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Size dependence of the dielectric breakdown strength from nano- to millimeter scale

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ABSTRACT

Dielectric breakdown decisively determines the reliability of nano- to centimeter-sized electronic devices and components. A systematic investigation of the size-dependent dielectric breakdown strength reveals a thickness-independent intrinsic regime and a thickness-dependent extrinsic regime. Besides that the breakdown strength scales with the inverse square root of the permittivity. Only recently, the intrinsic breakdown strength could be theoretically explained by density functional theory calculations, which confirmed von Hippel's electron avalanche model. This thickness dependence resembles the difference between an intrinsic mechanical strength and a volume dependent defect size controlled Weibull mechanical strength distribution. Therefore, the hypothesis whether the thickness dependence of dielectric breakdown can be explained by a weakest link concept is discussed. Finally it is shown that the prevailing electrical conduction mechanism at the onset of dielectric breakdown is most probably dominated by space charge injection. A Griffith type energy release rate breakdown model including space charge conductivity is presented, which allows for the explanation of the empirical results in the extrinsic regime.