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Copper polishing with a polishing pad incorporating abrasive grains and a chelating resin☆

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ABSTRACT

This study sought to decrease dishing and erosion as they cause reduced yield in copper chemical mechanical polishing (Cu-CMP), which is a multilayer interconnect process that is a part of the overall semiconductor manufacturing process. We prepared a polishing pad that incorporated abrasive grains (AC Pad) and used a chelating resin in the matrix (resin). Moreover, we studied whether this polishing pad was applicable to the Cu-CMP process. Results indicated that the pad was selectively abrasive to copper (Cu) and that in the polishing of patterned wafers, it vastly decreased dishing to 1/8th and erosion to half of their respective levels in abrasive polishing. Therefore, the pad has considerable potential for use in Cu-CMP.

1. Introduction

Today's semiconductor devices have very high densities and often have a wiring pitch of 65 nm; the primary connection material for these devices is copper (Cu), which has a low electrical resistance. Accordingly, metal chemical–mechanical polishing (CMP), which is the CMP process used to produce connections, is also beginning to focus on Cu-CMP. As shown in Fig. 1, Cu-CMP polishes copper using a barrier metal as a stop layer; therefore, normal polishing without dishing requires that a substance be selectively abrasive to copper. In addition, a mechanical action that is very strong will produce defects like erosion and scratches. Therefore, chemical polishing stronger than the CMP of a silicon dioxide film is required [1], and conventional methods require that a polishing slurry with a strong chemical action be supplied. However, this polishing slurry has a considerable impact on the environment during waste treatment and should not be used whenever possible. In response to the dishing and erosion and the environmental concerns, new attempts at environment-friendly approaches like abrasive-free slurry polishing [2–4] are being made; however, their results lack consistency in terms of performance.

The use of a loosely held abrasive (LHA) pad, which is a polishing pad incorporating an abrasive, in the CMP of silicon dioxide films has been determined in order to allow polishing that produces little polishing waste and is environment-friendly [5]. However, the use of an LHA Pad in Cu-CMP requires that a strong chemical polishing slurry be supplied from the outside since the LHA Pad has a weak chemical action on the metal, resulting in polishing that is not environment-friendly.

A previous study by the Sato et al. [6] determined that chelate groups are effective at nanoprocessing metals (i.e., tape texturing on hard disks). The current study anchored a chelating agent to the resin matrix of a polishing pad incorporating abrasive grains and prepared a chelating resin polishing pad incorporating abrasive grains (AC Pad) that preferentially polished only the portion of an object that was in contact with the pad. Then, the potential for use of such a pad with a strong chemical action in Cu-CMP was explored.

2. Experimental

2.1. Preparation of the polishing pad

AC Pad S and AC Pad A were created by combining glycine, a naturally occurring amino acid and chelating agent, with an epoxy

☆ This study is based on research conducted at the Graduate School of the Nagoya Institute of Technology (from April 2003 to March 2005).

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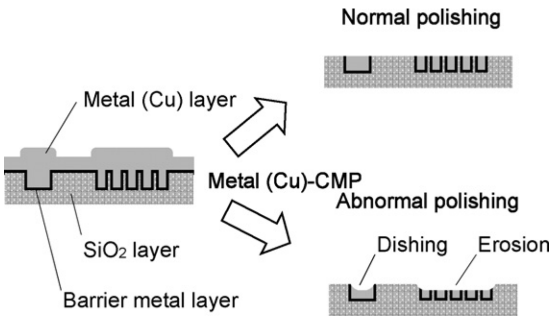

Fig. 1. CMP process for the metal layer.

resin, and then mixing it in with spherical silica (AC Pad S) with an average particle size of 0.25 μm or alumina (AC Pad A) with an average particle size of 0.6 μm and allowing the result to harden. The pad composition is shown in Table 1. In addition, the cross sections of both AC Pads are shown in Fig. 2. Although both polishing pads incorporated abrasive grains, the shapes of the respective grains were obvious because the interface of the resin matrix and the abrasive grains was visible. This implies that the abrasive grains were not attached to the resin matrix and that they were readily liberated.

2.2. Cu^{2+} ion adsorption verification test for the polishing pads

In order to verify the adsorption of Cu^{2+} ions by chelate groups in the prepared polishing pads, an AC Pad S (size: 50 mm × 10 mm × 1 mm) was fashioned; the test piece was immersed in deionized water for 6 h and then dried for 6 h at 333 K. Next, for the immersion liquid, Cu^{2+} ion concentration was adjusted to 200 mol/m^3. Further, a Cu^{2+} ion solution was prepared by changing its pH levels to 1.4, 2.1, 3.1, 3.9, 7.0, 8.3, and 9.6 using hydrochloric acid and aqueous ammonia. The test piece was immersed for 6 h (21,600 s) in a 50 cm^3 Cu^{2+} ion solution kept at a liquid temperature of 296 K and then dried for 6 h at 333 K. The weight before and after the tests was measured down to the scale of 0.01 mg with a precision electronic balance, and the difference in weight was considered to be the amount of adsorption. The tests were conducted five times for each pH value.

2.3. Polishing test

In order to assess the polishing performance of the prepared polishing pads, a polishing test was conducted under the conditions given in Table 2 using the equipment shown in Fig. 3. Prior to the polishing test, a conditioner as shown in Fig. 4 was installed, and the surface of the pad was conditioned on the basis of the conditions tabulated in Table 3 in order to achieve consistency. During the polishing test, the temperature of the platen was maintained at 300 K by using a chiller.

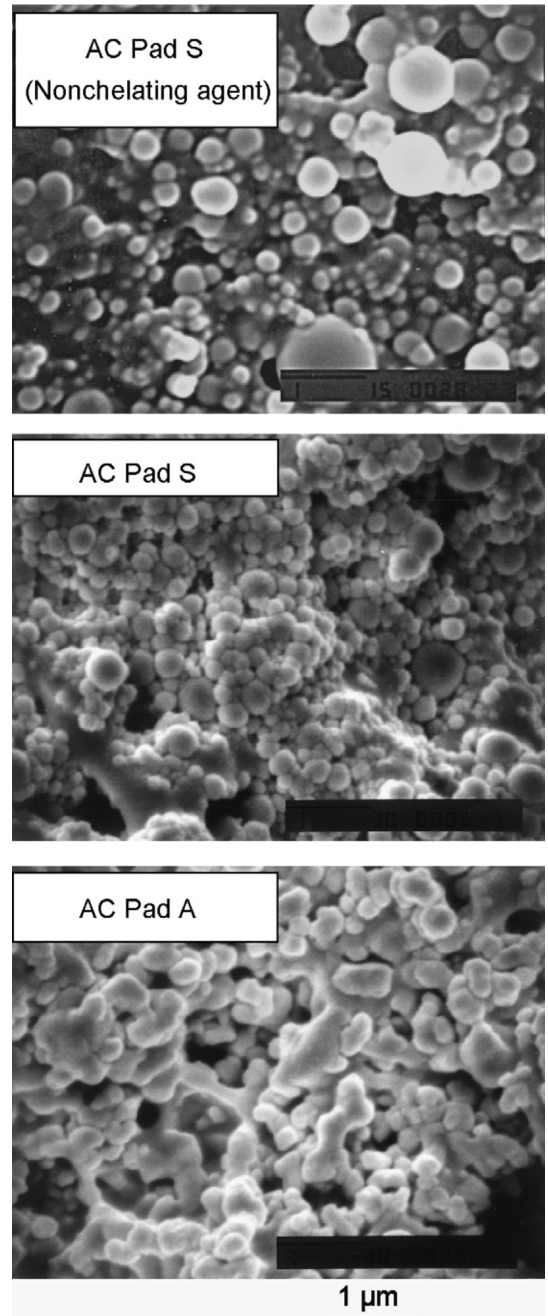

Fig. 2. SEM micrographs of a cross section of the polishing pads.

Table 1
Polishing pad components

Polishing pad	Component
AC Pad S (nonchelating agent)	Silica abrasive: 43 vol% Bond: 51 vol% (glycine: 0 mass% in bond)
AC Pad S	Silica abrasive: 37 vol% Bond: 48 vol% (glycine: 9 mass% in bond)
AC Pad A	Alumina abrasive: 35 vol% Bond: 45 vol% (glycine: 9 mass% in bond)

Table 2
Polishing conditions

Polishing pad revolutions	1 s^{-1}
Workpiece	Cu wafer (φ 100 mm) TaN layer wafer (φ 100 mm) SiO_2 layer wafer(φ 100 mm) Si_3N_4 layer wafer (φ 100 mm) Poly-Si layer wafer (φ 100 mm)
Workpiece revolutions	1 s^{-1}
Polishing pressure	9.3 kPa
Slurry flow	167 mm^3 s^{-1}
Polishing time	1800 s, 600 s