

# Lead-Free Ceramics in Prestressed Ultrasonic Transducers

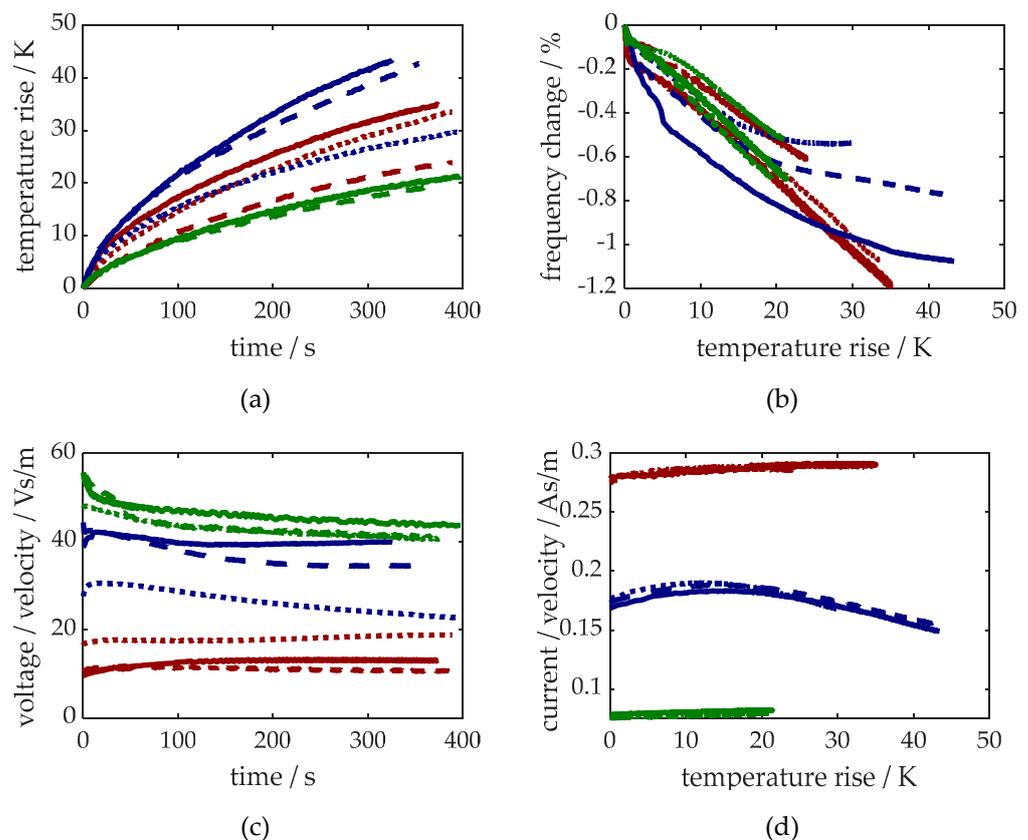
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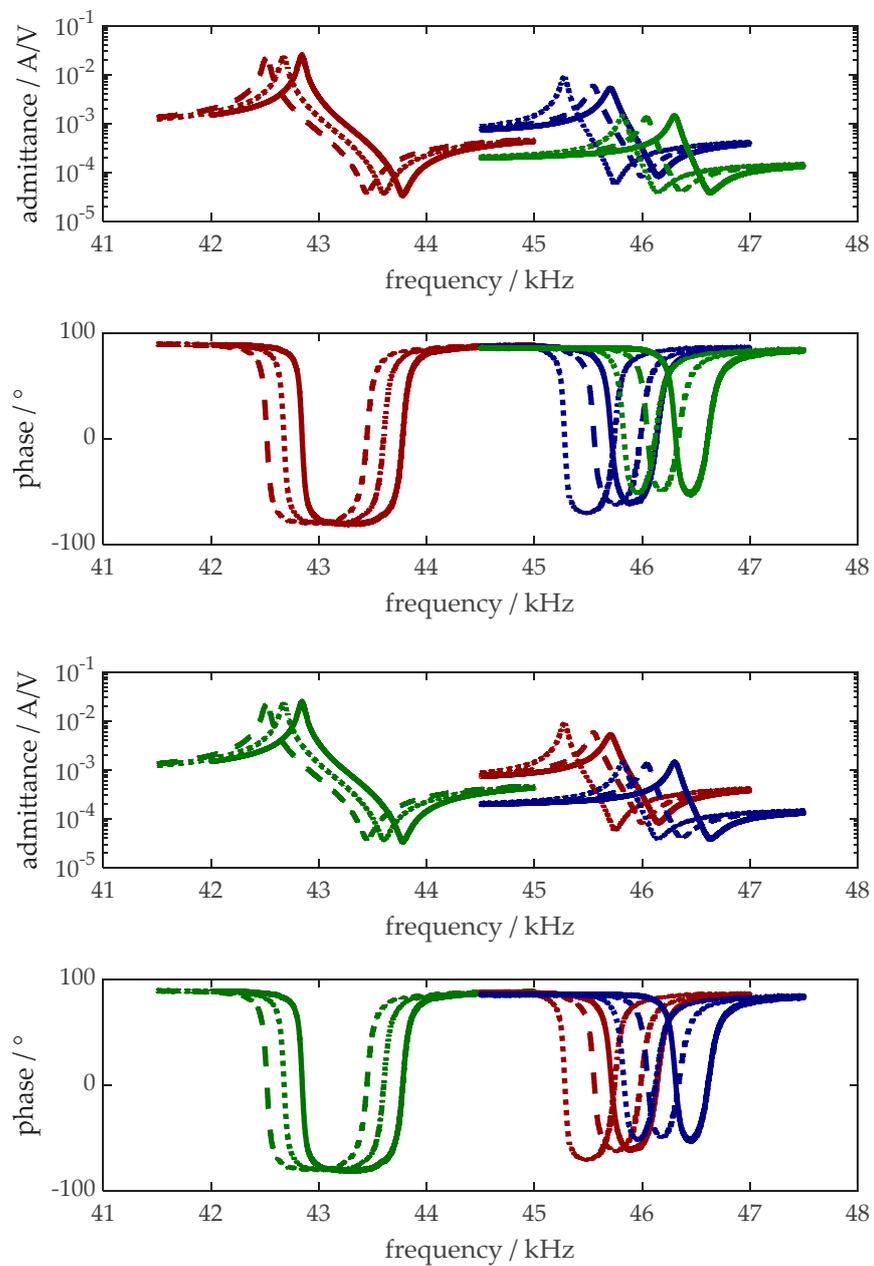
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Measurements in this study were made with all made transducers (five individual transducers for each of the three materials). As the scope of this study is to compare characteristics of transducers with different materials as well as showing scattering between individuals, but reading out data from figures is limited, the following supplementary figures contain data for three individual transducer samples made with the different materials. Further data are available under request. The numbering of the figures was chosen so that a comparison with the manuscript is easily possible.

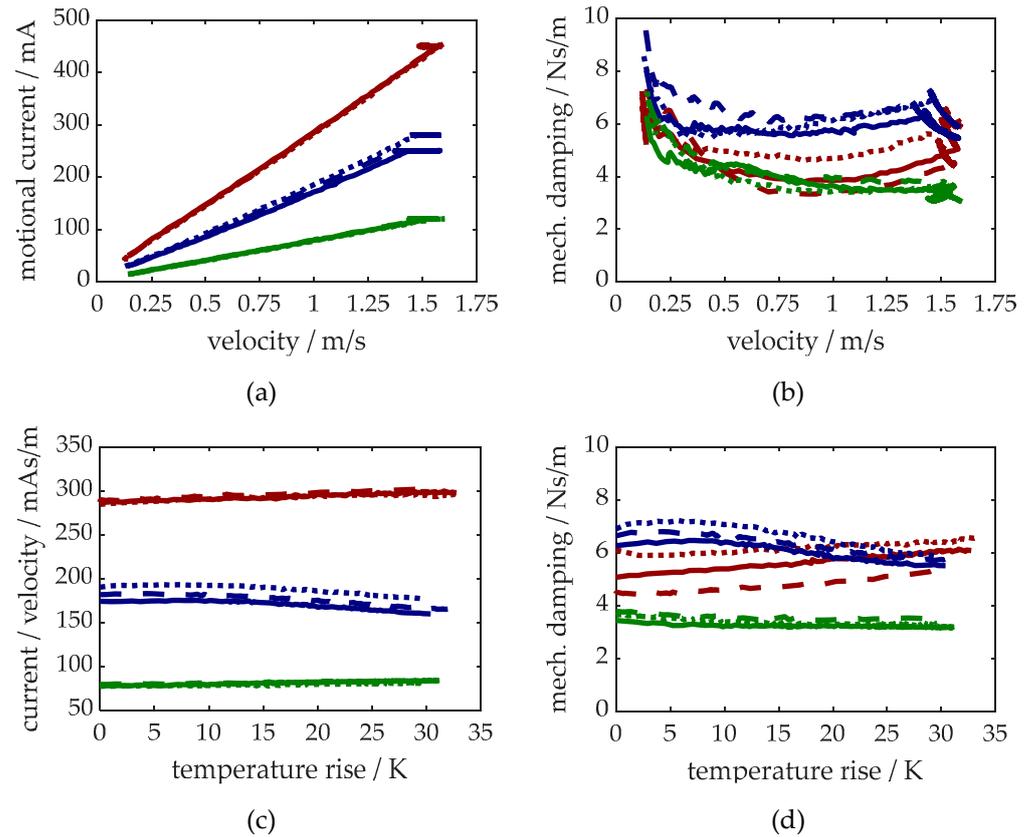


**Figure S1.** (Relates to Figure 5): Results of burn-in process (free resonant vibration at  $\approx 1$  m/s for  $\approx 6$  minutes); line types indicate individual transducer samples (solid, dashed, and dotted lines), and colours stand for different materials (PIC 181: red, PIC 758: blue, PIC HQ2: green): (a)

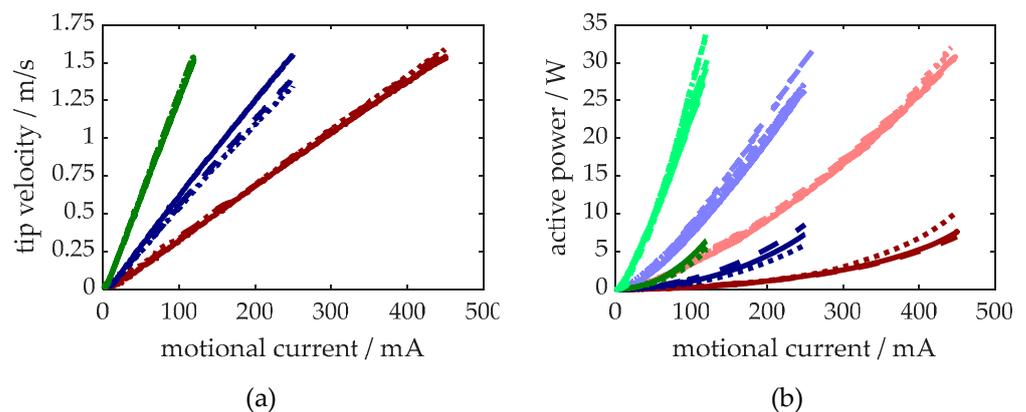
temperature rise over time, (b) resonance frequency change over temperature rise, (c) voltage related to tip velocity over time, (d) motional current related to tip velocity over temperature rise.



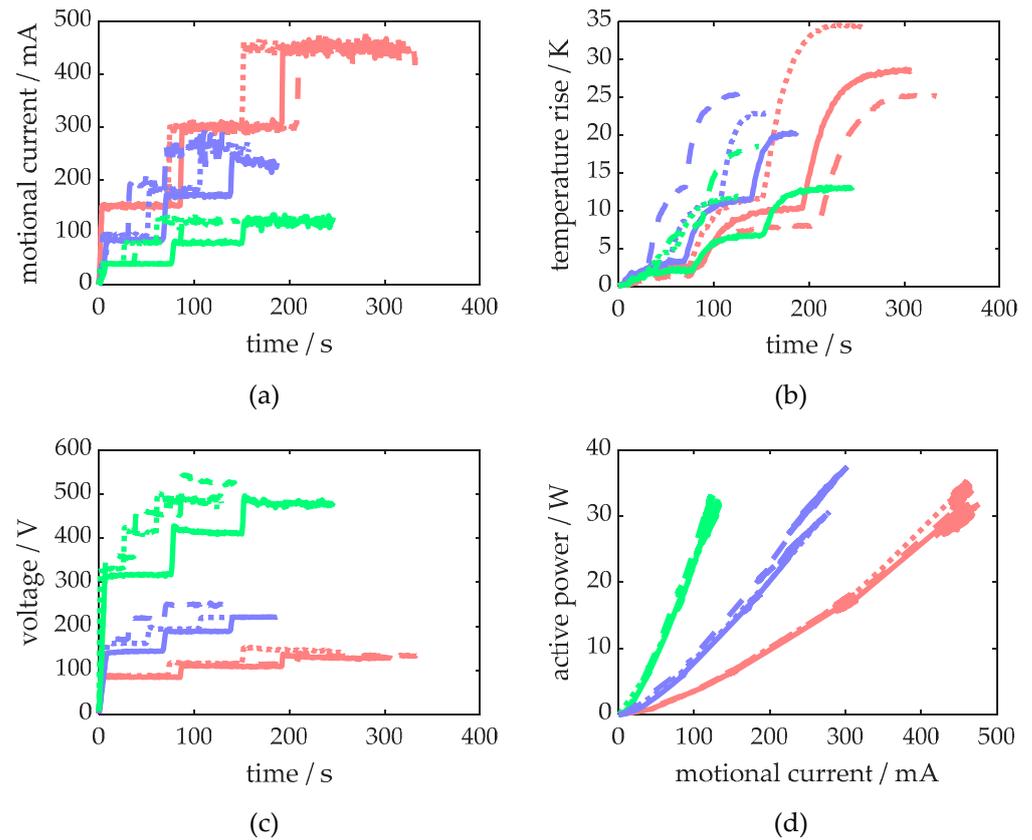
**Figure S2.** (Relates to Figure 6): Small-signal admittance characteristics (free vibration, room temperature); line types indicate individual transducer samples (solid, dashed, and dotted lines), and colours stand for different materials (PIC 181: red, PIC 758: blue, PIC HQ2: green).



**Figure S3.** (Relates to Figure 7): Results of tests (resonance-controlled continuous vibration up to 1.5 m/s, heat up over time); line types indicate individual transducer samples (solid, dashed, and dotted lines), and colours stand for different materials (PIC 181: red, PIC 758: blue, PIC HQ2: green): (a) dependency of tip velocity and motional current, (b) mechanical damping factor over tip velocity, (c) ratio of motional current and tip velocity over temperature rise, and (d) mechanical damping factor over temperature rise.



**Figure S4.** (Relates to Figure 8): Results of short-term operation tests; line types indicate individual transducer samples (solid, dashed, and dotted lines), and colours stand for different materials (PIC 181: red, PIC 758: blue, PIC HQ2: green): (a) dependency of tip velocity and motional current for the no-load vibration of the transducer being fixed in the clamping, and (b) active power over motional current at free vibration (dark colours) and under water load (light colours).



**Figure S5.** (Relates to Figure 9): Results of load tests with heating up (immersion of transducer tip into water, controlled vibration at different levels of motional current, continuous drive until steady state temperature); line types indicate individual transducer samples (solid, dashed, and dotted lines), and colours stand for different materials (PIC 181: red, PIC 758: blue, PIC HQ2: green): (a) motional current amplitude over time, (b) temperature rise over time, (c) voltage amplitude over time, and (d) active power over motional current amplitude.