184 Microstructure of Ni-P and its mechanical characterization by micro-compression testing

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Abstract. Electroless plated nickel-phosphorus is of great importance for the functionality and reliability of electronic devices. This study focuses on its mechanical properties at the micro- and sub-micrometer scale, as this has not been systematically addressed in the literature. It is found that the as-deposited material, which is in amorphous state, does not show size effect while the annealed samples that are partially crystallized show some trend of size effect and much higher strength.

Introduction

Electroless nickel-phosphorus (EN-P) plating is a popular deposition process with widespread applications in microelectronics, e.g., metal finishing of printed circuit boards, filling of via-holes in multi-level interconnection and as diffusion barriers to slow down the formation of intermetallic compounds between the copper leadframes and the tin contained solder materials [1, 2]. Much emphasis has been given on the plating process and on the physical and chemical properties of the plated EN-P layers; however their mechanical properties down to the sub-micrometer dimensions have not been elucidated systematically. In this work, we study the mechanical properties of EN-P as a function of annealing states using *in situ* pillar compression technique [3].

Materials and experiments

A nickel-phosphorus layer is electroless plated on a copper-coated silicon wafer (Fig. 1a). Micro-compression samples (Fig. 1b) with different dimensions but same aspect ratios are fabricated using focused ion beam and tested with an Asmec Unat indenter inside a Zeiss Gemini 500 scanning electron microscope (SEM).

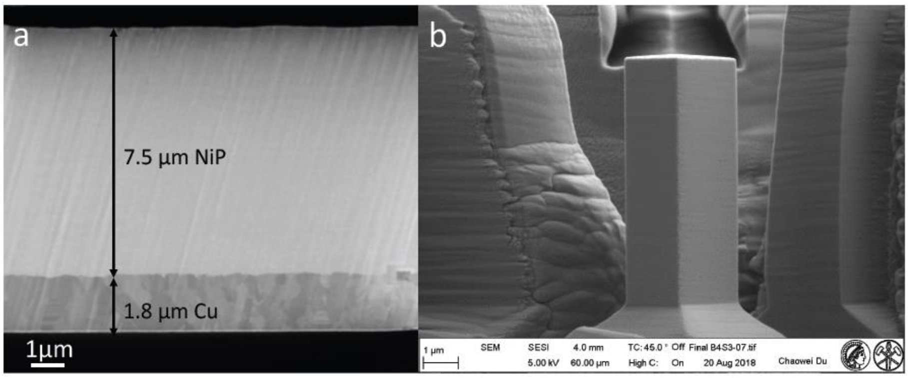

Fig. 1, a. SEM picture of the EN-P film cross-section; b, SEM picture of a rectangular micro-compression specimen of EN-P with a width of 1.2 µm and aspect ratio of 3.

Results and discussion

As-deposited EN-P films. The as-deposited EN-P films are found to be amorphous by XRD and TEM investigation. Three dimensions (0.5 µm, 1.2 µm, 2.5 µm, all with an aspect ratio of 3) of micro-pillars in the as-deposited state have been tested. The samples with all the dimensions show linear elastic behavior, as evidenced by the stress-strain curves shown in Fig. 2a. Note that the strain includes the contribution from the sample as well as from the testing setup due to its compliance. The strengths of the three tested dimensions are within the error bars identical, documenting the absence of a size effect to 500 nm for the as-deposited EN-P films (see Fig. 3).

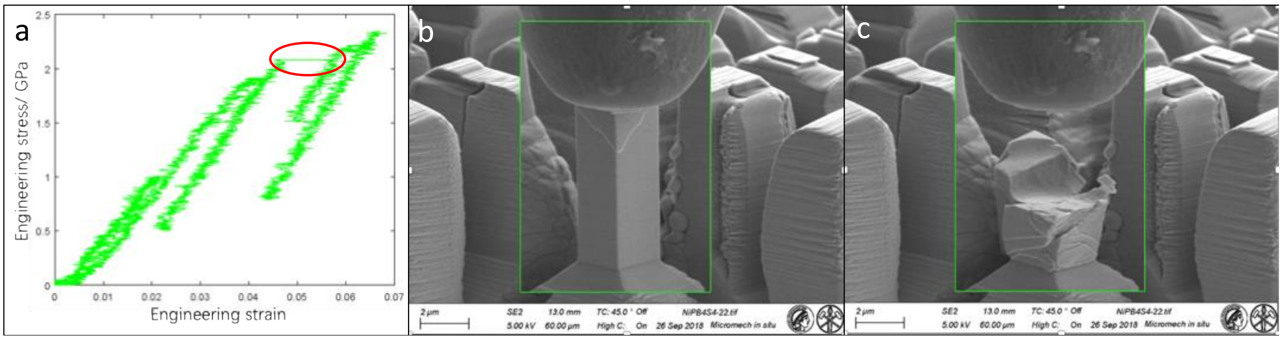

Fig. 2, a. A representative engineering stress-strain curve of the micro-compression samples (from a sample with width of 2.3 µm); b, the formation of shear band at the top of the pillar which corresponds to the strain burst marked by red circle in a; c, the sample after testing.

Annealed EN-P films. The as-deposited EN-P films were annealed for 30 min at 380°C to obtain crystallized Ni. In contrast to the as deposited material, the annealed samples show a possible size effect and much higher strength (blue data points in Fig. 3). This different behaviour is primarily attributed to the nano-sized crystallized domains that functions as barriers against the formation of shear bands propagating through the entire cross-section.

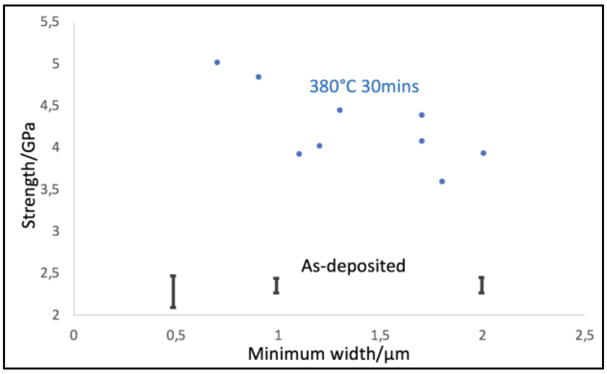

Fig. 3, Overview of the strengths of the EN-P micro-compression samples as a function of their minimum sizes. The as-deposited samples show no size effect, while the samples annealed at 380 °C for 30 mins show some trend of increasing strength when the sample size decreases.

Conclusion

It is found that the as-deposited EN-P shows no size effect down to the size of 500 nm, while some trend of size effect is observed in the annealed samples with much higher strength.

References

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