Copy

Interface science
enper

Ariel

OCLC ILL Number: 4225212

Ariel: 128.111.96.251

Mar 16, 2004 9:43 AM

Ship to:
University of California - Santa Barbara
Davidson Library - ILL
Building 525
Santa Barbara, CA 93106-9010

Symbol: CUT

Email: ill@library.ucsb.edu
Phone:
Fax: (805) 893-5290

Patron: Clarke, David R (Faculty)

Lending String:

*WAU,EYM,EYM,VA@,VA@

Default / IFM / CC / MA / DA

Maxcost: 50.00IFM

Journal Title: Interface science. (Boston ; Kluwer Academic Publishers, 199)

Volume: 3() **Issue:** **Month/Year:** 1996 **Pages:** 169-193

Article: Bagchie, A

Copyright: CCG

Notes: Borrowing Notes; YES DTD Email;clarke@engineering.ucsb.edu

OCLC #: 30461857

UWE #: L 65028

UWorld Express
Univ of Washington Libraries
Box 352900
Seattle, WA 98195-2900

(206) 543-1878 / (800) 324-5351
uworld@u.washington.edu
www.uworldexpress.info
Fax: (206) 685-8049

The total charge for this item is $ 15.00 IFM

INTERFACE SCIENCE

Volume 3—1996

INTERFACE SCIENCE

ISSN 0927–7056

INTERFACE SCIENCE 3, 169–193 (1996)

The Mechanics and Physics of Thin Film Decohesion and its Measurement

A. BAGCHI AND A.G. EVANS
Division of Applied Sciences, Harvard University, Cambridge, Massachusetts 02138

Received December 1, 1995; Accepted December 1, 1995

Abstract. The intent of this review is to utilize the mechanics of thin films in order to define quantitative procedures for predicting interface decohesion motivated by residual stress. The emphasis is on the role of the interface debond energy, especially methods for measuring this parameter in an accurate and reliable manner. Experimental results for metal films on dielectric substrates are reviewed and possible mechanisms are discussed.

Keywords:

Notation

a	crack half length
a_0	initial crack size
A	section area
b	Burgers vector
c	constant ≈3
C_i	constants related to thin film decohesion
D	dislocation free zone near crack
E	Young's modulus
	plane strain value of E
E^*	average modulus (Eq. (2.9))
$\mathcal{G}$	strain energy release rate
$\mathcal{G}_{ss}$	steady-state $\mathcal{G}$
$\Delta\mathcal{G}_{ss}$	reduced $\mathcal{G}_{ss}$ caused by bending
h	film thickness
h_c	critical superlayer thickness
H	substrate thickness
I	sectional modulus
K	stress intensity factor
L	characteristic length
	prescribed length to define the mode mixity
M	moment
p	constant related to Dundurs parameters (Eq. (2.33))
P	edge force
r	distance from crack tip
R_0	plastic zone size
T	external stress
U	stored energy
W_{ad}	work of adhesion
Y	dimensionless quantity for the K-calibration
α	Dundurs parameter (Eq. (2.3))
β	second Dundurs parameter (Eq. (2.3))
γ	interaction angle (Eq. (2.31))
δ	location of neutral axis
ε	strain
η	thickness ratio, h/H
θ	polar angle
κ	curvature
λ	cracking number
μ	shear modulus
ν	Poisson's ratio
ξ	loading combination (Eq. (2.38))
Π	non-dimensional $\mathcal{G}_{ss}$
σ_{ij}	stress tensor
σ_R	residual stress
σ_0	yield strength
σ^*	peak stress for the cohesive zone rupture
ψ	mode mixity angle
	mode mixity defined at a prescribed length
ω	relative loading phase
Γ	fracture energy
Γ_i	interface fracture energy

Γ_s	substrate fracture energy
Γ_p	plastic dissipation
Γ_0	plastic dissipation for the cohesive zone rupture
Δ	normalized location of neutral axis, δ/H
ϵ	oscillation index (Eq. (2.5))
Σ	modulus ratio, E_1/E_2

1. Introduction

The number of applications for thin films and multilayers that take advantage of their special mechanical, thermal, electronic and optical characteristics has steadily increased. The associated technologies include multichip modules, thermal and oxidation protection coatings, wear and abrasion resistance coatings, etc. In general, the layers are deposited by vapor deposition (either physical or chemical). One of the problems, that has limited the more widespread use of such systems, has been the incidence either of interface decohesion or of delamination within one of the brittle constituents motivated by residual stresses [1–5]. Such stresses are inevitable in vapor deposited layers and are exacerbated when the constituent materials have vastly differing thermomechanical properties, such as polymers on metals and metals on ceramics. The stresses arise for two reasons. (1) Intrinsic stresses develop during deposition [6]. These stresses persist, unless they are relaxed by plastic deformation or annealing. (2) The mismatch in thermal expansion induces stresses when the temperature is changed [7].

Controlling the stress in order to inhibit decohesion and delamination without compromising the functional characteristics of the system is not usually an option. Instead, thermomechanical design of multilayer systems to resist these failure modes is required. This goal is crucially dependent upon the attainment of an adequate interface debond toughness, Γ_i. The toughness requirement is manifest in the fail-safe design solution, [1, 8]

$$\Gamma_i \geq h\sigma_R^2/\bar{E}\lambda \tag{1.1}$$

where h is the film thickness, $\bar{E}$ is its appropriate Young's modulus (plane strain or biaxial plane stress), σ_R is the residual stress and λ is a cracking number (of the order unity). When Eq. (1.1) is satisfied, there is insufficient energy stored in the film to permit an interface crack to propagate and the film *must remain attached to the substrate*.

In order to implement this fail-safe criterion, methods for the accurate measurement of Γ_i on the actual interfaces of relevance must exist. The principal intent of the present review is to describe and analyze the available methods with the objective of identifying those capable of providing the quantitative information needed to apply Eq. (1.1). There have been several reviews on aspects of this topic. These include surveys of test methods, [9–12] the thermomechanical integrity of films and multilayers [13], the mechanics of crack growth along interfaces [14], residual stresses and their origin [15]. The present review differs from these by focusing on the quantitative aspects of thin film decohesion and its measurement. Most thin film adhesion tests empirically infer the adhesive strength by subjecting the film to some external loading (like scratching, pulling or inflating) and measuring the load at which decohesion occurs. These tests are simple and effective for routine ranking of bond quality. However, they do not measure Γ_i, because the strain energy release rate cannot be deconvoluted from the work done by the external load [12]. An ideal test should *duplicate* the practical situation as closely as possible and be able to modulate the available strain energy. It must also explicitly incorporate the contribution to decohesion from the residual stress. The test methods are assessed against this ideal.

2. Mechanics of Thin Film Decohesion

2.1. Basic Principles

Most decohesion problems of interest involve films subject to residual tension. This case is given the major emphasis in the present article. Relatively few remarks are made about the corresponding problem when the films are in compression. Films in tension are able to decohere from the substrate by relaxing the residual stress in the film above the interface crack. For the simplest case of a thin, homogeneous film subject to uniform residual stress on a thick substrate, the steady-state energy release rate, $\mathcal{G}_{ss}$, for an interface crack is given by *the strain energy in the film*. The non-dimensional form for a film is,

$$\Pi = \bar{E}\mathcal{G}_{ss}/\sigma_R^2 h \tag{2.1}$$

where Π is a non-dimensional quantity of the order unity. The same form arises for other problems, but its numerical magnitude differs, as elaborated below.

DOCKET ALARM

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts

Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research

With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips

Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.

WHAT WILL YOU BUILD? | **sales@docketalarm.com** | **1-866-77-FASTCASE**

fastcase® Smarter legal research.