

Electroforming of Low-Stress Iron-Group Alloys

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Background

Iron group metals (i.e. Ni, Fe, Co) and alloys (e.g. CoNi, NiFe, CoFe, CoNiFe) are very important structural and functional materials for Micro Electro Mechanical Systems (MEMS) including high aspect ratio, LiGA-based devices, due to their excellent physical, chemical and magnetic properties.

There are several deposition and microfabrication techniques available for incorporating iron group materials into MEMS. Electrochemical processes, including electrodeposition (electroforming) and electroless deposition, are especially well-suited to meet the requirements for high yield and cost effective processing. Electrodeposition (Electroforming) is the most important technique for the fabrication of high aspect ratio microstructure components.

The presence of residual stress in the electroformed films is an important factor to consider in LiGA devices because such stresses could, in some cases, exceed the strength of the films, resulting in film cracking, deformation of devices, and interfacial failure. Many factors contribute to the development of residual stress in electro-deposits, including film composition, nature of the substrate surface and of the deposit, solution composition (metal ion concentration, pH, complexing agent, additives, anions), temperature, current density, current waveform, agitation, and the deposit thickness. Dini (1) observed that in electrodeposited transition metals, which exhibit the highest residual stress values, there is an apparent relationship between the stress and the melting points of these metals. Generally, a high residual stress is observed at the beginning of the electrodeposition, reaching a constant value for thicknesses in the range of 12.5 to 25 μm . The high initial intrinsic stress in the deposit is associated with lattice mismatch and with the grain size of the underlying substrate.

Since there are many parameters influencing the stress of deposits, the deposition conditions have to be optimized for each material. In this paper, the interrelationships of the various parameters affecting the composition and microstructure of electrodeposits as well as the residual stress, will be reported

Figure 1a shows the role of current density on the residual stress and surface morphology of nickel electrodeposits from sulfamate baths. Lower current densities lead to the formation of stressed deposits. With increasing current density, this stress tends to level out. From figure 1b it can also be clearly seen that the morphology of the film is highly dependent on the applied current density.

Best-known stress reducing agents for the electrodeposition of nickel are sulfur containing organic additives (e.g. saccharin, thiourea, aminobenzene sulfonic acid, benzene sulfamide, benzene sulfonic acid, etc). Thiourea additions also influence the residual stress in cobalt electrodeposits. Slightly compressive cobalt films were obtained using a plating solution containing 25 to 50 mg/L thiourea (2). These sulfur containing organic additives suffer decomposition on the substrate surface and the products are partially incorporated in the deposit (e.g. sulfur, carbon, or both). Figure 2 shows the effect of saccharin concentration on the residual stress of Ni, 85Co15Ni, and 65Co15Ni20Fe films (residual stress data for the 65Co15Ni20Fe film is taken from literature (3)). Small additions of saccharin to plating solutions can alter the residual stress of nickel from tensile to compressive.

References:

1. J. W. Dini, "Electrodeposition - The Materials Science of Coating and Substrates", Chap. 9, Noyes Publications, (1992).
2. Yu. K. Vyagis, A. I. Bodnevas, and Yu. Matulis, *Protection of Metals*, 1, 468 (1965).
3. I. Tabakovic, V. Inturi, S. Riemer, *J. Electrochem. Soc.*, 149, C18 (2002).

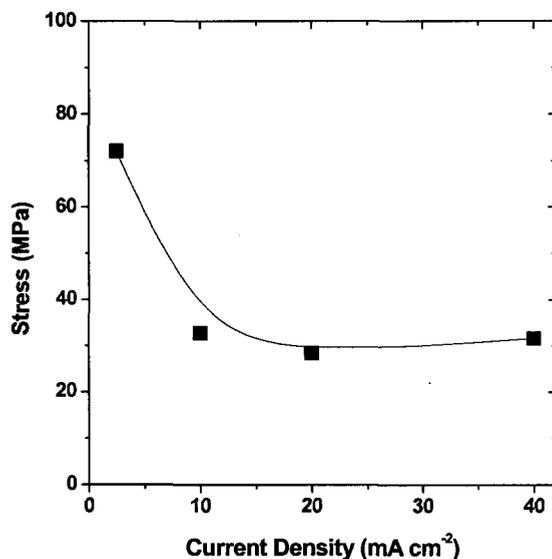


Figure 1a. Intrinsic stress of electrodeposited Ni from 1 M Ni sulfamate bath, pH = 4.0, Temp = 60 °C.

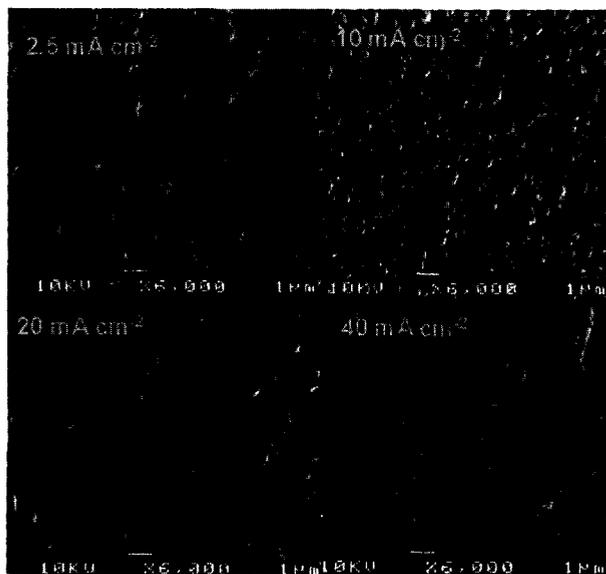


Figure 1b. SEM micrographs of Ni films electrodeposited from a 1 M Ni sulfamate bath, pH = 4.0, Temp = 60 °C.

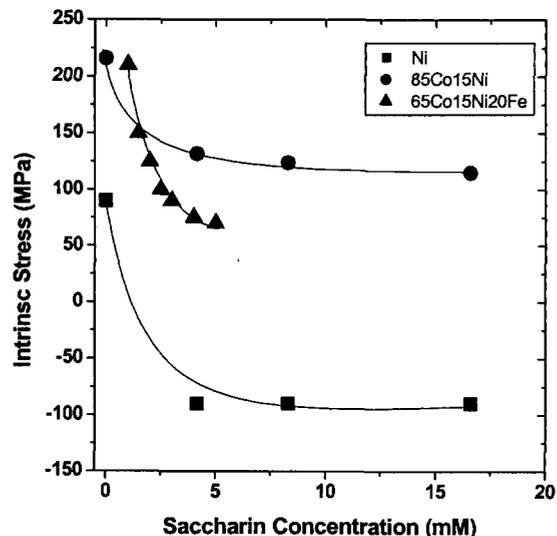


Figure 2. Residual stress of electrodeposited Ni, 85Co15Ni, and 65Co15Ni20Fe films. Ni and 85Co15Ni were electrodeposited from sulfamate baths, 65Co15Ni20Fe film data is from literature (3).