o→p)=60V.

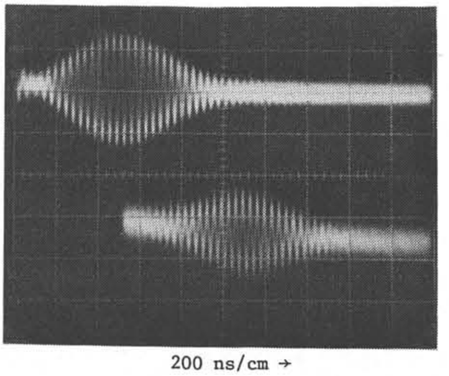
Middle trace: $(\text{PI-DMOS})_{out}$, $V_{DD}=V_{GS}$=0V.

Bottom trace: $(\text{PI-DMOS})_{out}$, V_{DD}=9V., V_{GS}=18V. I_{D0}=300µA, R_L=10kΩ

Delay time : 22 µs.

Fig. 3. Detection of bulk acoustic wave at 6.7 MHz by PI-DMOS

↑ 20 mV/cm



200 ns/cm →

Top trace : Output from Interdigital transducer (IDT).

Bottom trace: Output from PI-DMOS, V_{DD}=11V., V_{GS}=20V. I_{D0}=160µA, R_L=1kΩ

V_{RF}=(input)=±10V.

Delay time : INPUT/IDT=3.2µs, IDT/PI-DMOS= 0.6 µs

Fig. 4. Detection of Surface acoustic wave at 28 MHz by PI-DMOS