



IBULE PHOTONICS

MEMS APPLICATIONS

A world leader in the development of high performance piezoelectric single crystals and applications.



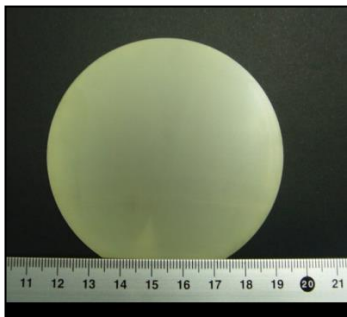
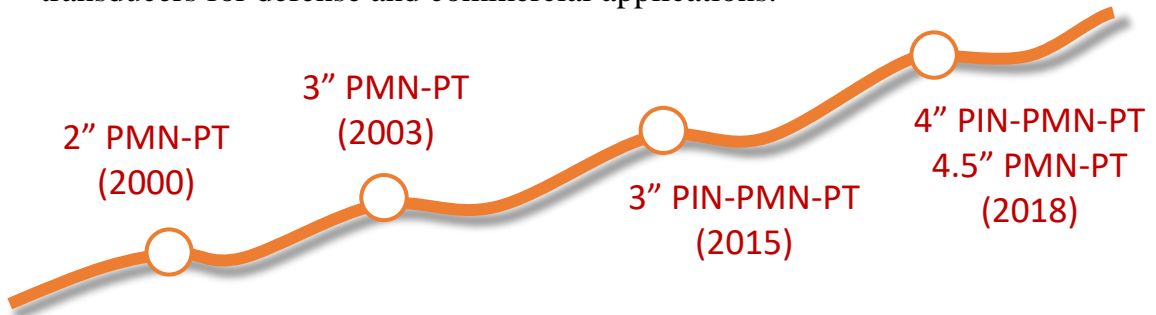
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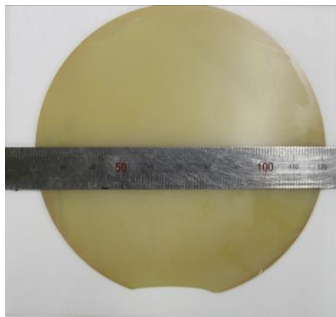
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Company and Products

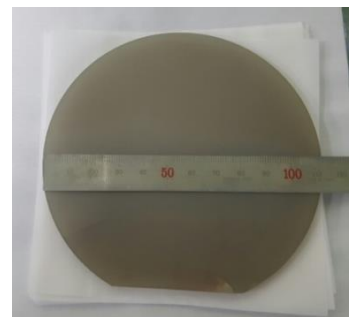
- Founded in 1999, iBULe Photonics had successfully developed the single crystal growing technology based on the Bridgman method, and is currently producing PMN-PT, PIN-PMN-PT and Mn:PIN-PMN-PT with [001], [011] and [111] growth directions in sizes up to 4.5" in diameter.
- iBULe is now a world leader in the development and manufacture of high-performance single crystals, and is rapidly expanding production capacities in order to provide customers with new opportunities for the next generation of transducers for defense and commercial applications.



3" PIN-PMN-PT



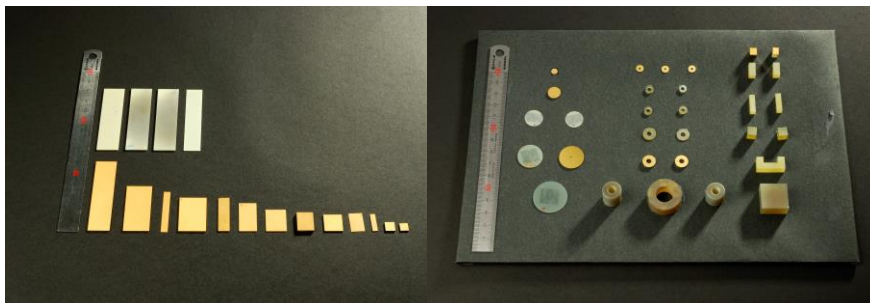
4" PIN-PMN-PT



4.5" PMN-PT

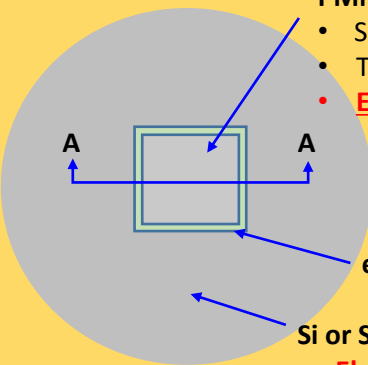
Commercialization

iBULe, with over 18 years of experience in single crystal growth and characterization, has commercialized producing various sizes of [001]-poled PMN-PT wafers for medical ultrasound imaging transducers.



Film Piezo single crystal(FPSC) MEMS Applications

IBULE PHOTONICS, Inc. has process that can bond PMN-PT Single Crystal on silicone wafer and process it into thickness appropriate to application. Application is possible in products such as MEMS acoustic sensor or P-MUT (Piezoelectric micromachined ultrasonic transducers).

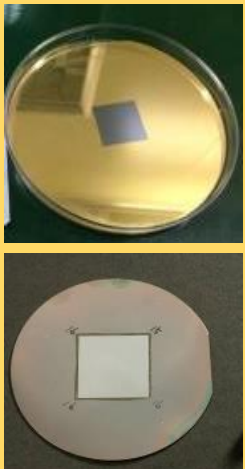


PMN-PT single crystal

- Size : normal 20 * 20, max 40 * 40
- Thickness : minimum about 5um
- **Electrode(option) : anything possible**

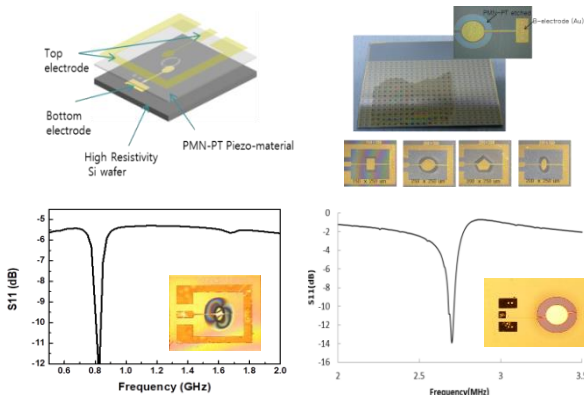
Si or SOI wafer

- **Electrode(option) : anything possible**



FPSC MEMS resonator

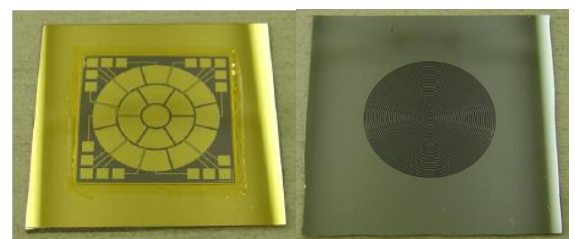
- 0.8~1.5GHz resonance using [001] single crystal
- Wine-Glass mode resonators using [011] single crystal
- Wideband resonator



FPSC MEMS deformable mirror

- Single crystal PMN-PT block bonded on an SOI wafer (thickness 30um)
- 19 annular ring type actuators
- 17 mm diameter membrane
- Large stroke over 10 um at 20 V for each actuator
- High operating bandwidth up to 874 Hz

Ref. Journal of Microelectromechanical Systems, Volume: 20, Issue: 6, Dec. 2011



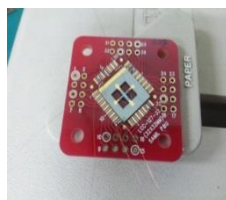
Actuator side

Mirror side

FPSC MEMS accelerometer

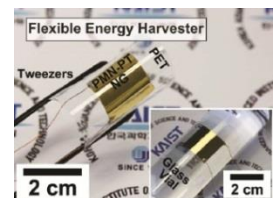
❖ The advantages of the use of piezoelectric.

- More controlled temperature dependence
- No need for a stable driving source
- Better long term stability
- Higher possible band width



FPSC Energy Harvest : Nano-generator

- Flexible Single Crystalline PMN-PT Piezoelectric Energy Harvester
- Bending : Generation of high current signal of up to 0.223 mA and output voltage of 8.2 V



Ref. Advanced Materials, Volume 26, Issue 28, July 23, 2014

	PZT	PMN-PT
Voltage sensitivity (mV/g)	0.31	0.75
Charge sensitivity (pC/g)	0.026	0.4
Resonance Freq. (kHz)	11	10
Size (mm)	10 x 10	10 x 11

Items	Specification
PMN-PT	Thickness : 8um
Mother substrate	Silicon wafer
Stressor	Ni film (Thickness : 20um)
Plastic substrate	Polyethylene terephthalate(PET)

Single Crystal Properties

■ PMN-PT

Parameter	Units	[001] poled		[011] poled	
		Low-PT	High-PT	Low-PT	High-PT
$\epsilon_{33}^T/\epsilon_0$	-	4842	7000	3760	5770
d_{ij}	$\times 10^{-12}$ C/N	$d_{33}=1282$	$d_{33}=1620$	$d_{32}=-1140$	$d_{32}=-1820$
s_{ij}^E	$\times 10^{-12}$ m ² /N	$s_{33}^E=47$	$s_{33}^E=56$	$s_{22}^E=53$	$s_{22}^E=78$
Trt	°C	95	85	95	85
Ec	KV/cm	2	2.5	2	2.5
Density	Kg/m ³	8080			

■ PIN-PMN-PT

Parameter	Units	[001] Poled		[011] Poled	
		Low-PT	High-PT	Low-PT	High-PT
$\epsilon_{33}^T/\epsilon_0$	-	4457	5666	3449	4656
d_{ij}	$\times 10^{-12}$ C/N	$d_{33}=1226$	$d_{33}=1840$	$d_{32}=-1323$	$d_{32}=-1870$
s_{ij}^E	$\times 10^{-12}$ m ² /N	$s_{33}^E=49$	$s_{33}^E=79$	$s_{22}^E=72$	$s_{22}^E=99$
Trt	°C	120	90	120	90
Ec	KV/cm	4	6	4	6
Density	kg/m ³	8154			

Unique piezocrystal properties create opportunities for unprecedented system performance.