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Damage-growth-induced evolution of contact resistance of a RF MEMS switch

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ABSTRACT

This study presented the evolution of the contact resistance induced by the growth of the contact damage between the switch contact tip and the drain surface in the lifetime of an ohmic RF MEMS switch. Omron 2SMES-01 commercial switch was selected for the experiment. All switches were operated under the hot-switching condition with a steeply rising actuation voltage. The voltage across the switch (switching voltage) was maintained as 20x of manufacturer's specified value. Per million-cycle interval, the switching voltage, current, and contact resistance were recorded. The measurements showed three different situations of the contact resistance evolution: (i) the contact resistance monotonically decreases initially to a minimum and then monotonically increases; (ii) the resistance initially decreases to a local minimum, then increases to a local maximum, subsequently decreases to another local minimum, and finally increases; (iii) the resistance decreases initially and then increases until the switch fails in contact; the switch functions again after an intermitted response, and subsequently the resistance decreases again and then increases. A nonadhesive contact model is developed to explain these three situations. The modeling results show that the hot-switching condition changes properties of the contact materials, i.e., the elastic modulus and the yield strength, around the contact region and then causes some plastic deformation around the tip summit. The contact penetration and the contact area increase gradually due to the growth of the plastic deformation. Thus, the contact resistance which is reciprocally proportional to the contact area decreases in the initial stages of all cases. After unloading the tip per contact cycle, a residual depth is produced between the tip and the drain. The growth of the plastic deformation increases the residual depth. When the contact penetration reaches the value corresponding to the maximum contact area, the fixed electrostatic force cannot make the tip a deeper penetration due to a quite large residual depth. Consequently, the reduced contact penetration decreases the contact area. Therefore, the contact resistance dependent on the contact area rises gradually in the second stage as the first case. If the tip displacement caused by the electrostatic force is close to the tip–drain gap within a residual depth, a local minimum contact area will be produced to cause a local maximum contact resistance in the switch lifetime as the second case. A temporary failure in contact occurs when the tip displacement is smaller than the tip–drain gap within a residual depth. The slowing growth of the residual depth allows the tip–drain contact again as the third case.