Nondestructive Ultrasonic Evaluation of Electrically Degraded Multilayer Ceramic Capacitors

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Multilayer ceramic capacitors (MLCCs) are a vital circuitry component, responsible for 30% of all circuit failures. A common degradation mechanism in MLCCs is insulation resistance degradation caused by electromigration of oxygen vacancies under DC bias which limits part lifetime. This work utilizes high frequency ultrasound (100 MHz) as a nondestructive characterization tool to spatially identify regions of degradation caused by oxygen vacancy migration. Ultrasonic attenuation, which results from absorption and changes in acoustic impedance that lead to scattering, was explored. Thermally stimulated depolarization current (TSDC) was utilized to degrade parts and electronically evaluate the presence of oxygen vacancies. A set of commercial 1812 BME X7R MLCCs (52 dielectric layers, 100 V rated, 560 nF) were characterized using a custom ultrasonic immersion setup in both a pristine state and after TSDC (130°C, 140°C , 150°C at 300 V for 8 hours and 10 deg/min heating rate). Each TSDC condition indicated oxygen vacancy migration across grain boundaries. Average ultrasonic attenuation increased (1-22%) and changes in the spatial attenuation response were observed after TSDC. The most extreme poling conditions resulted in the largest variations in the spatial attenuation response which could indicate sensitivity to structural or microstructural damage caused by electromigration of oxygen vacancies. SEM voltage contrast imaging on a degraded sample showed increased oxygen vacancy migration in the regions of high attenuation response compared to the regions of low attenuation response which further indicates possible sensitivity to structural changes caused by oxygen vacancy migration.