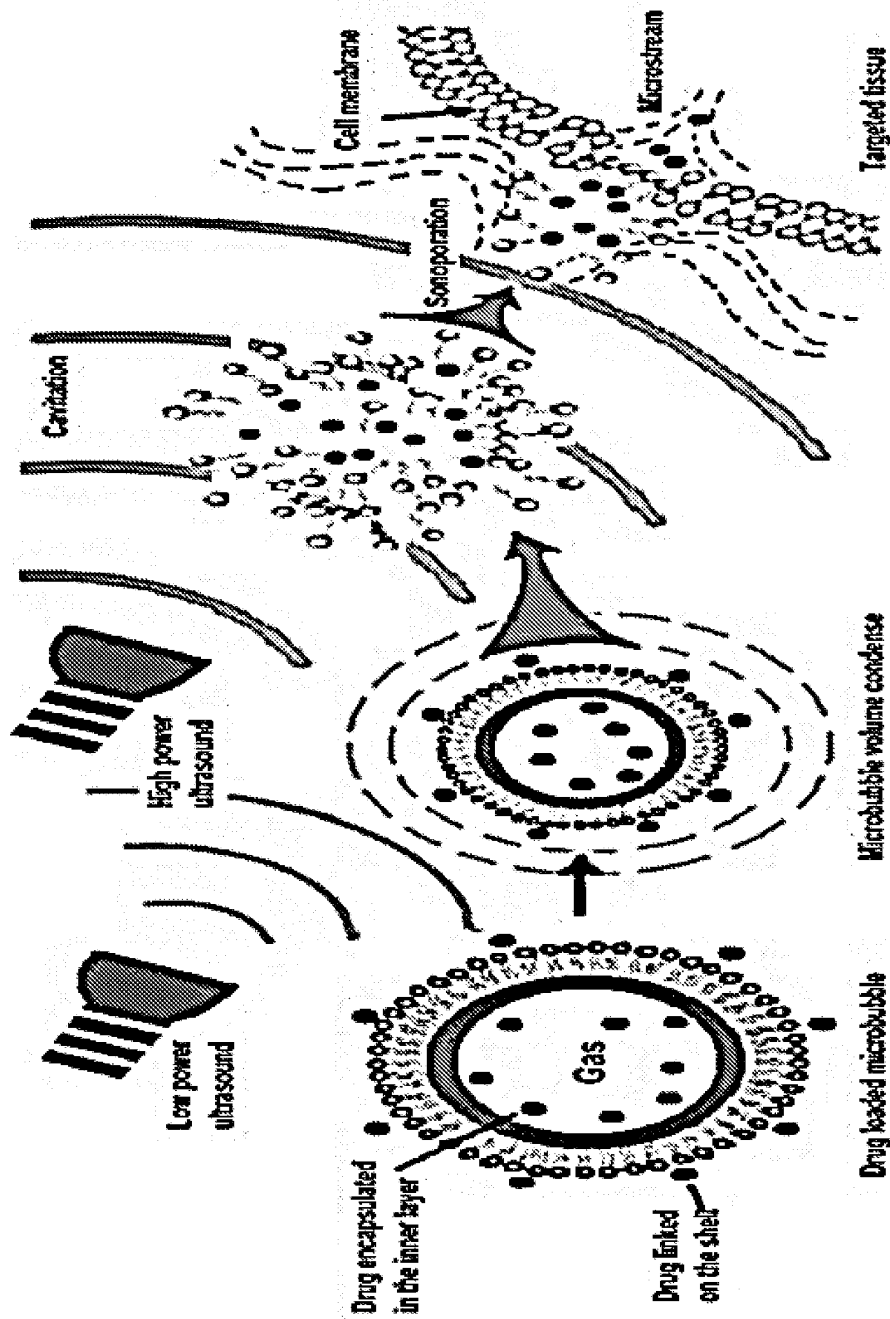
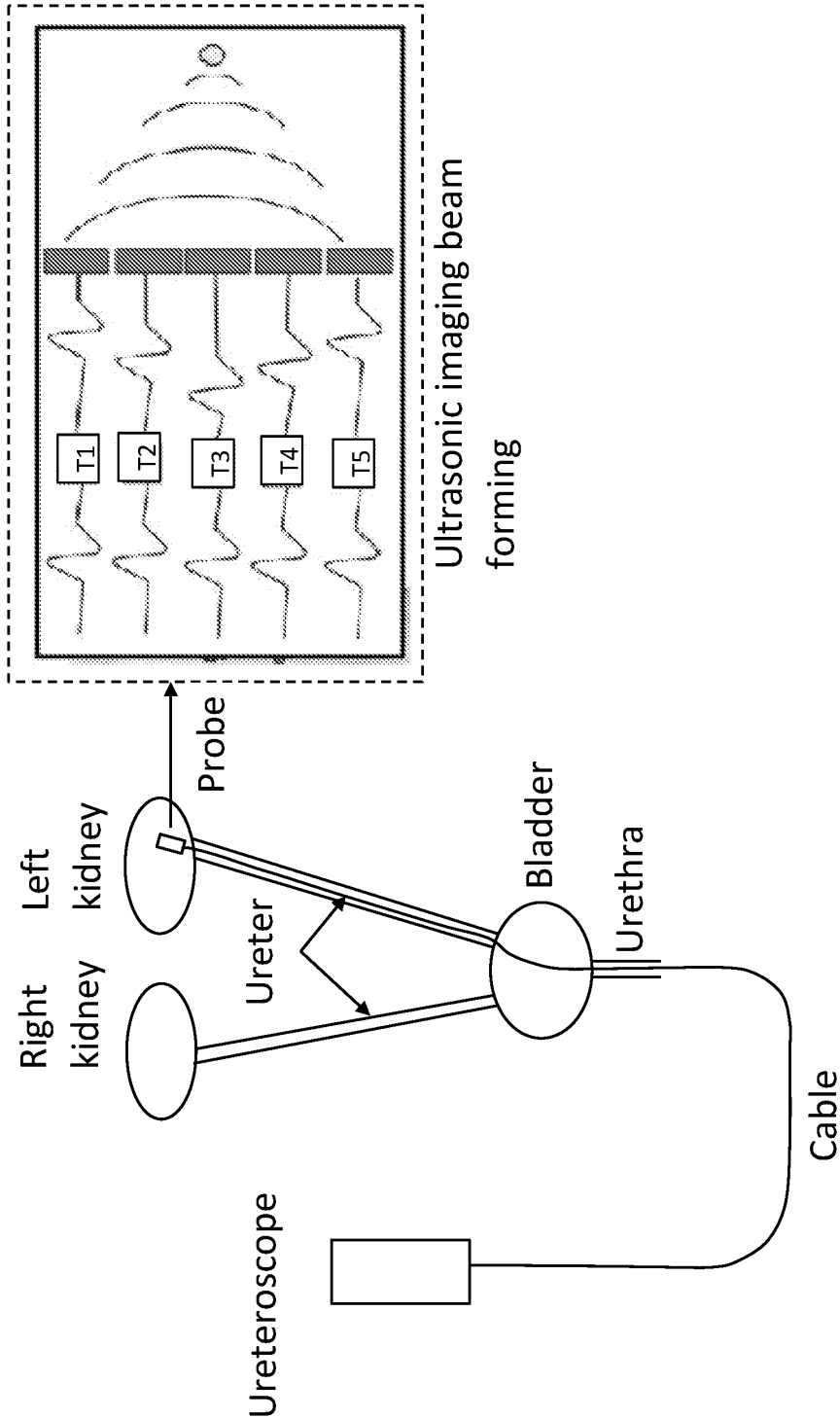


FIG. 1A



PRIOR ART

FIG. 1B



PRIOR ART

FIG. 2A

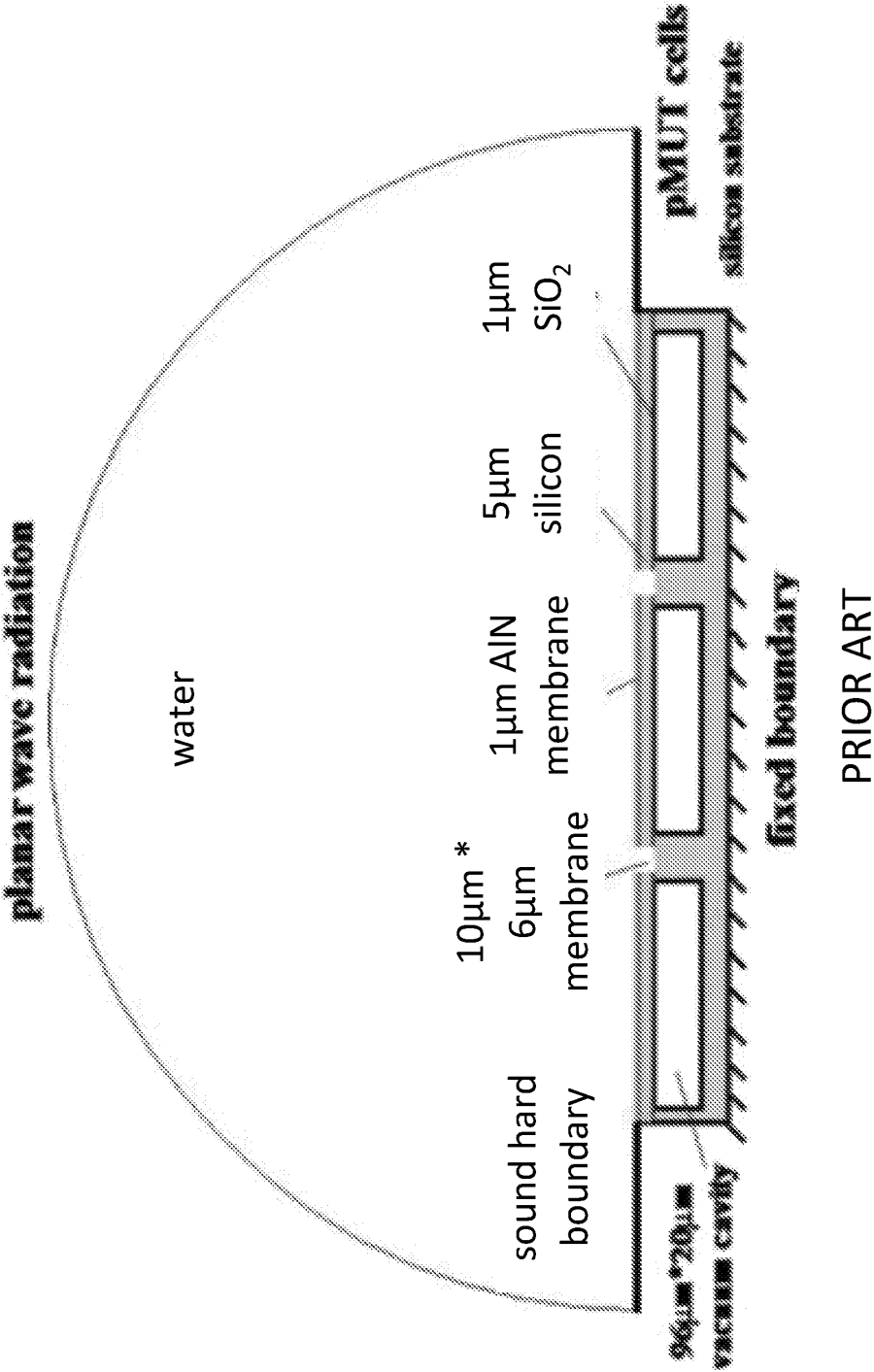


FIG. 2B

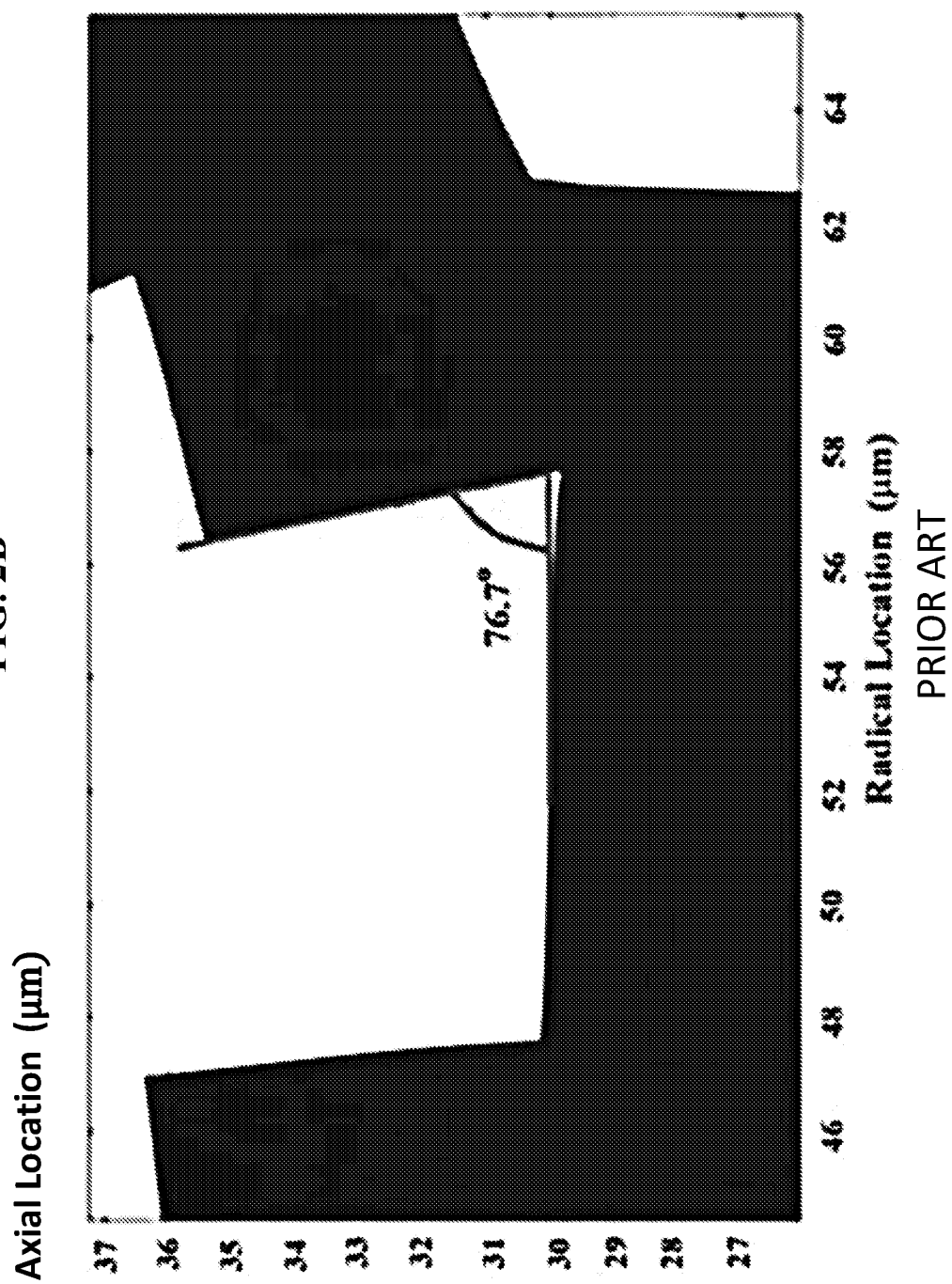
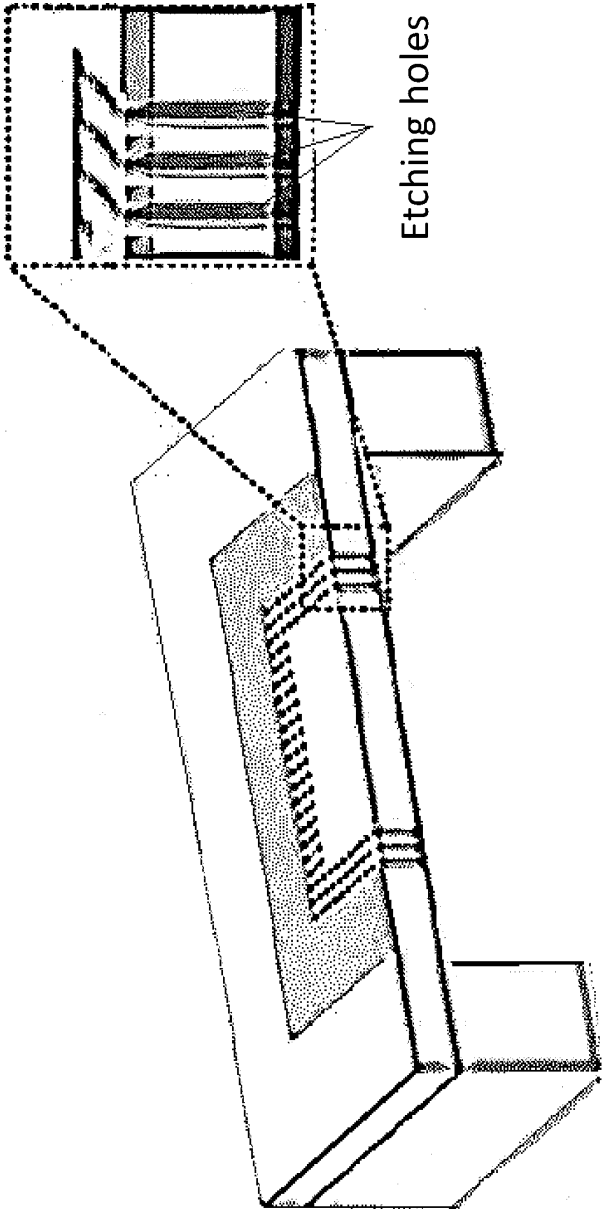
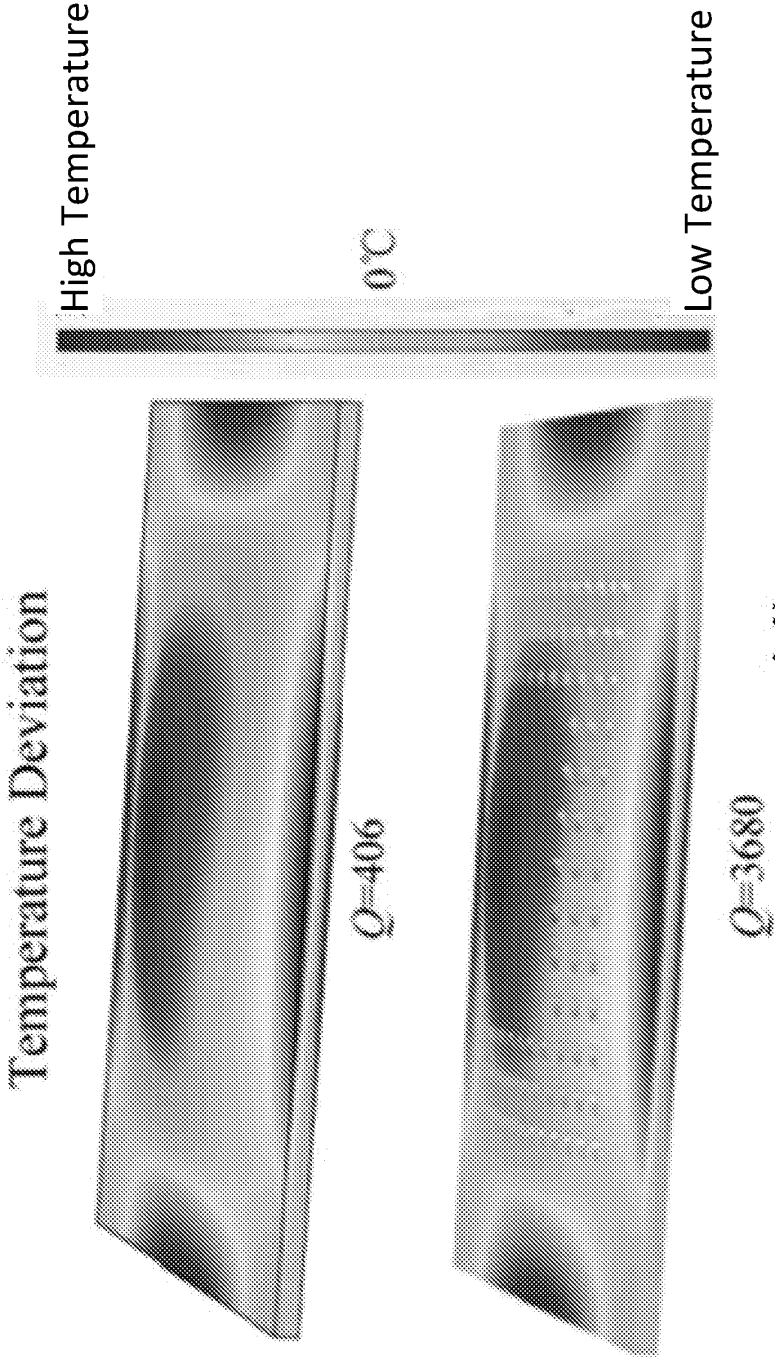


FIG. 2C



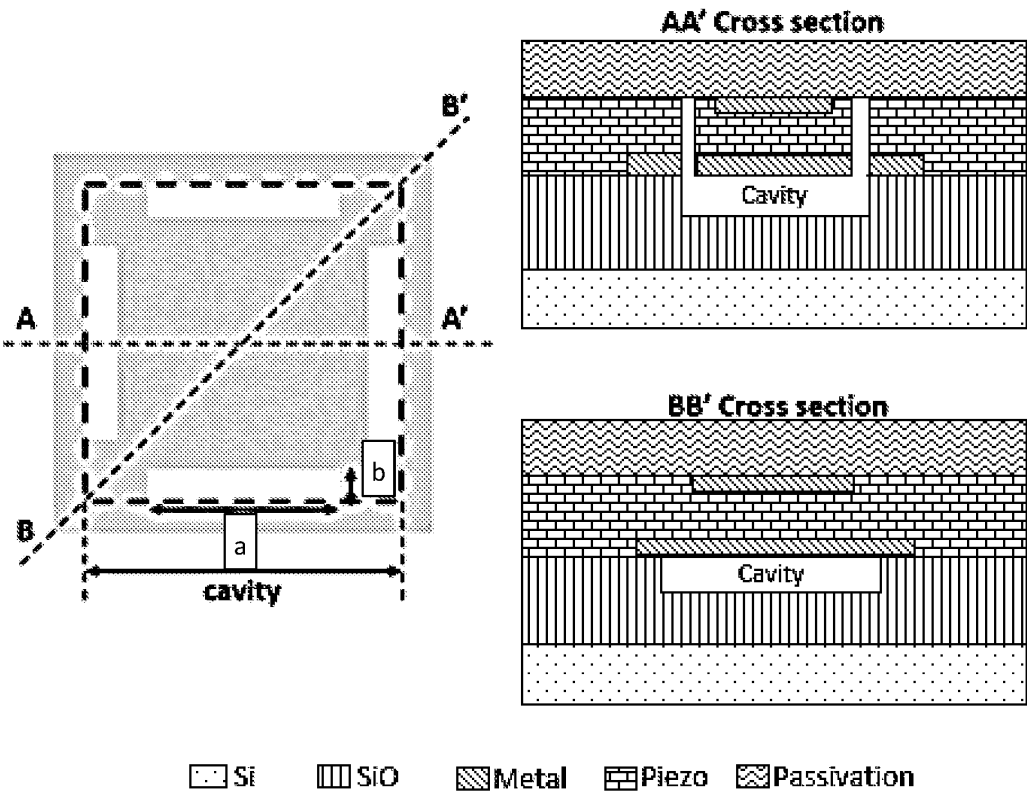
PRIOR ART

FIG. 2D



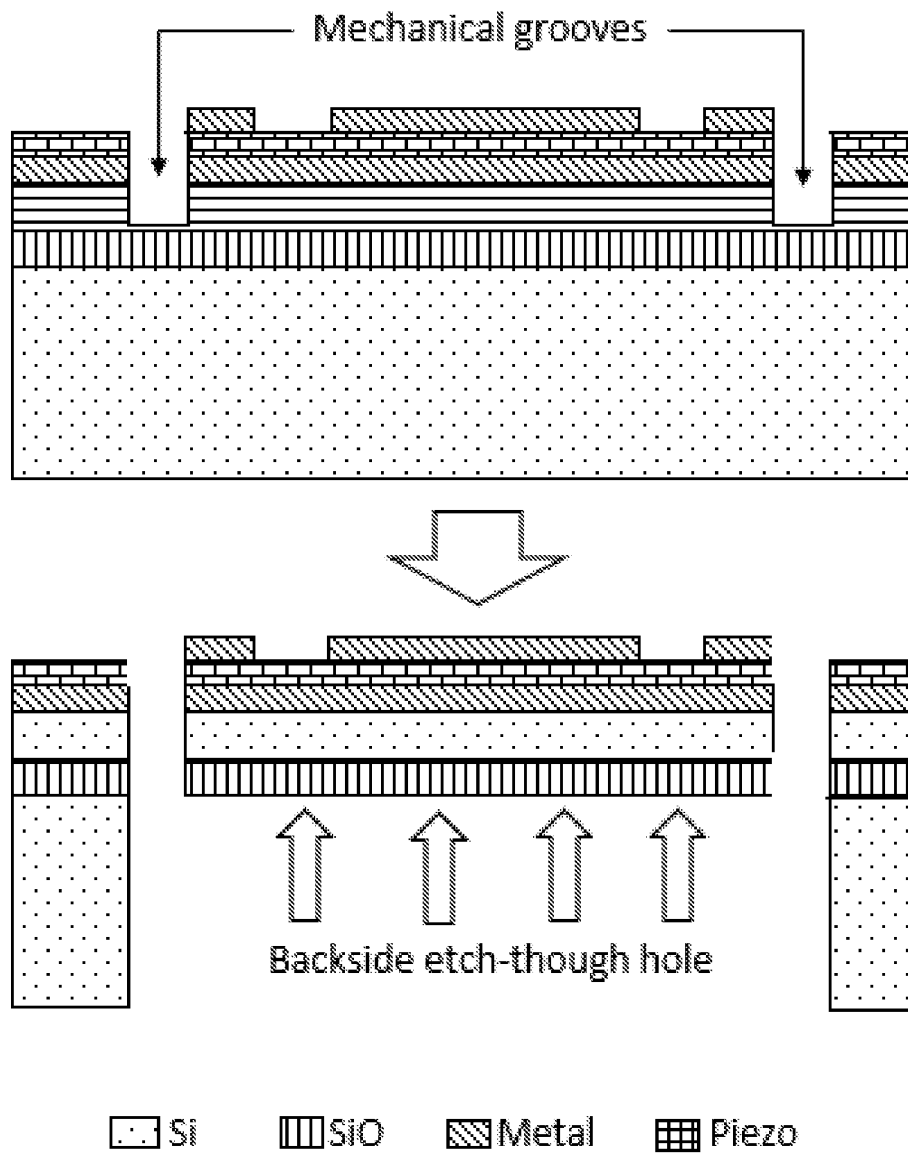
PRIOR ART

FIG. 3A



PRIOR ART

FIG. 3B



PRIOR ART

FIG. 4

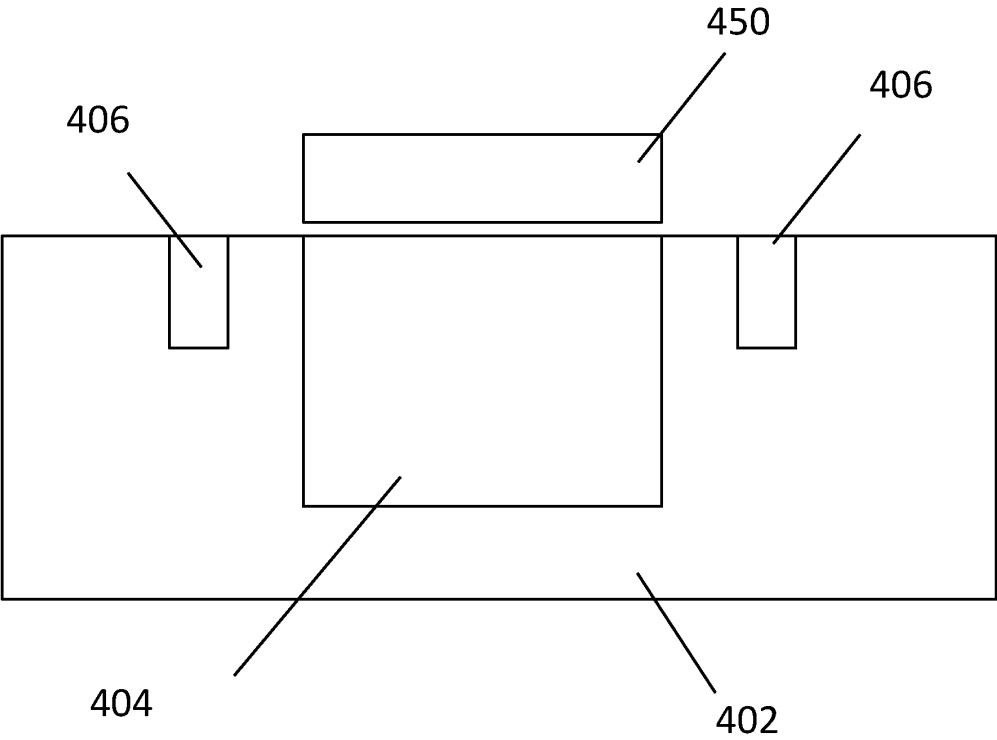


FIG. 5

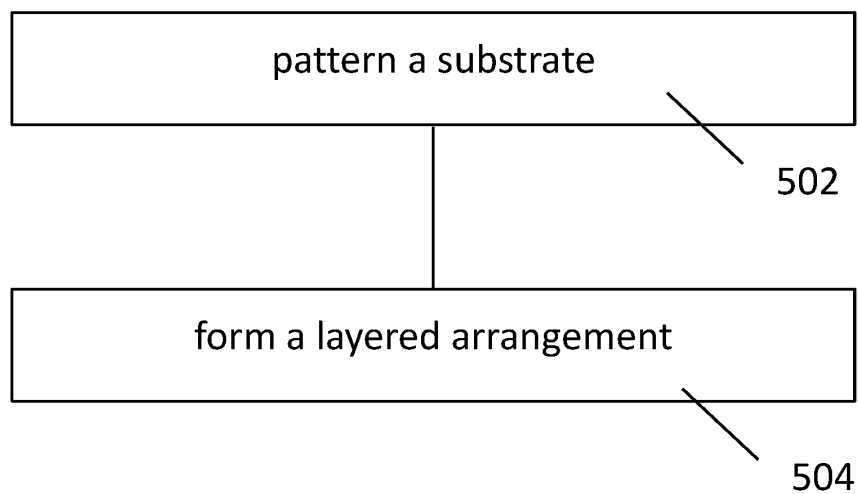


FIG. 6A

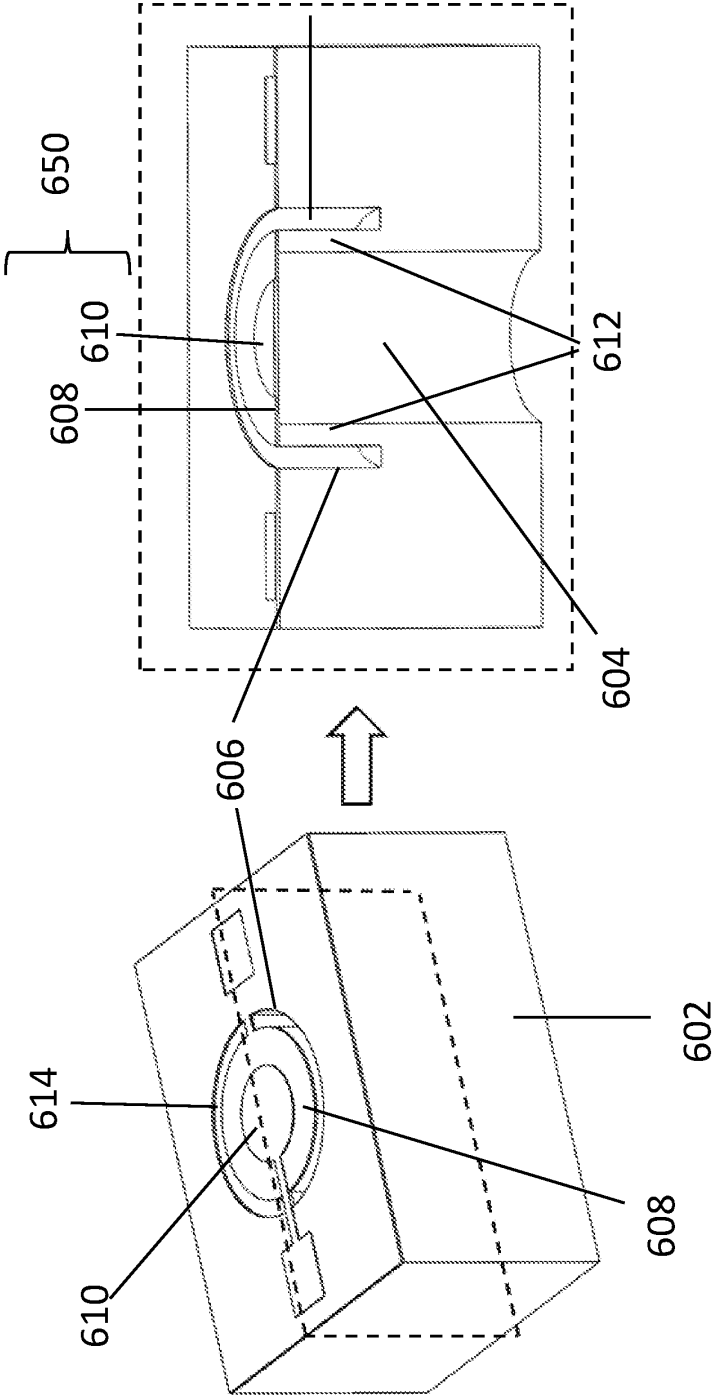


FIG. 6B

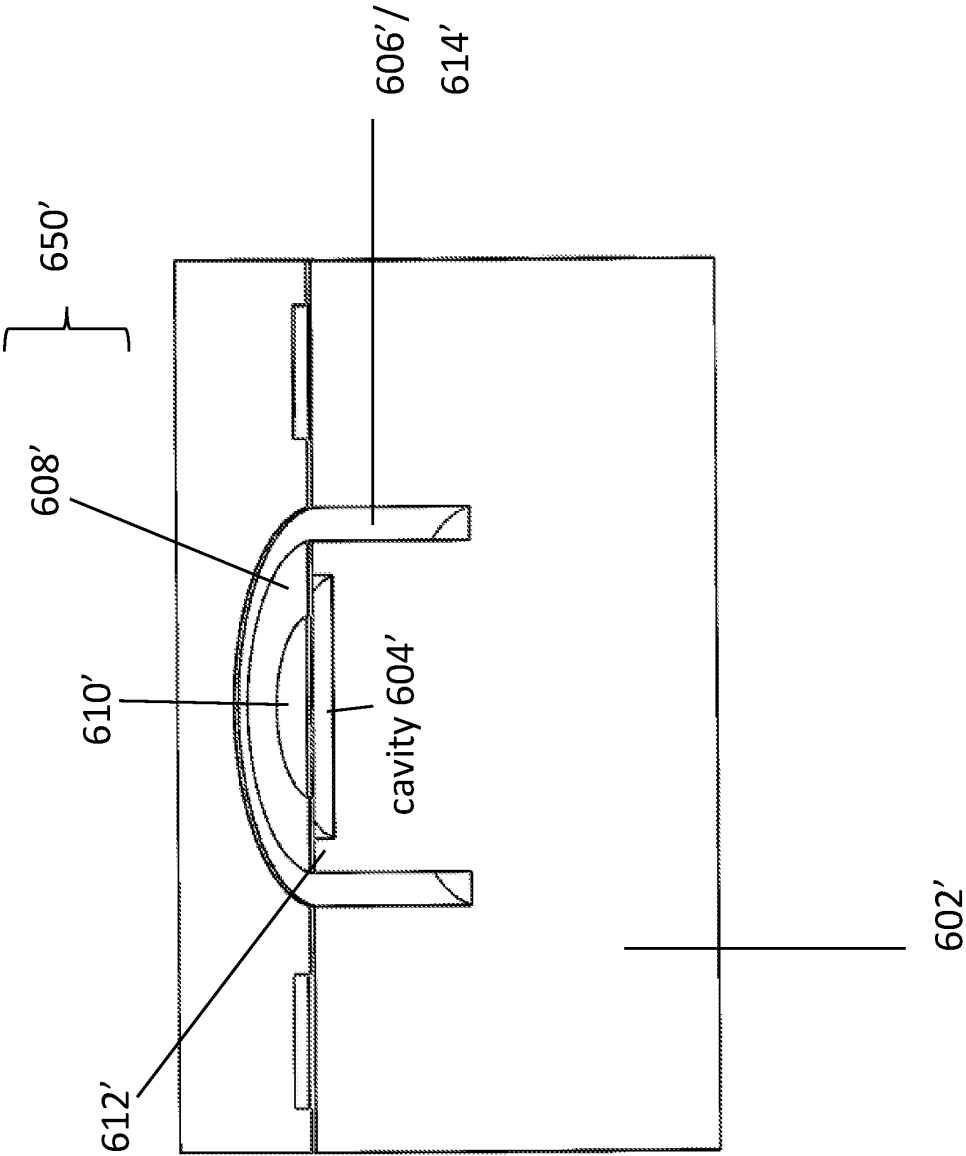


FIG. 6C

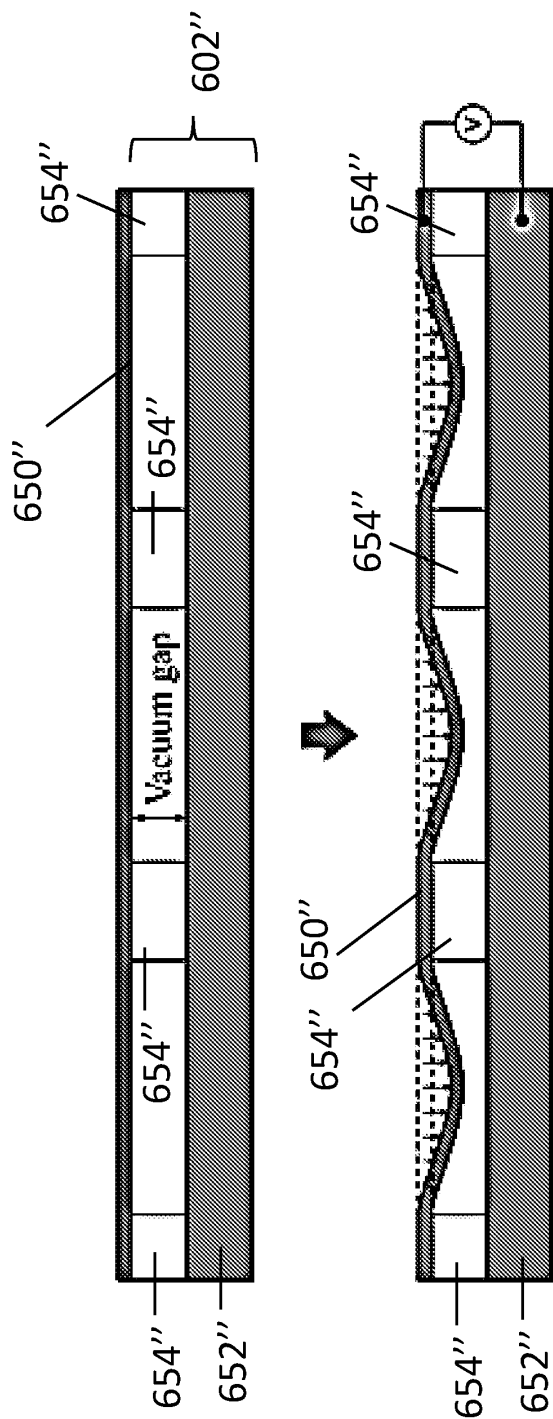
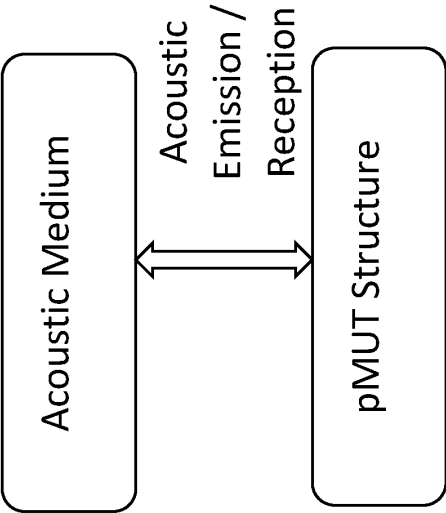
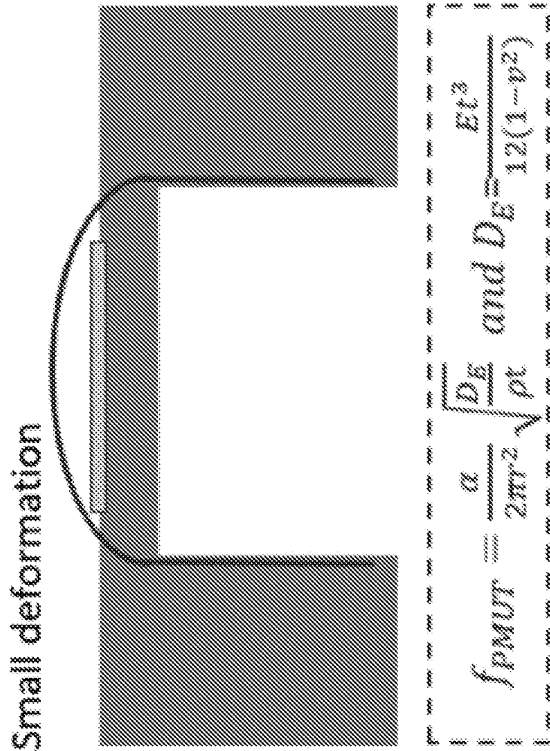


FIG. 7



PRIOR ART

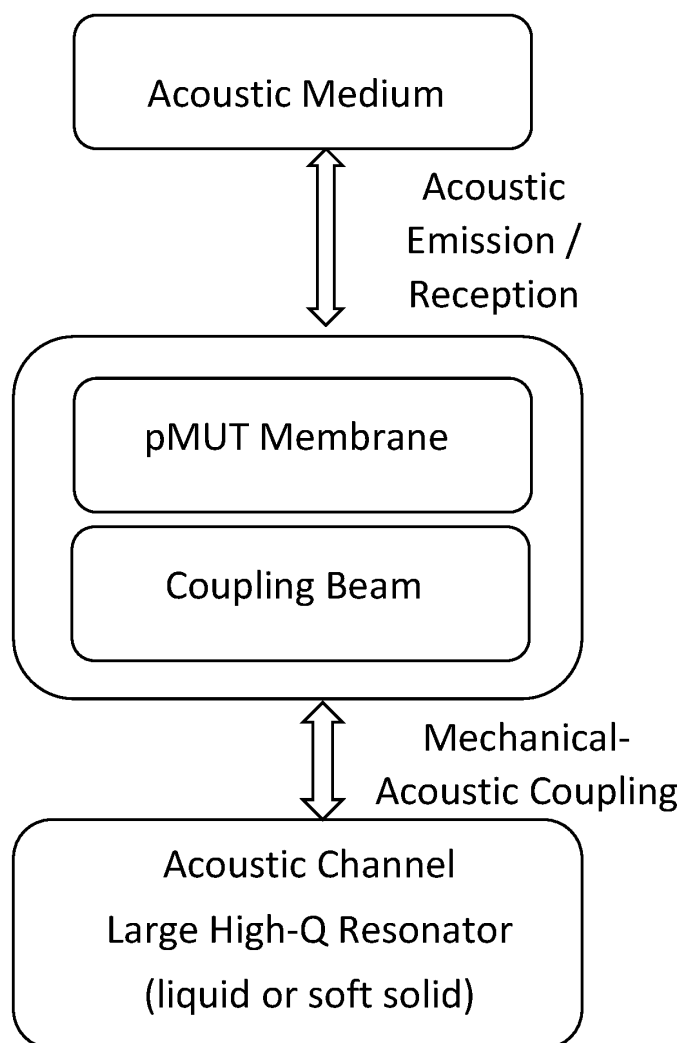
FIG. 8A

FIG. 8B

pMUT $f_{PMUT} = \frac{\alpha}{2\pi r^2} \sqrt{\frac{D_E}{\rho t}} \quad \text{and} \quad D_E = \frac{Et^3}{12(1-\mu^2)}$ α: Resonance mode constant E: Young's modulus r: Radius of cavity t: Thickness of diaphragm ρ: Density of diaphragm μ: Poison ratio	
Beam Wall $f_{Beam} = \frac{1}{2\pi} \sqrt{\frac{k}{M}}$ k: Effective Stiffness M: Effective Mass	
Acoustic Channel $f_{Channel} = \frac{v}{\lambda}$ $h + 0.4d = \frac{(2n + 1)\lambda}{4}$ $n = 0, 1, 2, 3 \dots$ v: Acoustic velocity of medium	

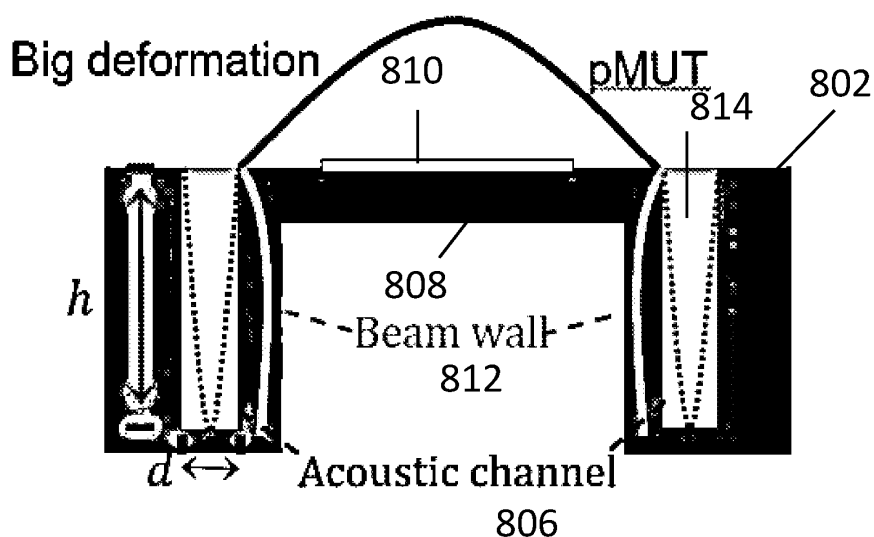


FIG. 9A

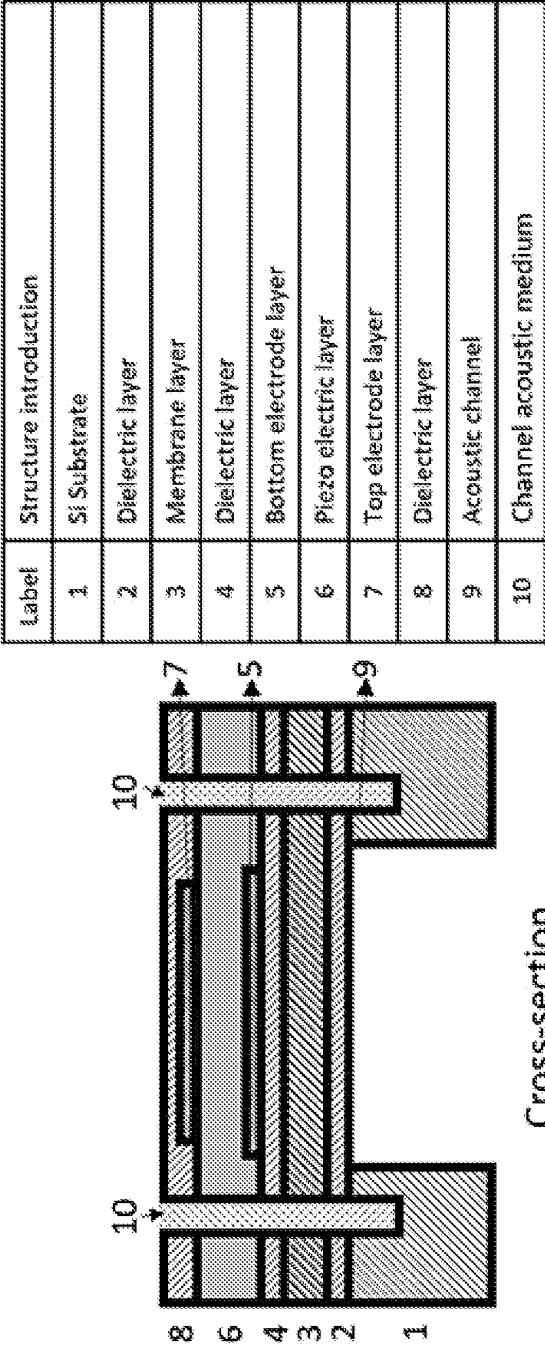


FIG. 9B

	Mechanical boundary	Property
1	Bottom surface	Low-Reflecting

Mechanics(solid)

	Electrical boundary	Property
1	Top electrode	1V
2	Bottom electrode	Ground

Electrostatics(es)

1	Acoustic Structure Frequency Domain (solid-acpr coupling)	
2	Piezoelectric Effect (es-solid coupling)	

Multi-physics

	Acoustic medium	Property
1	Material	Water
2	Outer surface boundary	Radiation
3	10/30/50/.../1000um top of the pMUT surface	Pressure probe

Pressure Acoustics, Frequency Domain(acpr)

Embodiments	Filled material
Liquid-filled embodiment	Water filled
Soft-solid embodiment	Polyimide filled
	PDMS filled

Simulation scheme

FIG. 9C

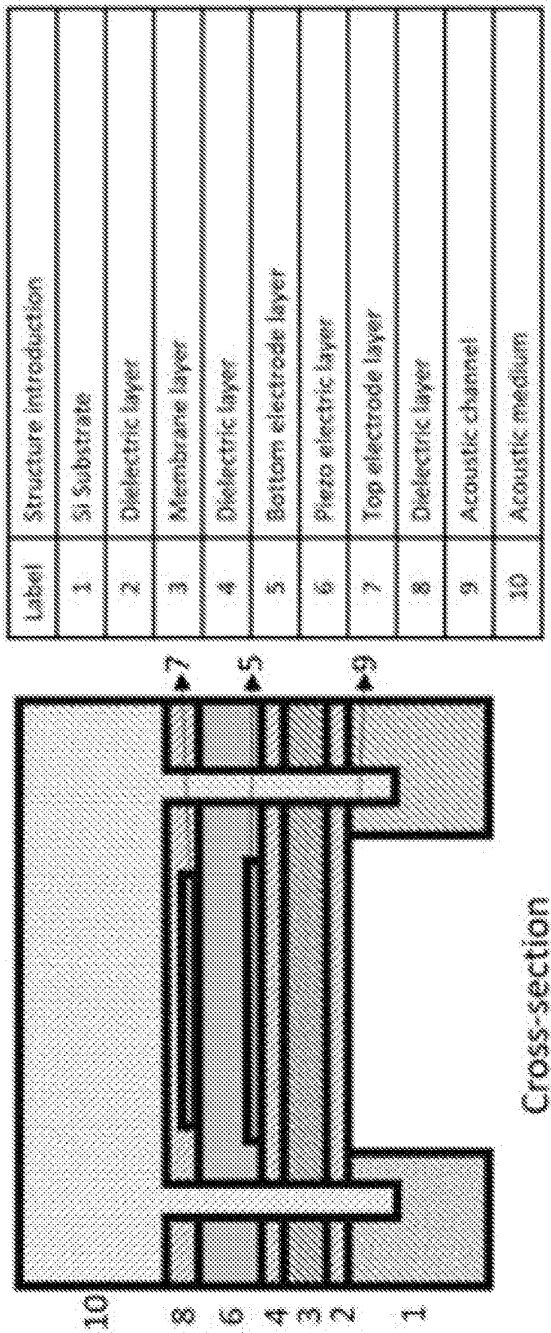
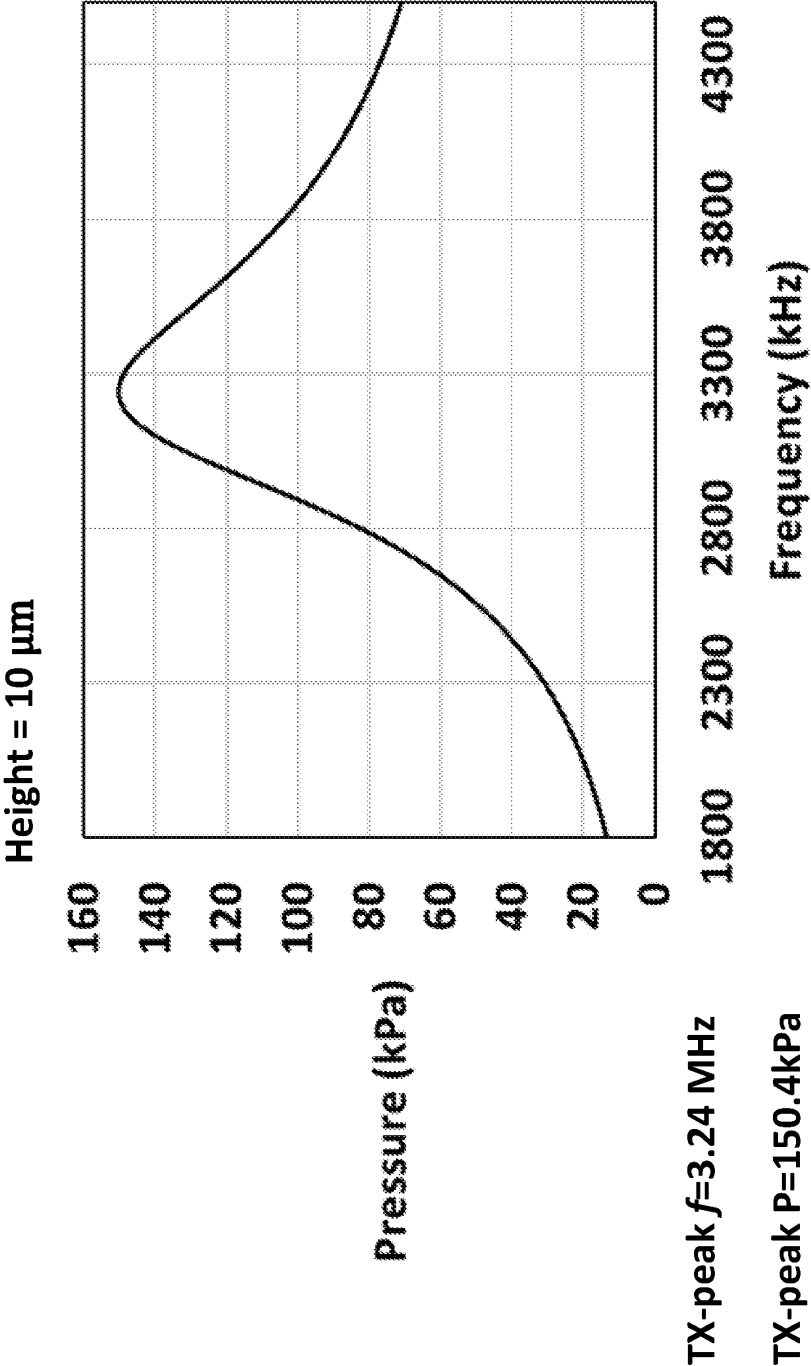


FIG. 10A



PRIOR ART

FIG. 10B

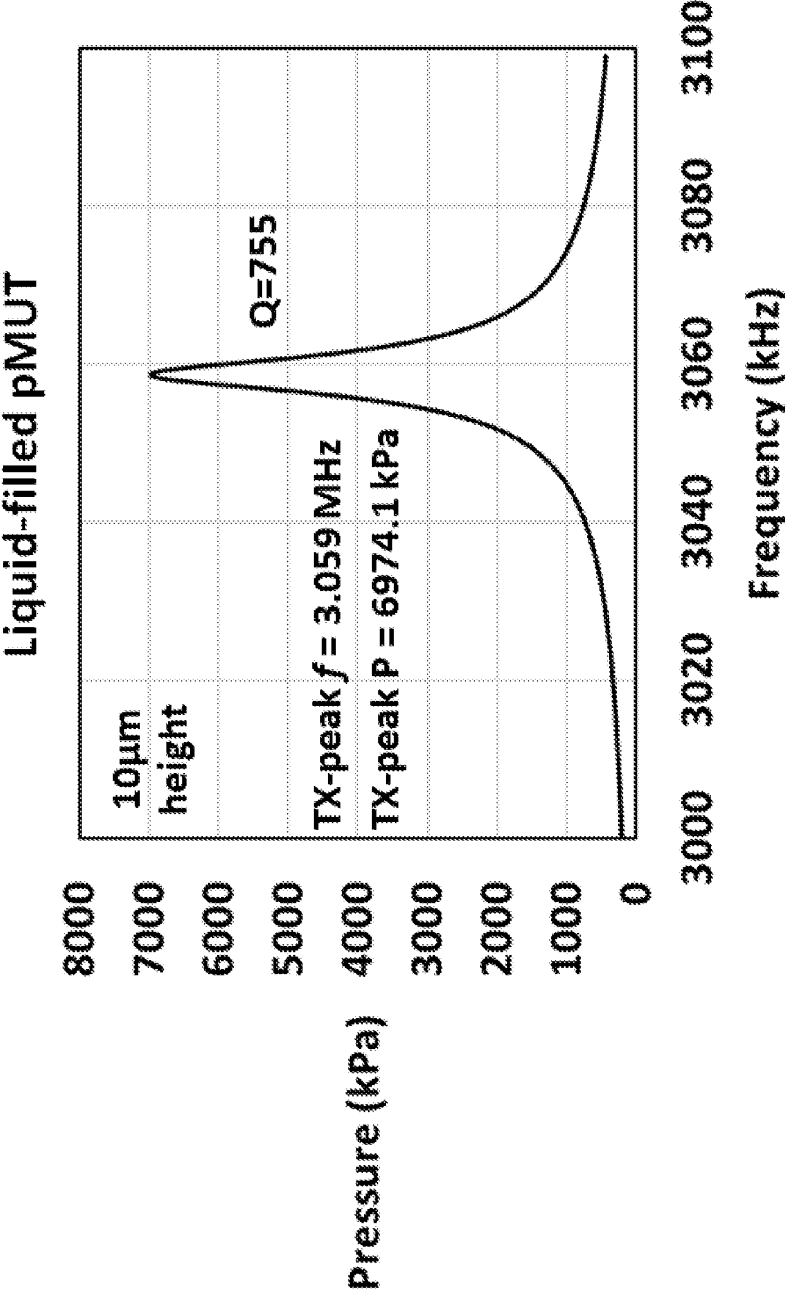
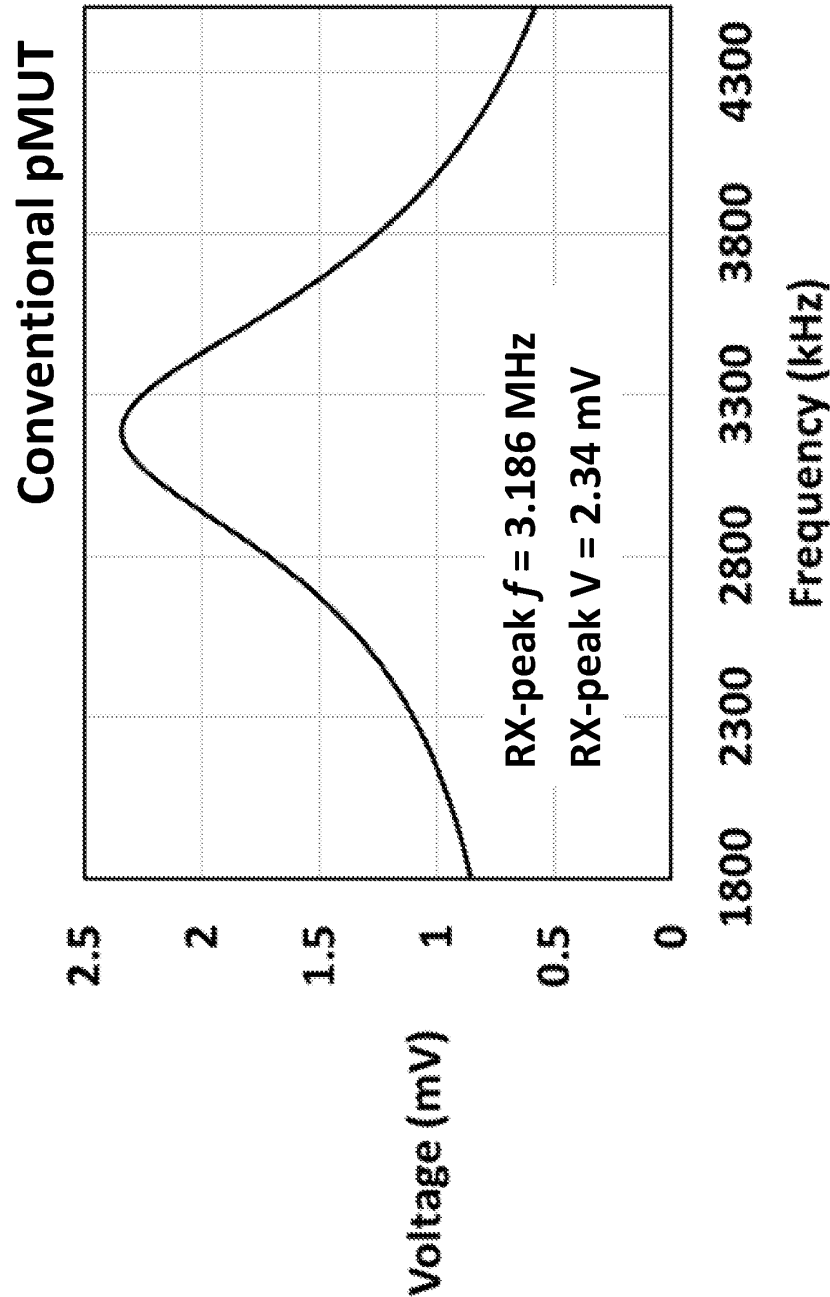


FIG. 11A



PRIOR ART

FIG. 11B

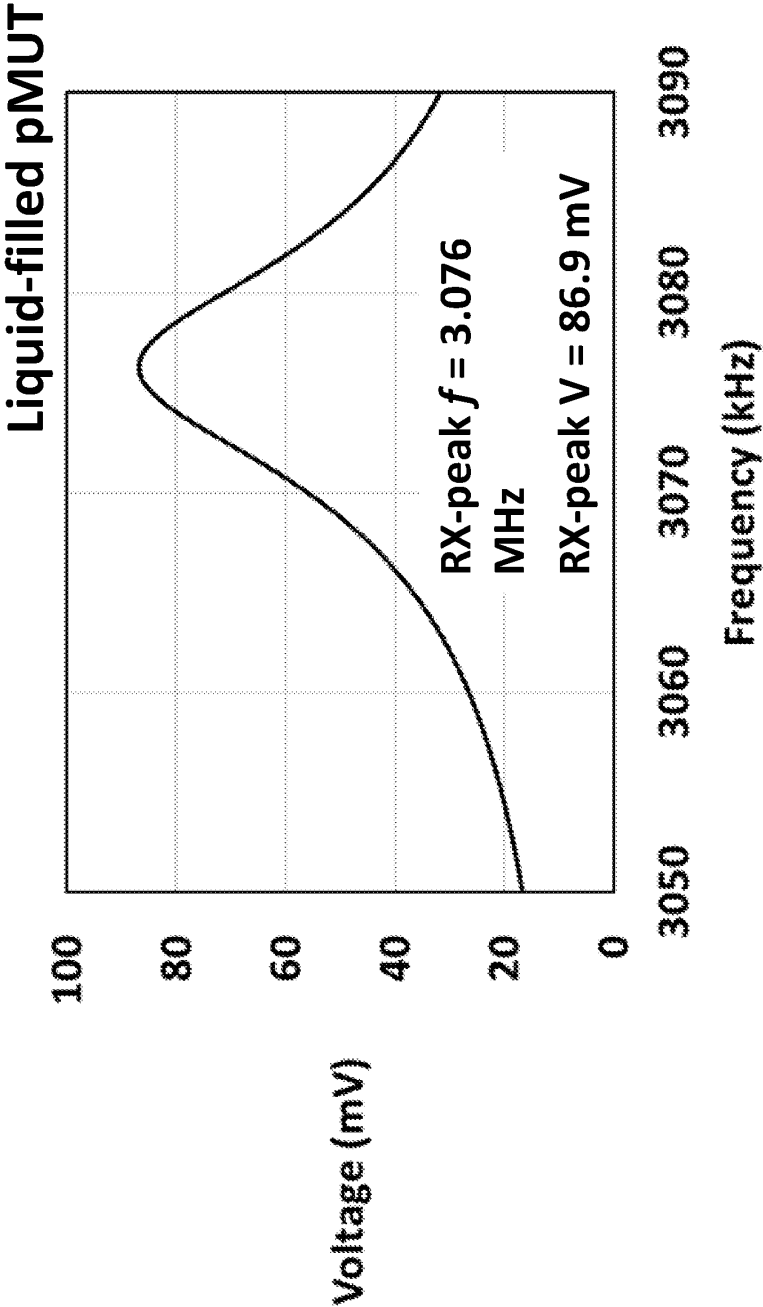
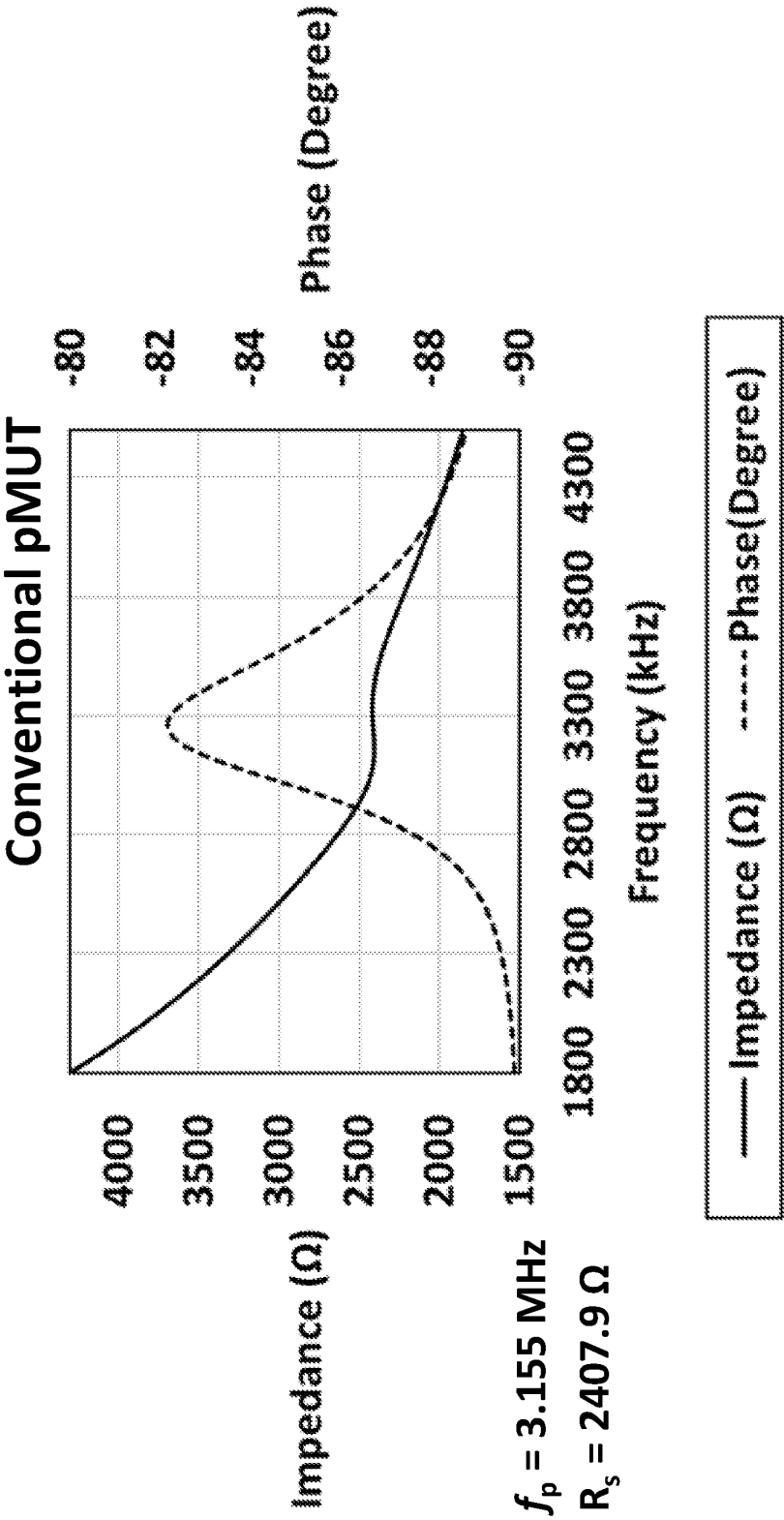


FIG. 11C



PRIOR ART

FIG. 11D

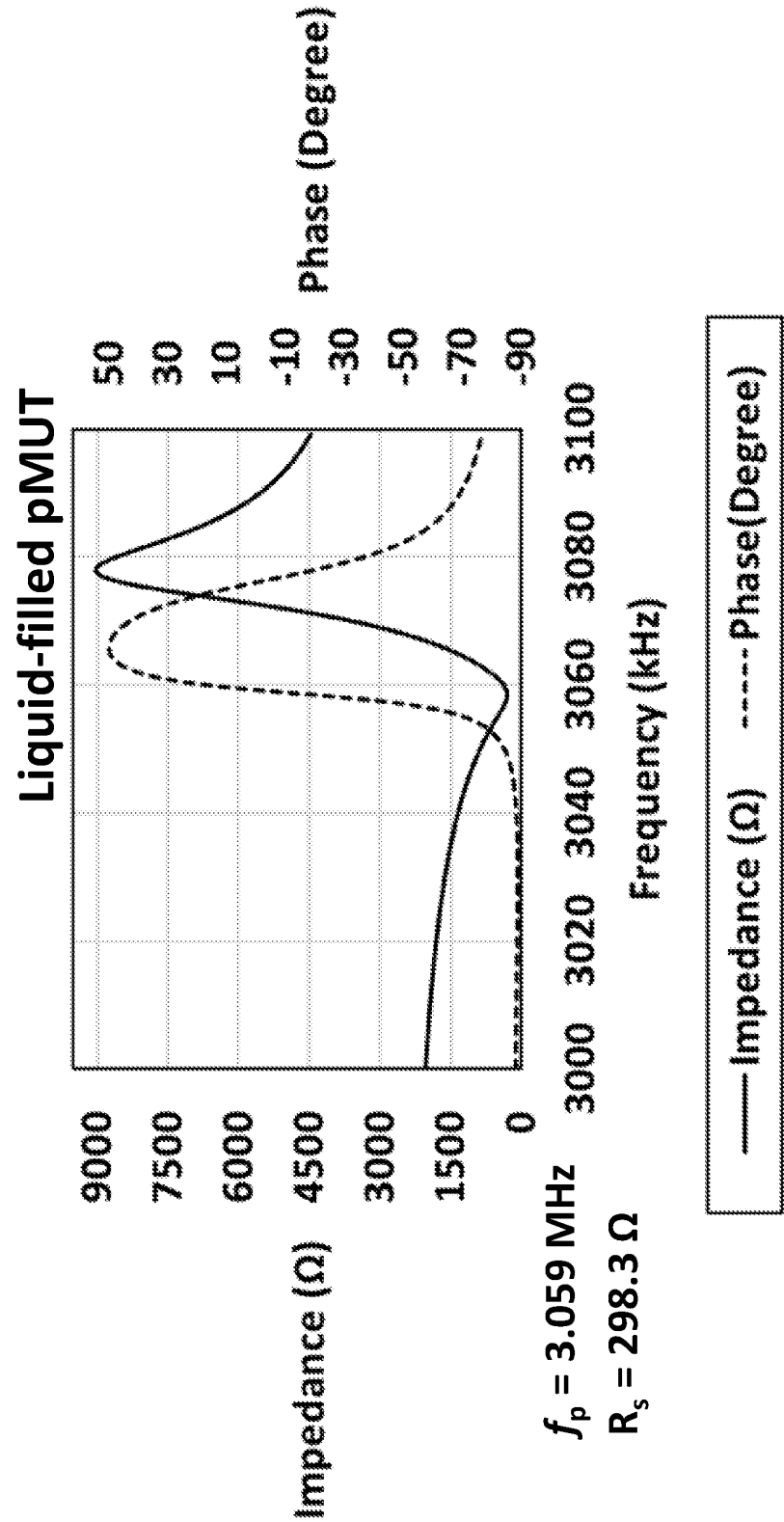
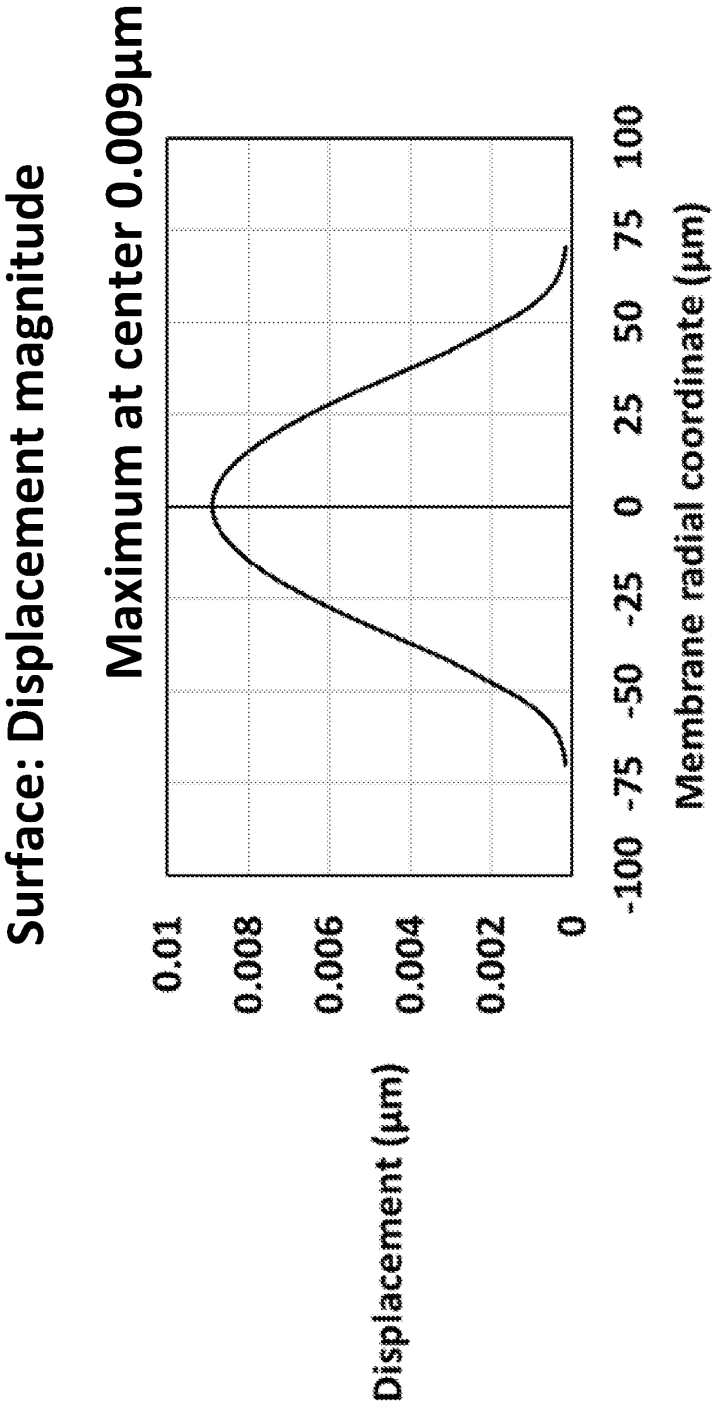


FIG. 12A



PRIOR ART

FIG. 12B

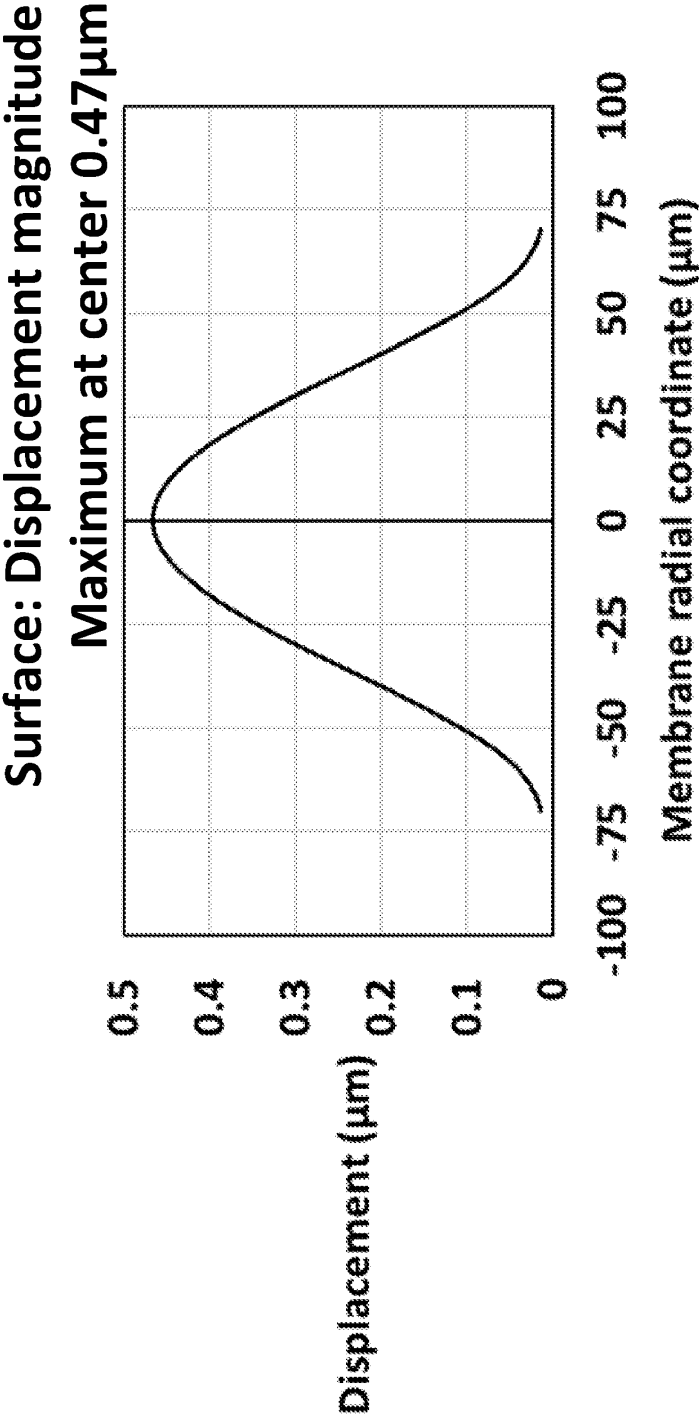


FIG. 13

Properties	Conventional pMUT	Liquid-filled embodiment	Soft-solid PI embodiment	Soft-solid PDMS embodiment
Tx-peak (kPa/V)	188.5	9 times	12 times	11 times
Tx-peak frequency (MHz)	7.5	-13%	-15%	-8%
Rx-peak (mV/kPa)	0.99	11 times	18 times	12 times
Rx-peak frequency (MHz)	7.3	-9%	-12%	-4%
Displacement (nm/V)	3.5	11 times	14 times	11 times
Quality factor	3.0	104 times	55 times	32 times

FIG. 14A

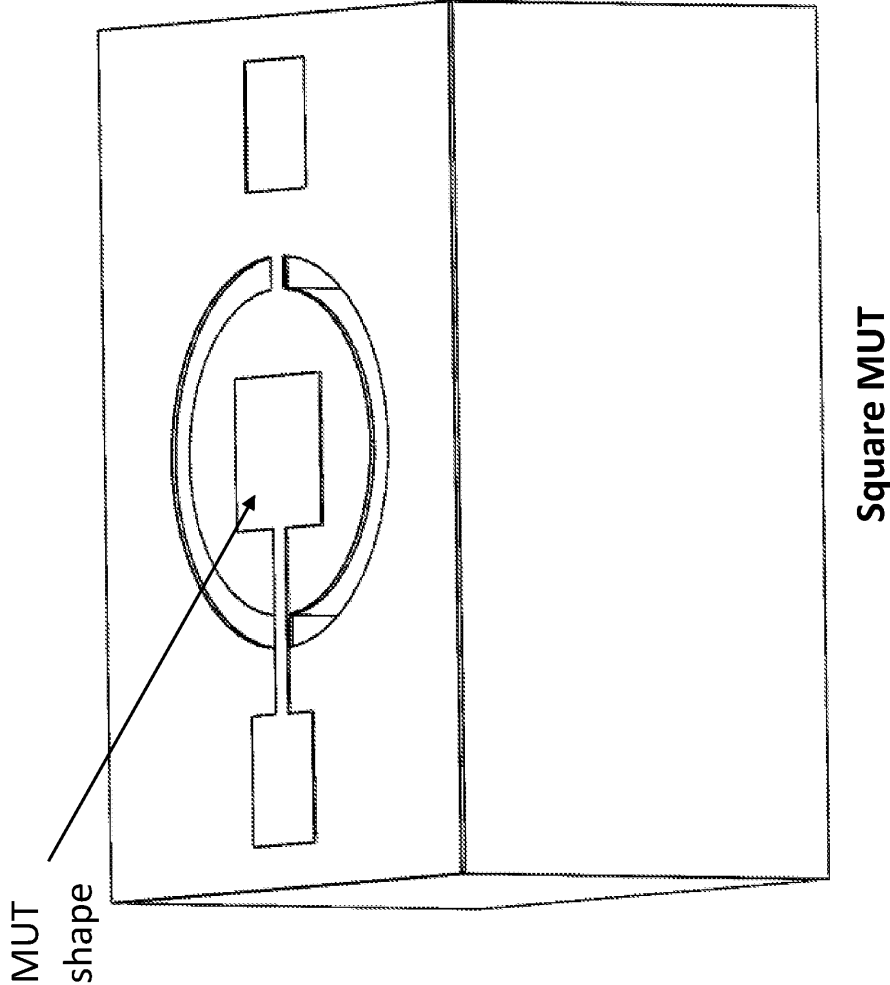


FIG. 14B

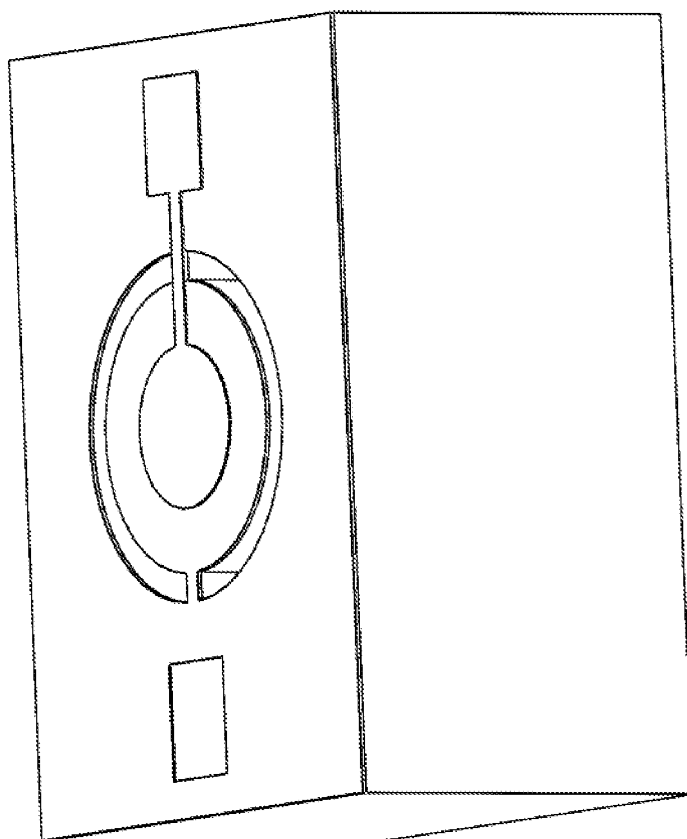


FIG. 14C

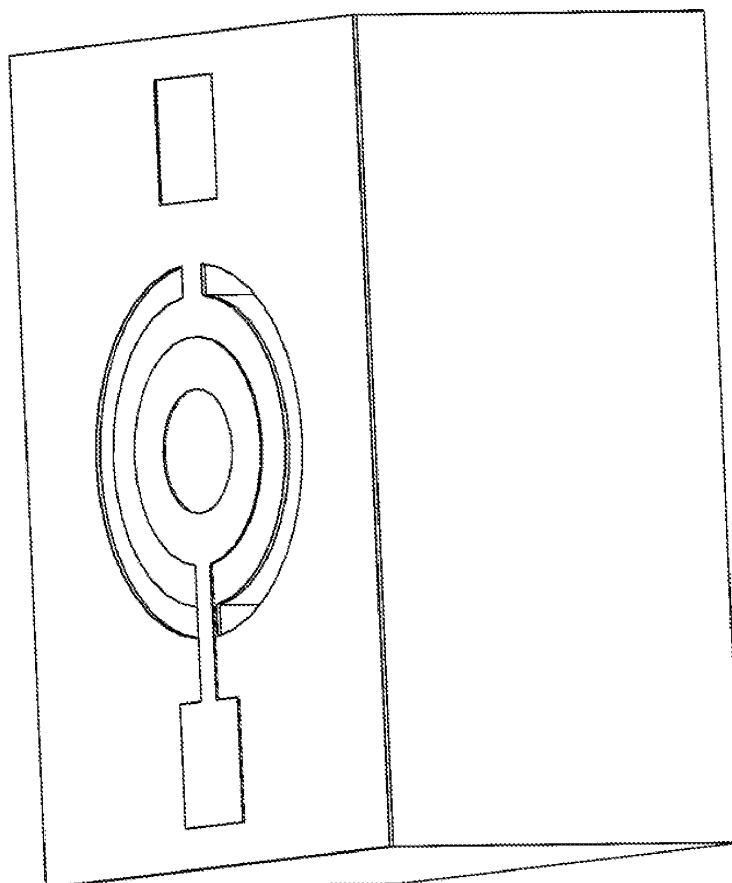


FIG. 14D

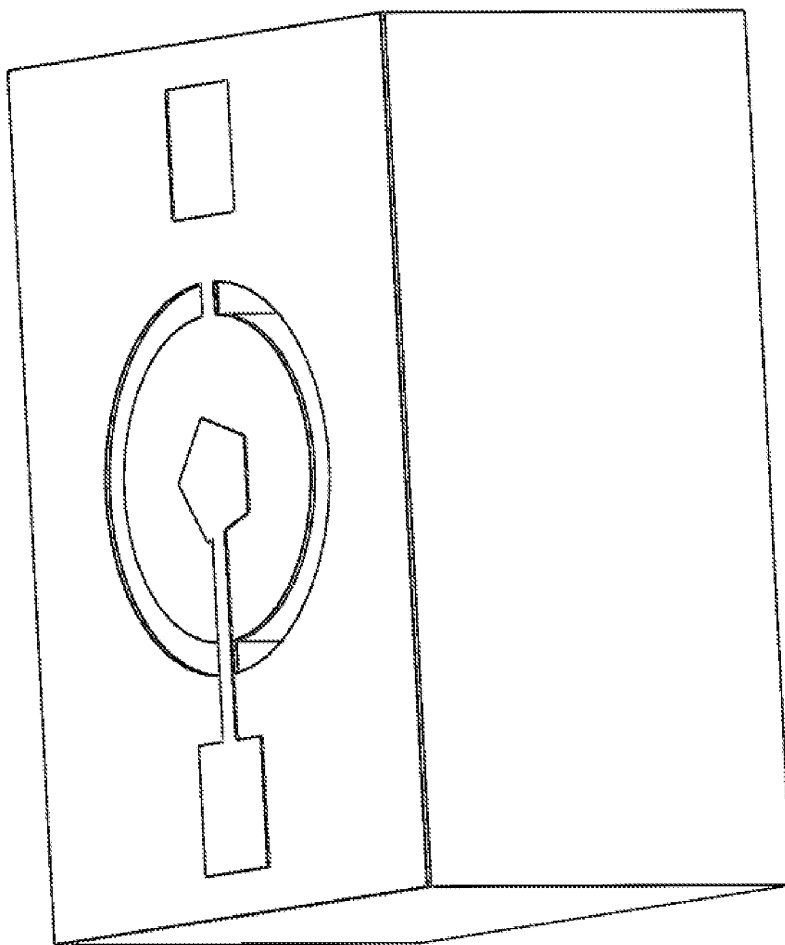


FIG. 15

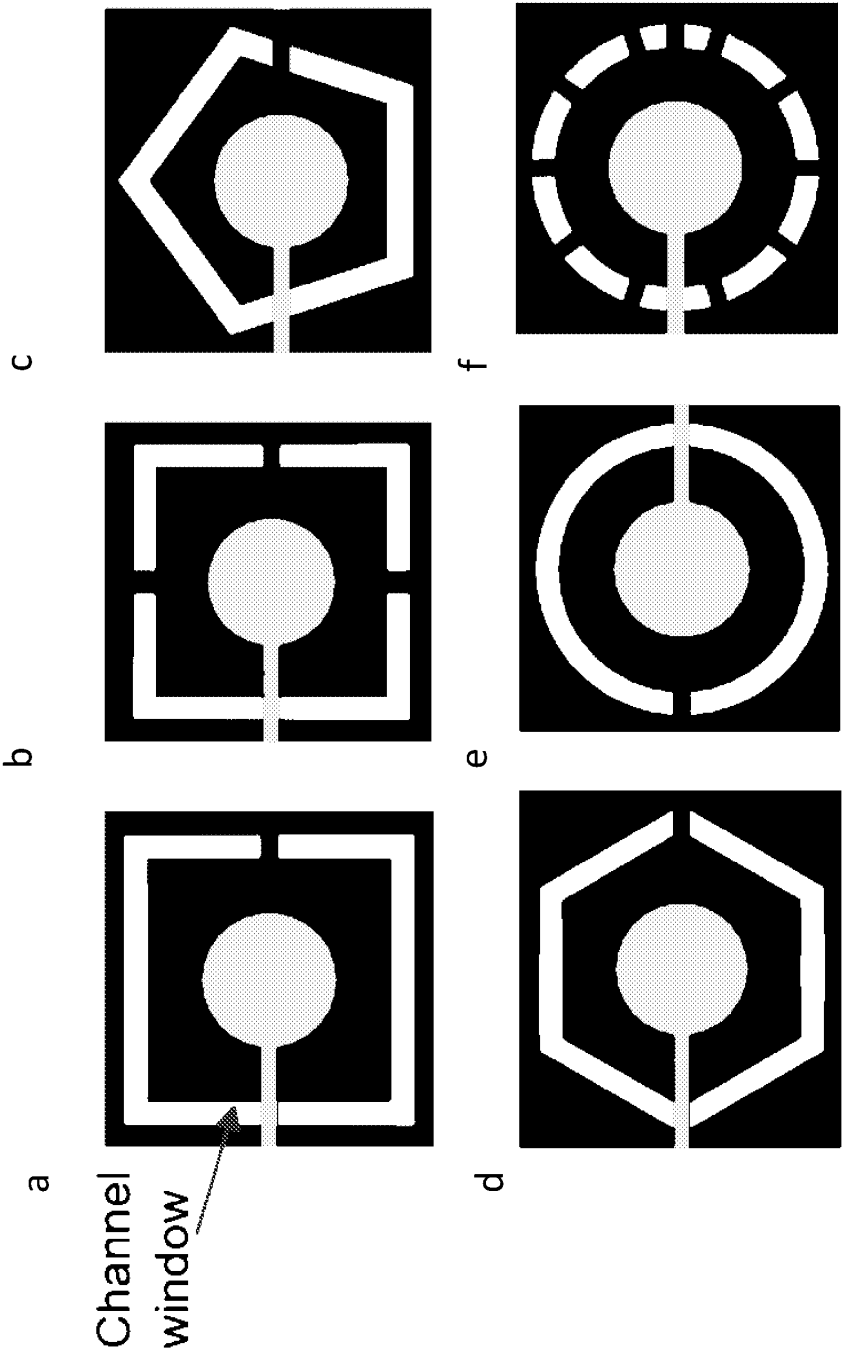


FIG. 16A

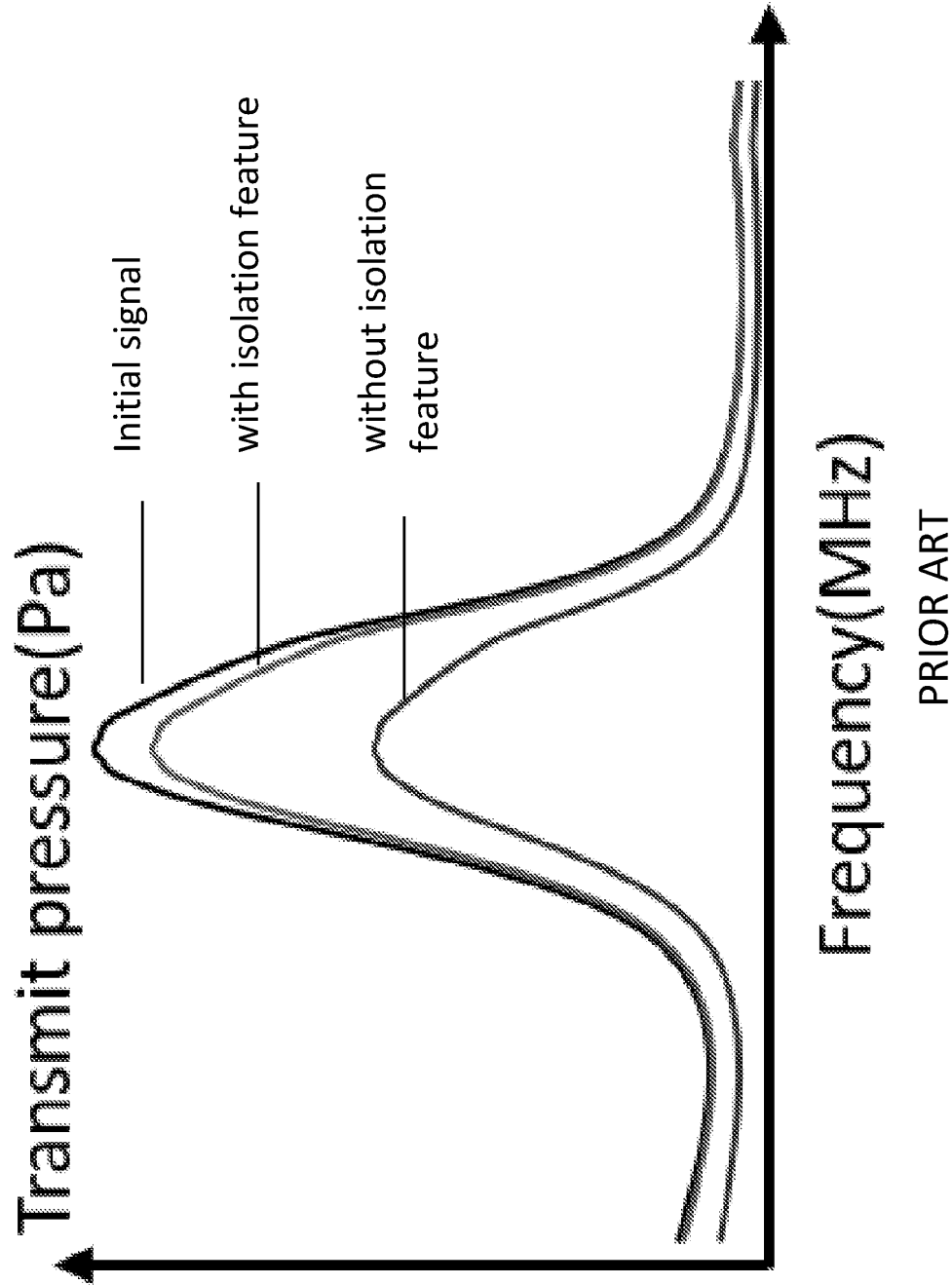
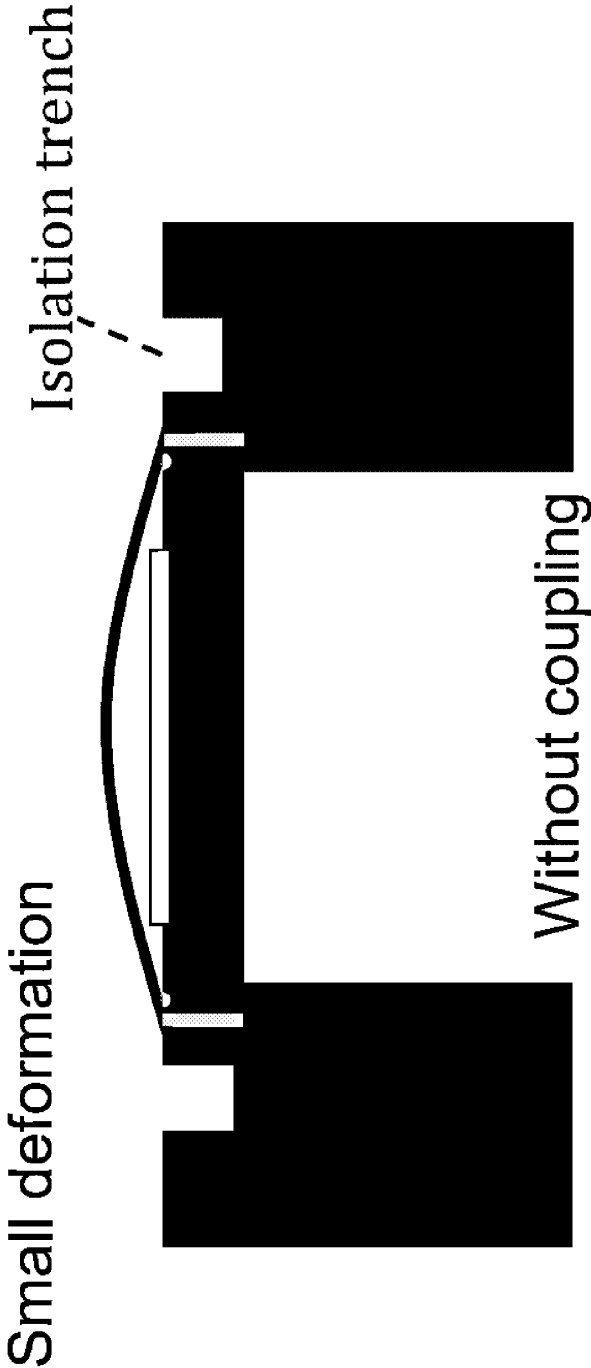


FIG. 16B



PRIOR ART

FIG. 16C

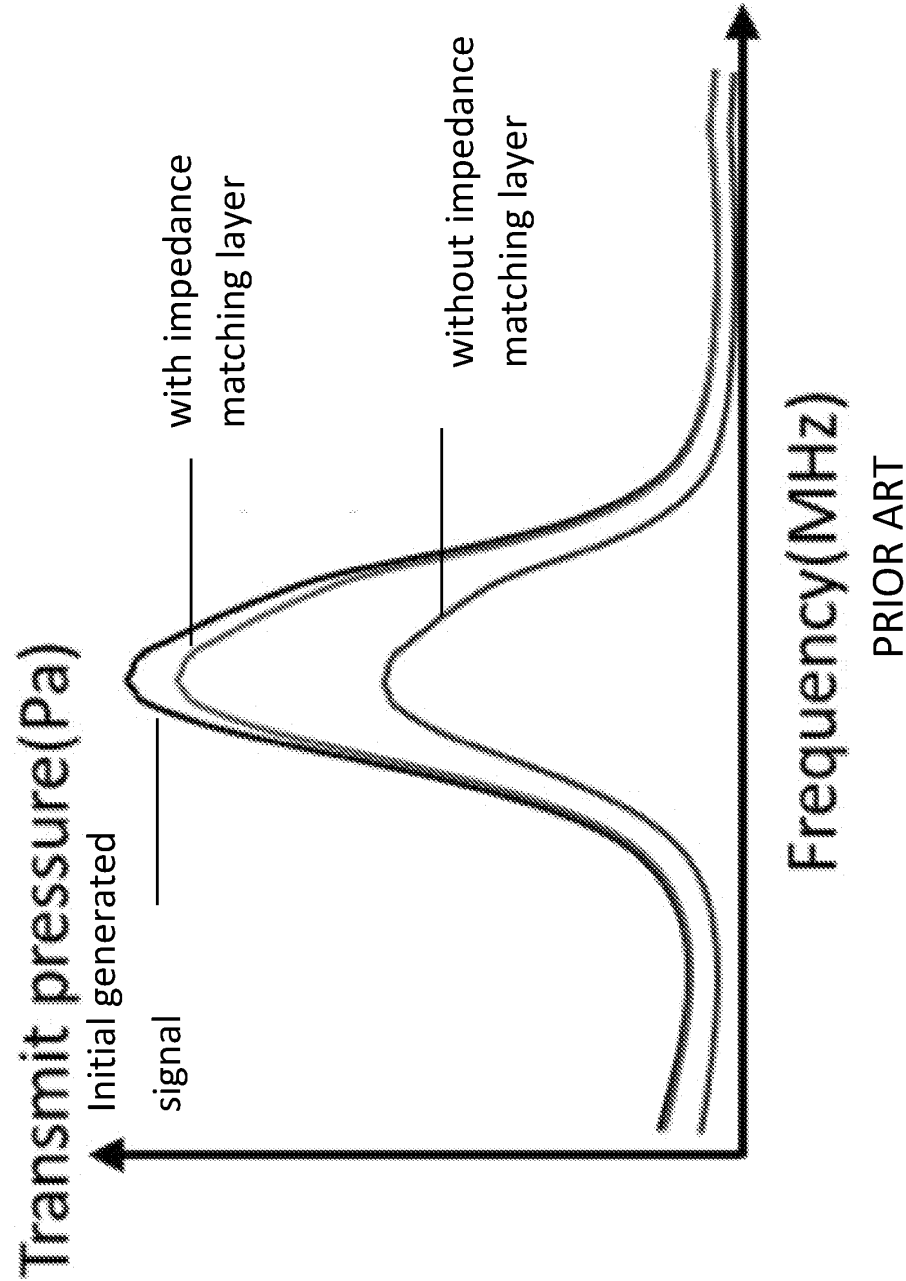


FIG. 16D

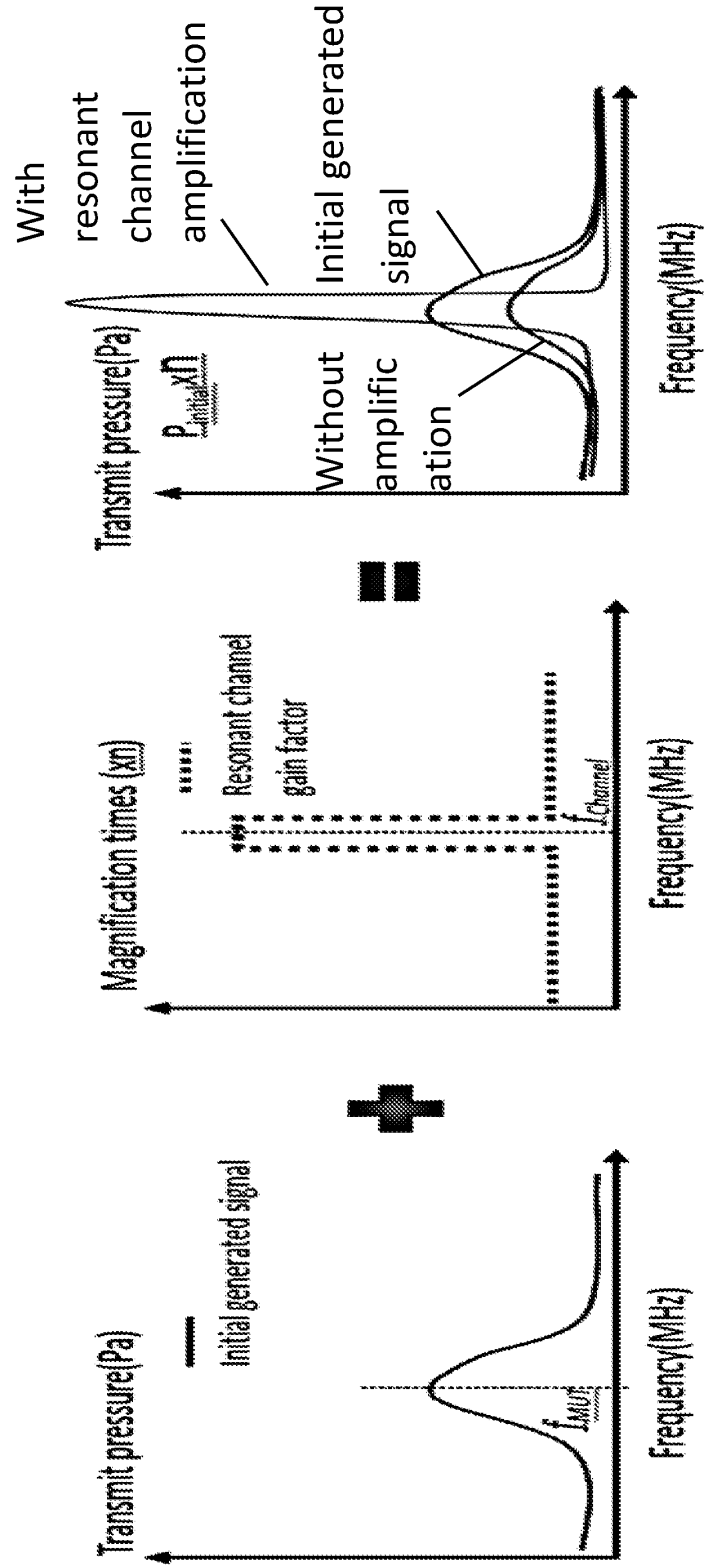


FIG. 17

