DIRECT OBSERVATION OF YIELD IN FILMS BY FLAT PUNCH INDENTATION

John B. Pethica, School of Physics, CRANN & AMBER, Trinity College Dublin, Ireland
jp12@tcd.ie
Owen Brazil, School of Physics, CRANN & AMBER, Trinity College Dublin, Ireland
Johann P. de Silva, School of Physics, CRANN & AMBER, Trinity College Dublin, Ireland
Warren C. Oliver, Nanomechanics Inc. & the University of Tennessee, USA
Jason Kilpatrick, Adama Innovations, Dublin, Ireland
Graham L. W. Cross, School of Physics, CRANN & AMBER, Trinity College Dublin, Ireland

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In regular indentation many strain states are simultaneously present in the indented region, so measured parameters such as hardness and modulus are average values over a wide range of strains. Testing of structures such as pillars, levers or film bulges enables determination of yield point and modulus with uniform strains in the sample, but requires specialised sample preparation and can be significantly affected by surface condition.

Here we show how in-situ indentation with a flat punch allows direct observation of a discrete yield point in soft films on more rigid substrates. The yield point is clearly observable from the load displacement behaviour and from post indent AFM imaging. The film is in uniform uniaxial strain. Finite element simulations show that effective self-confinement by surrounding film material leads to uniformity throughout the film material down to surprisingly low aspect ratios around 4:1. This occurs for a significant range of stresses above the yield point. Eventually at even higher stresses the film material is extruded laterally.

The characteristics of the yield event will be described as a function of temperature and film thickness for thin to ultrathin films. At higher aspect ratio and with sufficient stiffness of punch and substrate, quantitative, in-situ measurement of intrinsic stress vs. strain to well beyond the elastic limit becomes possible for thin films. The extent to which full constitutive relations for polymer films can be determied will be discussed, along with limitations of the technique.