Mechanical integrity of polymer film used in microelectronics: a identification of the thermoelastic properties and a coupled criterion analysis of the failure properties

B. Vavrille[1,2,3], L. Vignoud[1], L-L Chapelon[2], R. Estevez[3]

Université Grenoble Alpes, CEA, Leti, 38000 Grenoble, France
STMicroelectronics, 38926 Crolles, France
Université Grenoble Alpes, Laboratoire SIMaP, 38000 Grenoble, France
(Rafael.Estevez@simap.grenoble-inp.fr)

Polymer films are used in microelectronics at various stages of the stacking, in various applications. Their thickness is of some microns, and specific techniques are required to identify their thermoelastic properties. The latter are necessary to predict the mechanical integrity of heterogeneous multi-layers subjected to thermal cycles of various amplitudes during the processing and in-use.

We first present a characterization method based on the curvature variation with temperature of a polymer film deposited on a silicon wafer. An inverse problem is set from which the thermoelastic properties are derived, namely the in-plane modulus and coefficient of thermal expansion (cte). These are dependent on the magnitude of the Poisson's ratio. A 'realistic variation' of this quantity allows to derive the Young modulus and cte within an interval which is discussed together with the uncertainties related to the inverse problem formulated. The estimations are cross-compared with measurements from other techniques (colored ultrafast acoustics for the mechanical properties and temperature-dependent ellipsometry for the cte), with a good agreement.

With these estimations, we address the problem of assessing the mechanical integrity of a micron-scale structure made of a polymer pillar, of which height ranges from two to four microns, the width being several time larger. Along the polymer surface, a thin glass film is deposited, of which thickness ranges from 0.2 to 0.4 micron. The structure exhibits a large thermomechanical contrast, the hard coat being brittle. Depending on the thickness ratio between the polymer and the hard coat and the thickness of the latter, failure of the hard-coat is observed or prevented for a relative temperature variation of 300 K. The origin of this is discussed, and the failure properties of the encapsulating layer, namely its material's strength and critical energy release rate, derived. This allows the definition of the 'domain of mechanical integrity' by considering the polymer-to-hard coat thickness ratio and in particular the hard-coat thickness.

Keywords: polymer film, thermoelastic identification, thermally induced curvature, mechanical integrity, encapsulating layer.