Capacitors at low temperatures revealed by cryo-synchrotron X-ray phase contrast microtomography

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Abstract

Electronic devices are used in extreme conditions such as in outerspace, exposing them to extreme low temperatures. Understanding their behaviour is important for optimizing their functionality and to better design and manufacture individual electronic components. Capacitors are such electronic components sensitive to temperature. Low temperature electric characterization of capacitors typically has no spatial information. Here we combine synchrotron cryo-microtomography down to 77 K (carried out at beamline BM18), impedance and electrical characterization down to 20 K (carried out at beamline BM28), to correlate the electrical and structural properties of commercially available capacitors. We characterized multilayer ceramic, Ta2O5 and Al2O3 electrolytic capacitors. Our experiment reveals that a change in capacitance at low temperature is dominated by structural changes than from possible intrinsic changes such as in resistivity, crystal structure or dielectric permittivity. For example, in a tantalum oxide capacitor, we find that the porosity can increase by about 20% at 77K, and is resulting in a change of capacitance from 47 μF at 300K to 37 μF at 77K. Our result shows a new insight towards the functionality of commercial capacitors at low temperatures and provide important benchmark for developing and designing future capacitors for extreme environmental conditions.

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