

MECHANICS OF THIN FILM STRUCTURES

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Summary With emphasis on interface delamination in thin film structures, a variety of phenomena are discussed. The effects of curvature of the substrate on buckling-driven delamination of thin films in compression are analysed. Details in the morphology of buckling-driven delamination and in particular the causes of the so-called telephone cord blister are discussed. Conditions for delamination at edges and corners are formulated and it is shown that steady-state delamination at a corner is possible at significantly lower stress levels than delaminations at straight-sided edges.

RECENT RESULTS IN THE MODELLING OF INTERFACE DELAMINATION IN THIN FILM STRUCTURES

Curved Substrates

Many applications of thin films involve systems with curved substrates or substrates with corners. The effects of curvature of the substrate and corners in the substrate on buckling-driven delamination of thin films in compression are analysed. In particular an analysis of buckling-driven delamination of a thin film on a spherical substrate has been carried out. The effects of the substrate having a double curvature compared to previous studies of delamination on cylindrical substrates turns out to be non-trivial: In addition to the effect of the shape of the substrate, a new non-dimensional geometrical parameter enters the conditions for steady-state delamination. It is shown that for a certain range of delamination widths, this additional geometrical parameter has only minor influence on the conditions for steady-state delamination. Furthermore, the shape of the substrate has profound influence especially on initiation of delamination growth.

Morphology of buckling-driven delamination

Details in the morphology of buckling-driven delamination and in particular the causes of the so-called telephone cord blister are discussed. Conditions for steady-state growth of buckling-driven delamination in thin film systems can be calculated by a simplified method where details around the growing front are not required. The simplified method relies upon estimates of the phase angle of loading along the propagating front of delamination and the accuracy of these estimates is investigated by comparing with finite element calculations of the fracture mechanics parameters along the growing front. The sensitivity of the parameters to the shape of the front is investigated and it is shown that the simplified approach for estimating the phase angle of loading on the growing front of delamination - based on a re-scaling of the phase angle of loading for a full circular delamination - is reasonably accurate. It has been shown that a semi-circle best approximates the shape of the growing crack front. This, however, is true only at moderate stress levels when a mode II independent interface fracture criterion is assumed. The shape of the front has not been determined at higher stress levels or for other fracture criteria. The simplified approach for estimating the phase angle of loading slightly underestimates the mode I stress intensity factor on the crack front. As a result, the range of stresses where growth along the front is favoured over growth along the sides is larger than predicted with the simple model. A comparison is made between steady-state delamination growth along circular paths of different curvatures but with identical widths so that the phase angle of loading on the growing front can be assumed to be the same independent of the curvature. The results for the energy release rate show that growth along a straight line is most likely to be observed at low stress levels while growth along curved paths are more likely at higher stresses. The mode of delamination that releases most energy at high stress levels has the centre of the circular path on one of the sides.

Delamination at edges and corners

Conditions for thin film delamination at edges and corners in the absence of film buckling are formulated. A local analysis of the region close to the intersection point between the crack front and the free edge shows that steady-state delamination at corners is possible at stress levels lower than those required to make an edge crack propagate under plane strain conditions due to the stress concentrations at interface corners.

Prediction of crack front shape

A numerical method based on the finite element method coupled to exact solutions near to the crack tip for calculating the shape of the crack front has been applied. The method involves an iterative procedure to adjust the shape of the crack front so that the fracture criterion is satisfied locally along the front. Results based on the numerical scheme shows that the shape of the crack front is sensitive to the interface fracture criterion and the level of residual stresses in the film.

References

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