Insole Embedded Lead Zirconate-Titanate Film Force Sensor Array

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Low power insole embedded force sensors monitor a patient′s balance, gait, and weight distribution while standing, walking or running. Flexible piezoelectric films as force sensors eliminate the need for standby energy, providing high sensitivity and flexibility in sensor array design. Lead zirconate-titanate piezoelectric films 1 μm thin were dip coat deposited onto a 25 μm thick stainless steel flexible metal foil. The film displayed a 47% Lotgering factor for the < 100 > crystallographic direction and exhibited a high-density granular perovskite structure with little pyrochlore near the middle and bottom of the dip cast film. P-E loops show high remanent polarization values of +_ _28.2 μC/cm2 and − _24.3 μC/cm2 and typical coercive fields of 59.4 kV/cm and − _56.7 kV/cm. This piezoelectric sensing array with 24 photolithographically defined electrodes enabled the simulation of a single toe response, the ball of the foot rolling during a step response, and a heel-strike emulation response. Voltage measurements extracted from cyclic applied forces from 0 to 30 N showed a linear response with a sensitivity of − _9.76 mV/N between 0 and 12 N and a nonlinear response between 12 and 30 N. The roll test provided ~100 mV responses when expected during a perpendicular and diagonal roll on four individual sensors, each with fast response times and some mixture of bending and compressive stresses. The heel-strike emulation above a single electrode exhibited a response of ~300 mV with 60 N compressive force, ~100 mV from a nearby electrode, and minimal response from electrodes further from the applied force. A discrete circuit was designed and tested on a printed circuit board for multi-channel sensing, digitization, amplification and wireless transmission of the activation signal.