Electromechanical reliability of metallization on flexible substrates

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The main advantages of flexible electronics in comparison to conventional rigid technology are light-weight design, mechanical and topological flexibility as well as large-area and cost-effective production. For realization of these advantages within a final device not only development of novel appropriate materials and fabrication methods but also understanding of reliability issues and failure mechanisms are required. In this contribution two important reliability issues of flexible electronics technology are discussed: behavior of metallization layers under different bending loading conditions and correlation between electrical degradation and mechanical damage induced by cyclic mechanical loading.

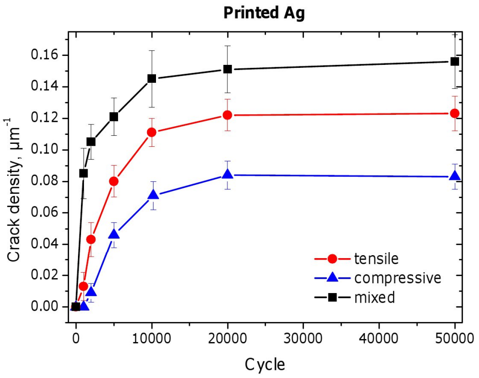

Fig. 1. Evolution of the crack density in 700 nm thick printed Ag with the cycle number for tensile, compressive and interchanging tensile-compressive bending strain. The bending radius is 5 mm, corresponding strain is 1.3% in all cases.

Using a newly developed bending test apparatus it is shown that even for the same amount of applied cyclic strain, i.e. for the same *bending radius*, the amount of mechanical damage differs significantly depending on whether tensile, compressive or alternating tensile-compressive strain is applied. In Fig.1 the evolution of the crack density induced in printed silver lines on PEN substrate by application of cyclic bending of three different types is shown. It is clearly seen that interchanging tensile-compressive bending condition appears to be the most fatal whereas pure compressive bending strain induces the lowest crack density at saturation. Detailed analysis of the fracture mechanisms together with comparison of printed and evaporated silver lines with different thicknesses will be given in more details during the talk.

Since ability to conduct electric current is the main functional property of metallization layers it is important to understand the correspondence between mechanical damage and electrical degradation of conductive lines on polymer substrate. In Fig. 2 the behavior of electrical resistance during application of cyclic tensile strain of 1% and 2% for 500 nm evaporated Au film on polyimide (a) 500 nm evaporated copper on polyimide (b) and 700 nm printed Ag on PEN (c) is shown. Distinct differences in resistance behavior are clearly visible in Fig. 2 for the 2% of cyclic strain. Gold films show virtually no resistance increase after 10000 cycles. Copper films demonstrate rapid growth of resistance after 1000 cycles. In the case of printed silver resistance starts to grow virtually from the first cycle and at the same time the amplitude of the resistance signal, i.e. the difference of resistance between peak and zero strain, becomes larger. A detailed analysis of the relationship between structure, mechanical fracture, and electrical degradation will be given during the talk.

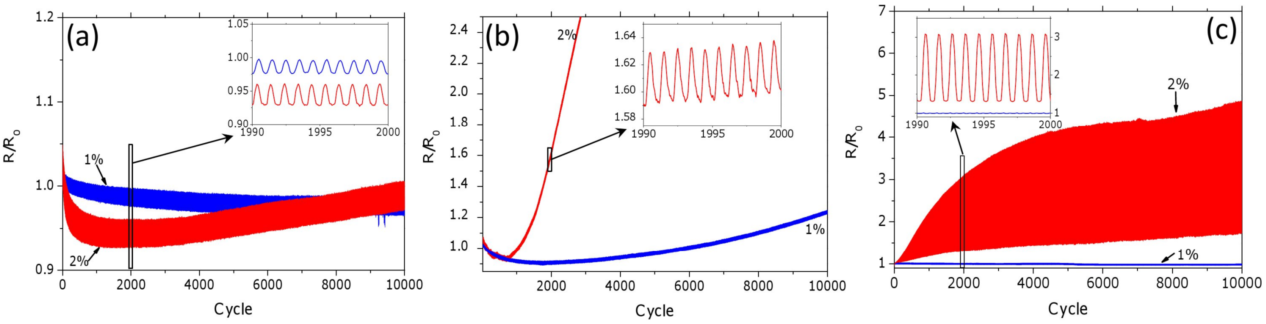

Fig. 2. Behavior of electrical resistance during application of cyclic tensile strain of 1% and 2% for 500 nm evaporated Au film on polyimide (a), 500 nm evaporated Cu on polyimide (b), and 700 nm printed Ag on PEN (c).