SIMULATION OF PIEZOELECTRIC MICRO ULTRASONIC TRANSDUCER FOR UNDERWATER APPLICATIONS

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ABSTRACT

This research aimed to analyze multiple underwater Piezoelectric Micro Ultrasonic Transducer (PMUT) models using several types of piezoelectric materials. The models were based on the basic structure of circular and square PMUT. Each structure was designed with and without a supporting layer of silicon dioxide. Due to limited literature and structured database of PMUT, the researchers use more time and cost through a try-and-error approach. This study analyzes the receiving and transmitting sensitivity of the PMUT. Circular and square PMUT, with and without supporting layers were designed and simulated using six different piezoelectric materials namely aluminum nitride, lithium niobate, lead zirconate titanate type 5A (PZT-5A), lead zirconate titanate type 5H (PZT-5H), quartz and zinc oxide. FEA simulation and modeling were carried out using the COMSOL Multiphysics 5.0 software. The models were analyzed based on structural and electro-acoustic parameters including thickness, radius, length, width, frequency and voltage. All parameters were varied and the PMUT performances were determined based on the acoustic pressure, sound pressure level, displacement of the piezoelectric material and mises stress. The findings show that PZT-5H has the best performance in receiving and transmitting sensitivities at 1954 dB acoustic pressure at 240 kHz and 12 V of the drive voltage. The total device thickness is 430 μm. In conclusion, a total of 24 PMUT models have been analyzed and the performance of each model has been determined. All findings were compiled in a structured database to assist and guide researchers in designing and developing PMUT for underwater applications.

SIMULASI TRANSDUSER ULTRASONIK MIKRO PIEZOELEKTRIK UNTUK APLIKASI BAWAH AIR

ABSTRAK

Kajian ini bertujuan untuk menganalisis beberapa Transduser Ultrasonik Mikro Piezoelektrik (PMUT) dalam air menggunakan pelbagai jenis bahan piezoelektrik. Model-model PMUT dibina berdasarkan struktur asas dalam bentuk bulatan dan segiempat. Setiap struktur dibina bersama lapisan dan tanpa lapisan sokongan dari silikon dioksida. Literatur dan pangkalan data berstruktur PMUT yang terhad, menggunakan lebih masa dan kos melalui pendekatan cuba-dan-ralat. Kajian ini menganalisis sensitiviti PMUT dalam menerima dan menghantar gelombang akustik. PMUT bulatan dan segiempat, bersama lapisan dan tanpa lapisan sokongan direkabentuk serta disimulasi menggunakan enam bahan piezoelektrik berbeza iaitu aluminium nitrida, litium niobat, plumbum zirkonat titanat jenis 5A (PZT-5A), plumbum zirkonat titanat jenis 5H (PZT-5H), kuarza dan zink oksida. Simulasi Analisis Unsur Terbatas (FEA) dan pemodelan telah dijalankan menggunakan perisian COMSOL Multiphysics 5.0. Semua model telah dianalisis berdasarkan parameter struktur dan elektro-akustik termasuk ketebalan, radius, panjang, lebar, frekuensi dan voltan. Setiap parameter telah dipelbagai dan prestasi PMUT telah ditentukan berdasarkan tekanan akustik, tahap tekanan bunyi, sesaran bahan piezoelektrik dan tegasan mises. Dapatan kajian menunjukkan PZT-5H adalah terbaik dalam kepekaan prestasi bagi menerima dan menghantar gelombang akustik pada nilai 1954 dB tekanan akustik pada 240 kHz dan 12 V voltan pemacu. Jumlah ketebalan peranti ialah 430 μm. Kesimpulan, kesemua 24 model PMUT telah dianalisis dan prestasi setiap model telah ditentukan. Dapatan kajian telah disusun dalam pangkalan data berstruktur untuk membantu dan membimbing pengkaji dalam proses mereka bentuk dan membangun PMUT untuk aplikasi bawah air.

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LIST OF ABBREVIATIONS

Al	Aluminum
AP	Acoustic Pressure
BER	Bit-Error-Rates
CMOS	Complementary Metal-Oxide-Semiconductor
CMUT	Capacitive Micro Ultrasonic Transducer
d	Displacement
FEA	Finite Element Analysis
HF	High Frequency
LDV	Laser Doppler Vibrometry
LF	Low Frequency
$LiNbO_3$	Lithium Niobate
MEMS	Micro-Electro-Mechanical Systems
MF	Medium Frequency
MS	Mises Stress
MUT	Micromachined Ultrasonic Transducer
NDT	Nondestructive Test
OCRR	Open Circuit Receiving Response
PMUT	Piezoelectric Micromachined Ultrasonic Transducer
PZT	Plumbum/Lead Zirconate Titanate, $Pb(Zr_x, Tr_{-x})O_3$
Si	Silicon

SiO_2	Silicon Dioxide
SPL	Sound Pressure Level
SPL	Sound Pressure Level
Ti-Pt	Titanium Platinum alloy
TVR	Transmitting Voltage Response
VHF	Very High Frequency
ZnO	Zinc Oxide

LIST OF SYMBOLS

c_X	Speed of Sound of Material X
s_E	Material Compliance
ε_0	Relative Permittivity
ε_X	Permittivity of Material X
d	coupling properties
D	Electric Displacement field
S	Strain
T	Stress

APPENDIX