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Microtensile testing of a free-standing Pt-aluminide bond coat

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ABSTRACT

A finite element method (FEM)-based study has been carried out for the design of flat microtensile samples to evaluate tensile properties of Pt-aluminide (PtAl) bond coats. The critical dimensions of the sample have been determined using a two-dimensional elastic stress analysis. In the present testing scheme, the ratio of the dimensions of the holding length to the fillet radius of the sample was found important to achieve failure within the gage length. The effect of gage length and grip head length also has been examined. The simulation predictions have been experimentally verified by conducting microtensile test of an actual PtAl bond coat at room temperature. The sample design and testing scheme suggested in this study have also been found suitable for evaluation of tensile properties at high temperature.

1. Introduction

Mechanical behavior of free-standing (or stand-alone) thin films and coatings used in applications such as micro-electromechanical systems (MEMS) [1–4], dental implants [5,6] and protective coatings [4,7] has been an active area of research over past few years. Studies in this area have led to significant understanding on the relation between the composition/microstructure of thin films/coatings and their mechanical integrity during use [4,7–9]. Such studies have also helped in understanding the operating failure mechanisms in various films/coatings [4,7–10]. A variety of techniques based on micro/nano indentation [4,10,11], bending [4,11], resonance [4] and uniaxial tensile testing [4,8,11–15] have been adopted for evaluating the mechanical properties of coatings. Among these techniques, tensile testing (which is often referred to as microtensile test) is by far the most widely used method for free-standing coatings, because of the several advantages associated with this method. Firstly, it is possible to generate a uniform strain in the free-standing coating/specimen during the tensile test. Secondly, unlike techniques such as indentation where the prediction of the coating properties is based on localized information, the tensile test measures the mechanical response over a much larger volume of the coating and is much more representative of the coating properties. Further, the data interpretation in case of microtensile tests is often much simpler as compared to that in indentation methods.

Carrying out the microtensile testing of free-standing coatings, especially the brittle ones, is very challenging because of the experimental and other associated difficulties. In case of testing of bulk tensile specimens, sample dimensions and test procedures are well established in form of accepted standards [16]. However, no such standard presently exists for microtensile testing, where the thickness of the specimen (microtensile samples, as they are normally called) is often less than a few hundred micrometers. In the literature, a few microtensile sample configurations have been reported. Samples with V-shaped ends and curved/parallel gage have been reported by Sharpe and coworkers [1] and Hemker et al. [4]. Other sample shapes such as rectangular stick [6,7], hour glass [6,7] and dog-bone with rectangular paddle [6,7] have also been used for evaluating the tensile properties of thin films.

Another major issue associated with microtensile testing is the method to be used for gripping the sample during the test. This issue is especially important in case of brittle samples which, during fixing, often tend to break at the neck or fillet region when the conventional method of gripping the sample between two flat plattens is used. To avoid this problem, several improvised methods have been adopted including gluing each end of the sample on a platten [4,12] and gluing of the whole sample onto a compliant substrate [13,17]. Use of slotted grips has also been reported, where the sample ends are held firmly during the test against the walls of the slots appropriately made in the grips [4,14,15]. Apart from the issue of sample gripping, fabrication of microtensile specimens is also a challenging task which involves precision machining and thinning. Methods such as electro-discharge machining (EDM) [4,15], lithographie galvanoformung abformung (LIGA) [4], etching [1–4] and deep reactive ion etching (DRIE) [3,4] have been used for the preparation of microtensile samples.

Ensuring failure of the samples within the gage length forms another important aspect of microtensile testing. In order to have valid tensile test results, the selection of sample configuration and the grip design should be such that the failure of the specimen

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