Stress Origin in Electrodeposited CoFe Alloy Films Deposited Using DC and Pulse Plating

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One of the difficulties associated with CoFe alloy deposition is the accumulation of high tensile stress during deposition. The stress easily cracks the films and limits the maximum film thickness. The reasons for this tensile stress include hydrogen incorporation due to high hydrogen overpotential and incorporation of impurities (e.g. O or S). However, the chemical reasons can not explain why the stress increases significantly with Fe composition in the film, while impurities do not increase with increase of Fe composition. Our study demonstrated that the dramatic increase of tensile stress with Fe composition seems to be originated from the grain refining effect of Fe deposition, which leads to high tensile stress during coalescence of nuclei. Fig 1 shows the surface morphology of three CoFe films with different Fe content. The surface cluster size decreases with the increase of Fe content.

Pulsed plating has been reported in the literature to be able to lower the deposition stress for some electrodeposition systems.[1] The pulse off period after each thin layer of deposition provides a stress relaxation time during deposition. For a system with hydrogen evolution, the pulse off time is claimed to provide a period for the reduced hydrogen to escape from the deposit and lower the tensile stress. In order to evaluate the effect of pulsing on our CoFe deposition system, a series of experiments were carried out to compare the stress level of DC plated samples with pulse plated samples for similar compositions. The IBM-Hitachi bath used in this study contains $CoSO_4$ + $FeSO_4$+ CH_3COOH + SBA(sulfur-bearing-additive).[2] The amount of $FeSO_4$ was varied to make five different baths with Fe:Co ratio in the solution to be 3, 3.5, 4, 4.5, 5 respectively. From each of these baths, 3 samples were deposited. One was DC plated. One was low frequency pulsing with pulse on-time and pulse off-time equal to 1 sec. And the other was high frequency pulsing with pulse on-time and pulse off-time equal to 0.1 sec. Fig 2 shows the stress of all these samples as a function of Fe composition in the films. As can be seen, the stress from DC, 0.1 sec pulse plating (0.1s-PP), and 1 sec pulse plating (1s-PP) follows the same trendline with similar stress at the same film composition. The stress increases with increase of Fe composition, no matter the sample was deposited at DC or high frequency pulsing or low frequency pulsing. The current efficiency for deposition was similar for different Fe composition, which indicated that hydrogen evolution was similar with different Fe composition. Therefore, hydrogen evolution was not the reason for the dramatic increase of tensile stress with increasing Fe composition.

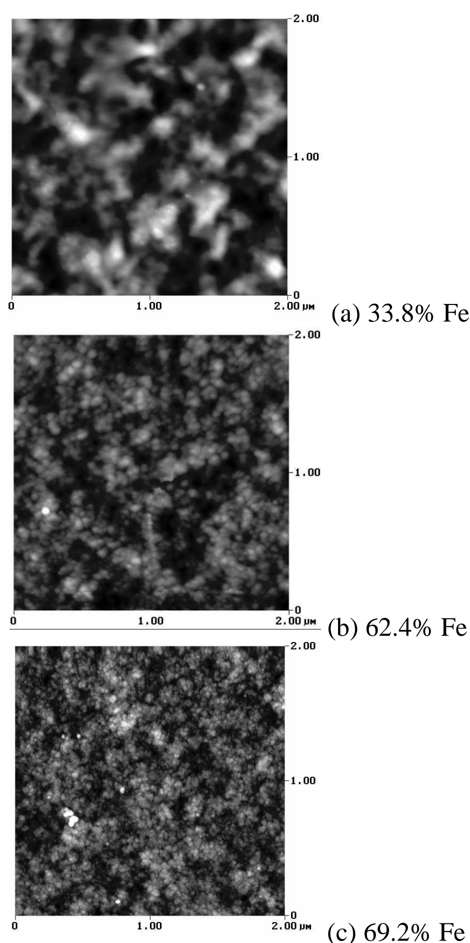

Fig 1. AFM images (2 x 2 µm) of three FeCo films with different Fe content. The surface cluster size decreases from lower Fe content to high Fe content films.

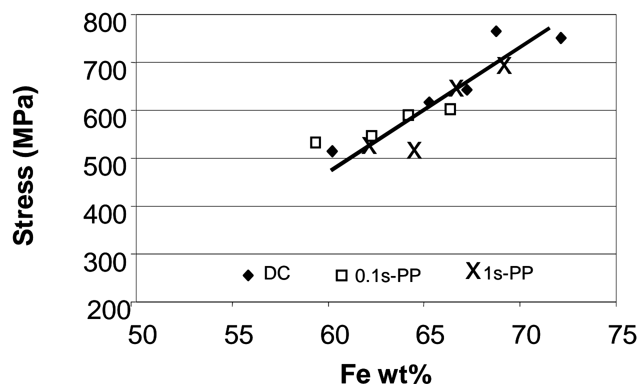

Fig 2. Deposition stress for CoFe films deposited from pulse plating and DC plating as a function of Fe content. Samples were deposited from 5 different baths with Fe:Co ratio in the solution to be 2.5, 3, 3.5, 4, or 4.5.

References:

1. J.C. Puippe and F. Leaman, *Theory and Practice of Pulse Plating*, American Electroplaters and Surface Finishers Society, 1986.
2. C. Bonhote, H. Xu, E.I. Cooper, and L.T. Romankiw, ECS Proc. Vol. 2002-27, p. 319 (2002).