High frequency annular array imaging system, based on piezoceramic thick film for HIFU applications

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Thick film technology

Screen printing

PZT powder is suspended in an organic vehicle
Thick film technology

Pad printing

PZT powder is suspended in an organic vehicle
High Frequency Acoustic Transducers

- The porous structure of the film makes it a perfect candidate for medical imaging due to the following:
  - Low acoustic impedance
  - Low dielectric constant
  - High frequency (more than 20 MHz)
TF2100 transducer

Ultrasonic image of the skin with anginoma.

Ultrasonic image of the skin cancer spinocellular carcinoma.
Lead free transducer

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HIFU – High Intensity Focused Ultrasound

Ultrasonic waves focused in a point
Lesion in focal point due to local heating to 42 – 50°C
No lesion outside focal point

Body will heal lesion "from the inside"

Potential uses for a wide variety of conditions
- Brain Cancer
- Skin cancer
- Fat reduction
- Cosmetology treatments
- Eye deceases

Typically single-use transducers
- No ageing concerns
- Sterility
Ulthera – Skin treatment

Limited use cartridge containing HIFU and imaging transducers

3 models depending on treatment type (4 – 10 MHz)

Treatment elements from traditional Ferroperm bowls

Imaging element from unique InSensor Thick-film elements
Assessment of skin pathologies using ultrasound
Cellulite

About 90% of women have cellulite - aetiopathogenesis is not clear.

- hormonal disorders
- disorders in blood circulation in capillary vessels
- incorrect lifestyle.
Typical Symptoms:

- edema changes
- fibrosis
- sclerosis of the subcutaneous tissue

Using the high frequency ultrasound in diagnostic of cellulite the morphology can be evaluated and the therapy monitored.
Imaging cellulite using US high frequency.

NORMAL SKIN

CELLULITE

subcutaneous tissue in dermis
Woman, age 34, 3 weeks after treatment.

» Red arrows show the sites of the subcutaneous tissue ingrowing into dermis.
» Green arrows – local swelling.

Woman, age 60, 3 weeks after treatment

- Red arrows show the sites of the subcutaneous tissue ingrowing into dermis.
- Green arrows – local swelling.

Concave substrate, gold electrodes

GREEN LASER – 1532nm, beam 30 µm, focus 160 mm
Concave substrate, platinium electrodes

FIBER LASER – 1064nm, beam 30 μm, focus 160 mm
Measurement of reflected impulse from a thick metal plate. Transducer was measured in a small tank with water.

**FLAT Transducers**

<table>
<thead>
<tr>
<th>Thick film</th>
<th>Pz 26</th>
<th>Pz 26</th>
</tr>
</thead>
<tbody>
<tr>
<td>Film thickness</td>
<td>20-45 um</td>
<td>25-36 um</td>
</tr>
<tr>
<td>Active film diameter</td>
<td>2 mm</td>
<td>4.5 mm</td>
</tr>
<tr>
<td>Substrate material</td>
<td>Pz 37</td>
<td>Pz 37</td>
</tr>
<tr>
<td>Substrate thickness</td>
<td>7.5 mm</td>
<td>7.5 mm</td>
</tr>
</tbody>
</table>

**SUPERB BANDWIDTH AND NO CLUTTER**

Transmitter Avtech (4 nS) + Ritec diplexer
Flat substrate, platinium electrodes

FIBER LASER – 1064nm, beam 30 μm, focus 160 mm
Flat substrate, gold electrode thick film and silver top electrode

Finished transducer with PZT thick film and silver top electrode
Pulses on individual elements: from central disk to outer ring
-6 dB beamwidth FWHM = 0.21 mm at 12 mm depth, 
= 0.25 mm at 14 mm depth 
= 0.30 mm at 16 mm depth

measured using Precision Acoustics 0.040 mm needle hydrophone 
+ Ritec BR640A amplifier + LeCroy 62Xi digital oscilloscope

Transducers (rings) excited with 130 V<sub>p-p</sub>, 25 MHz, 2 periods bursts
Dynamically focused 7 elements thick film annular array transducer outer diameter D = 5 mm, f = 25 MHz

Lateral cross-section of the acoustical pressure generated by annular array transducer dynamically focused at depth=12, 14 and 16 mm.
Axial beam pattern for annular array focused at $f = 12$, 14 and 16 mm.
Ultrasonic pulse and its FFT spectrum generated by annular array focused at 12 mm

pulse 70 mV\text{p-p} amplitude = 9.2 MPa\text{p-p}, \textit{(very efficient electromechanical coupling)}

21 MHz center frequency, beamwidth\text{3dB} = 12.4 MHz
Conclusions

» Thick film (piezoceramic film deposition) technology can be successfully combined with "semiconductor technology (laser patterning of the bottom electrode)
» Both technologies are industrial and easy to scale up
» Radiation pattern (axial and lateral pressure) consistent with theoretical calculations
» Controlling the fixed transmitting focusing and dynamic receiving focusing will improve the image resolution
» Very high electromechanical coupling coefficient
» Wide bandwidth allows using encoded transmission (Golay, Barcer, chirp)
» Very good annular arrays for high frequency can be produced at relatively low cost and high volume
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Thank you