Characterisation of the Transfer Function of an Advanced Process Control System for Chemical Mechanical Polishing (CMP)

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Abstract

Chemical Mechanical Polishing (CMP) is widely used for planarisation in semiconductor manufacturing. While the process is capable in terms of producing surfaces of extreme planarity and integrity, there is inherent drift due mainly to physical and chemical changes of the polishing pad surface. Our Research Centre is pioneering a new concept for advanced process control (referred to as multifunctional intelligent tooling, MIT) with the potential to provide a paradigm improvement in control capabilities. The test programme described below was designed to characterise the transfer function for an MIT control system. The tests involve monitoring the stress-strain response in a basic compression test of the pad and further simulating the basic CMP set-up where a geometrically similar pad is subjected to similar cyclical pressures. Results indicate that the sample material, geometrical dimensions and loading velocity all have effects on the pad compression stress-strain response, but pads demonstrate relatively linear behaviour within the 0 to 10% strain region under different experimental conditions.

1 Introduction

CMP is described as "the process of smoothing and planarising synergistically aided by combined chemical and mechanical effects" [1]. CMP provides surfaces that meet the tolerances for global and local planarity imposed by the depth of focus in optical lithography [2]. In the CMP process, the polishing pad properties, especially the elasticity, are critical due to its function in the primary mechanism of material removal and planarisation [3]. A stacked pad consisting of an IC1000 top layer on a

Suba IV sub-pad is currently the pad system commonly used [4]. Figure 1 shows a microscope image of a stacked pad and the plan view of their surfaces.

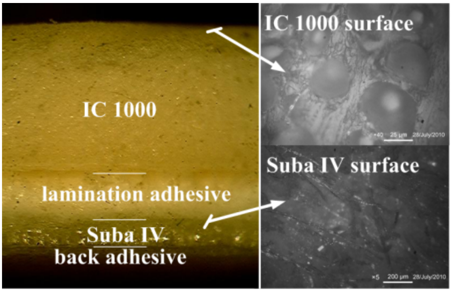

Figure 1: The cross-section of IC1000/Suba IV stacked pad and the microscope image of the plan view of their respective surfaces

2 Methodology

Since the elastic property of a stacked pad is evidently related to the properties of the individual layers, the stress-strain response for the individual pads (IC1000 and Suba IV, ROHM and HAAS Inc.) and the stack of both were investigated. The compression tests were conducted on a Hounsfield universal material testing machine. The number and range of the experimental parameters included four different diameters (12, 20, 30 and 40mm) and five different loading velocities (10, 20, 30, 50 and 90 mm/min). The experimental samples and the Hounsfield universal material testing machine are shown in figure 2. The samples were positioned centrally in the compression-testing machine after fully lubricating the loading surface and the machine was set for the specific loading velocity until a strain of 30% is reached, as shown in figure 3.

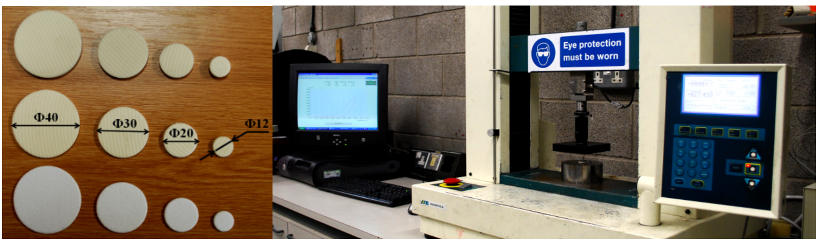

Figure 2: Experimental samples and Hounsfield universal material testing machine

The piezoelectric micro-actuator simulation system was designed to simulate the practical polishing downward pressure and compression range using a long-range piezoelectric micro-actuator, with an inline force sensor and Linear Variable Differential Transformer (LVDT) displacement measurement, as shown in figure 4.

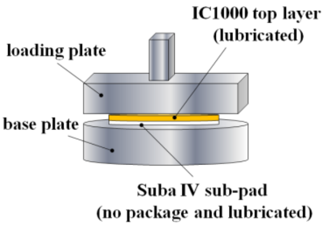

Figure 3: Compression set-up

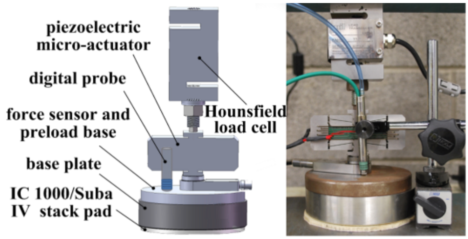

Figure 4: Actuator simulation system

3 Results and discussion

The stress-strain curves of the IC1000/Suba IV stacked pad in compression tests are shown in figure 5(a) and (b); figure (c) compares the responses for the individual materials and the stacked one. The experimental conditions are described in table 1. The pressure-strain curve of the IC1000/Suba IV stacked pad in the actuator simulation system is shown in figure 5 (d).

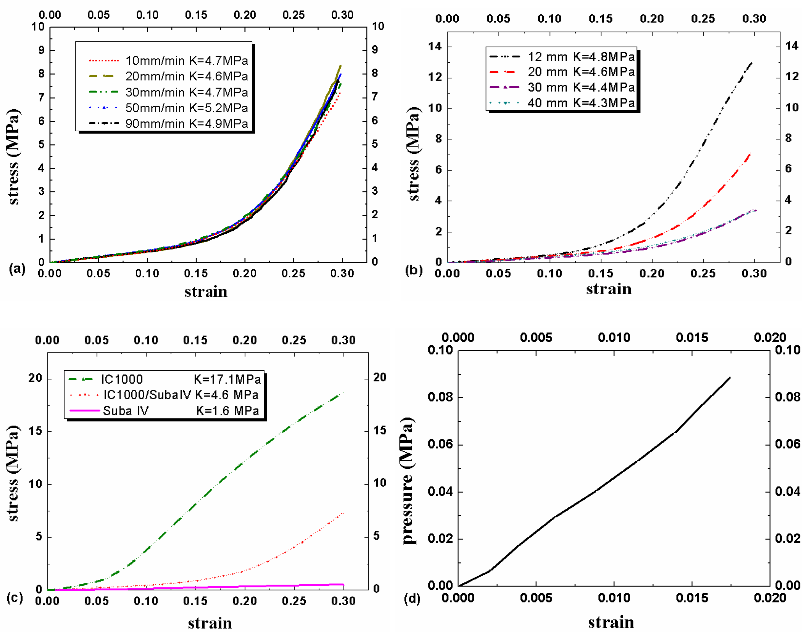

Figure 5: The stress-strain curves and pressure-strain curve

According to figure 5, the loading velocity had no significant effect on the pad stress-strain curves while the sample diameter exhibited a significant effect below 30mm. However, all pads demonstrate relatively linear behaviour in the 0 to 10% strain region under different experimental conditions. In figure 5(d), the strain range didn't exceed 10% which is typical of the CMP process, so the polishing pad can be treated as an elastic component. The slope of the stress-strain curve in its elastic deformation region (10% in this paper) can be calculated. The slopes for IC1000, Suba IV and IC1000/Suba IV stacked pad are shown in table 2.

Table1: testing conditions of experimental group (a),(b) and (c) in figure 5

Group	Material	Diameter	Velocity (mm/min)
(a)	IC1000/Suba IV stacked pad	20	10, 20, 30, 50, 90
(b)	IC1000/Suba IV stacked pad	12,20,30,40	10
(c)	IC1000, Suba IV and stacked pad	20	10

Table 2: the slopes of the stress-strain curves within the 0 to 10% strain region for IC1000, Suba IV and IC1000/Suba IV stacked pad

	Diameter	Thickness	Velocity	Strain range	Slope K
IC1000 pad	20 mm	2.14 mm	10 mm/min	10%	17.1 MPa
Suba IV		1.29 mm			1.6 MPa
stacked pad		3.39 mm			4.6 M Pa

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