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Fabrication and characterisation of high-frequency ultrasonic transducers based on piezoelectric thick films and porous backing

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The properties of the high-frequency transducer (>20 MHz), in particular its operating frequency, sensitivity and resolution, are defined by the geometry, microstructure and characteristics of piezoelectric material and backing. For the backing, acoustical impedance and attenuation coefficient are predominant properties to be determined. In this work, we proposed a novel method for the in-situ measuring of these backing's properties at the operating frequency of the transducer.

We report on the processing and characterization of lead-zirconate-titanate based (PZT) piezoelectric thick films on a porous backing with tailored amount, size and shape of the pores. As a porous backing we used ~5mm-thick ceramic with nominal composition $Pb(Zr_{0.53}Ti_{0.47})O_3$ (PZT). The ceramic was prepared by hetero-coagulation process of PZT and polymethilmetacrylate in water at pH 8 followed by sintering the powder compacts at 1080 °C. Ceramic exhibited homogeneous microstructure with 15 % porosity and spherical, ~1 and ~10 μm-sized pores, respectively. The PZT thick films, screen-printed onto the electroded backing and sintered at 900 °C, had a thickness of ~25 μm, porosity of 20 % and thickness coupling coefficient of 45 %.

This integrated piezoelectric structure allows direct acoustic measurements of transducer components. The PZT thick film is electrically excited to measure the electroacoustic response in water and also the back-wall echoes coming from the backing if its thickness is sufficiently thin. The thickness of the backing was successively reduced and the measurements were repeated.

In the frequency range 15-25 MHz, the attenuation coefficients of backings with 1- and 10-μm- sized pores were 0.7 dB/mm/MHz and 4 dB/mm/MHz, respectively, the group velocities were ~3400 m/s which results in the acoustic impedance of ~22 MRa. The high attenuation in backing with 10 μm-sized pores and moderate acoustical impedance enable substantial miniaturisation of high-resolution ultrasonic imaging transducers.

Recent Publications

1. Kuscer D, Rojac T, Belavič D, Santo Zarnik M, Bradeško A, Kos T, Malič B, Boerrigter M, Martin DM, Faccini M (2017). »Integrated piezoelectric vibration system for fouling mitigation in ceramic filtration membranes«. J. Membr. Sci., 540:277-284.
2. Mercier H, Malič B, Uršič H, Hreščakk J, Levassort F, Kuscer D (2017). »Electrophoretic deposition and properties of strontium-doped sodium potassium niobate thick films«. J. Eur.Ceram. Soc., 37[16] : 5305-5313.
3. Bakarič T, Rojac T, Abellard AP, Malič B, Levassort F, Kuscer D, (2016). »Effect of pore size and porosity on piezoelectric and acoustic properties of Pb(Zr0.53Ti0.47)O3 ceramics«. Adv. Appl. Ceram., 115 [2]: 66-71.
4. Kuscer D, Bernardo M, Santo Zarnik M, Malič B (2016). »Patterning of lead-zirconate-titanate thick-film structures by electrophoretic deposition from ethanol-based dispersions«. J. Eur.Ceram. Soc., 36 [2]: 291-297.
5. Bakarič T, Malič B, Kuscer D (2016). »Lead-zirconate-titanate-based thick-film structures prepared by piezoelectric inkjet printing of aqueous suspensions«. J. Eur.Ceram. Soc., 36 [16]: 4031-4037.
6. Abellard AP, Kuscer D, Gregoire JM, Malič B, Levassort F (2014). »Lead zirconate titanate-based thick films for high-frequency focused ultrasound transducers prepared by electrophoretic deposition«. IEEE transactions on ultrasonics, ferroelectrics, and frequency control, 61 [3]: 547-556.
7. Kuscer D, Noshchenko O, Uršič H, Malič B (2013). »Piezoelectric properties of ink-jetprinted lead zirconate titanate thick films confirmed by piezoresponse force microscopy«. J. Am.Ceram. Soc., 96 [9]: 2714-2717.

Biography

Asst. Prof. Danjela Kuscer, PhD in material science at the University of Ljubljana, Slovenia (1999). Current position: senior researcher at Jožef Stefan Institute and Assistant Professor at Jožef Stefan International Postgraduated School, Ljubljana, Slovenia.

Research: synthesis and characterisation of complex-composition ceramic applicable in electronics, including synthesis of (nano) powders by mechanically-assisted and solid state synthesis, synthesis of ceramic with tailored microstructure, patterning of thick film structures using water- and organic-based suspensions by electrophoretic deposition, screen- and inkjet printing, and their structural, microstructural and functional characterisation.

Publications: 120 publications and 150 technical reports. She holds one Slovenian, two USA patents and three PCT patent applications.She participated in 31 projects, of which she leads 7 EU and 5 national applied projects. Between 2014 and 2017 she won six national awards for the innovation in the field of ceramics, the most important being Puh recognition for 2015, the highest Slovenian science award for important applied work.

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