NANOCRYSTALLINE METALS FOR APPLICATION IN MEMS

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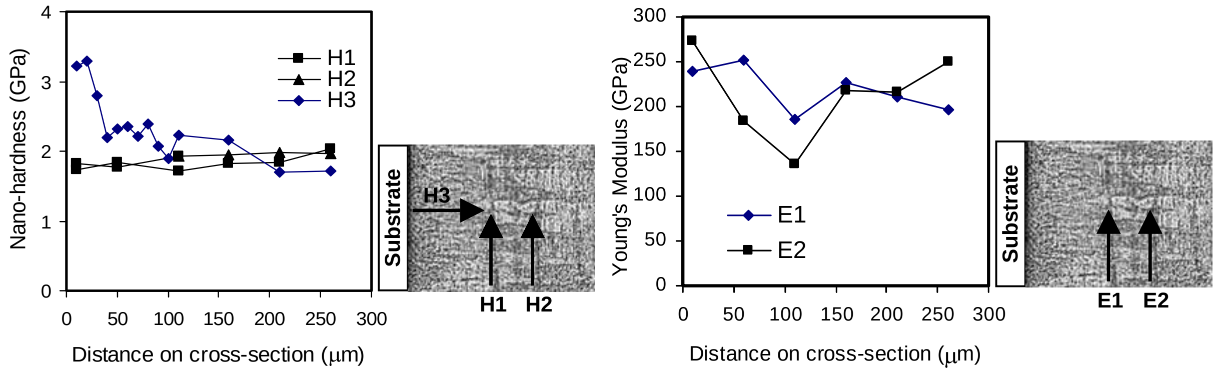
In recent years, considerable progress has been made in the development of MicroElectroMechanical Systems (MEMS), particularly in the lithography techniques such as LIGA (German acronym for lithography, electroforming, molding). However, in many cases the components produced by filling of the mold with metal during the electrodeposition process show considerable variations in their properties in particular mechanical properties (e.g. [1]). Large batch-to-batch as well as considerable local property variations within single components are often observed. With the continuously shrinking size and dimensions of the microcomponents such non-uniformities are becoming intolerable.

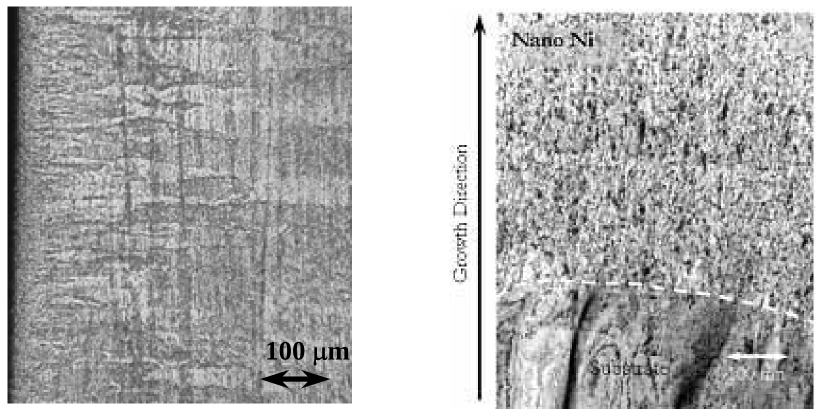
The current research addresses the issues of performance variability and reliability concerns frequently encountered with conventional nickel LIGA microcomponents produced by electrodeposition methods. Two types of nickel microsamples were synthesized using 1) conventional electrodeposition with polycrystalline structure and 2) a newly developed electrodeposition method that results in nanocrystalline structure. Microstructural characterization was performed on these materials in terms of chemical composition, grain size distribution and average grain size, as well as crystallographic texture. Microstructural analysis involved scanning and transmission electron microscopy (SEM, TEM) and orientation imaging microscopy (OIM) while the mechanical properties were evaluated using nanoindentation technique.

Nanoindentation results for conventional polycrystalline Ni electrodeposits have demonstrated (Fig.1a) low overall hardness with a gradient in the hardness profile perpendicular to the substrate surface of the deposit. In addition, Young's modulus measurements results polycrystalline Ni exhibited (Fig.1b) considerable variation through out the cross-section. This undesirable property variability is traced back to microstructural and scaling effects. The microstructure of the conventional electrodeposits (Fig. 2a) shows grain size gradients resulting from the fine grained to columnar structure transition with increasing component thickness. In addition the overall component size is often comparable to the relatively large grain size in these deposits. In contrast, the nanostructured deposits showed uniform small grain size throughout the entire cross-section of the component without the transition from fine to large grained columnar structure (Fig. 2b). Nanoindentation results on nanocrystaline Ni microcomponents demonstrated uniform hardness (Fig. 3a) and Young's modulus (Fig. 3b) in cross-section and a significant enhancement in the overall hardness. These properties result in improved performance indicators such as specific strength and elastic energy storage capacity which are important design factors for MEMS components.



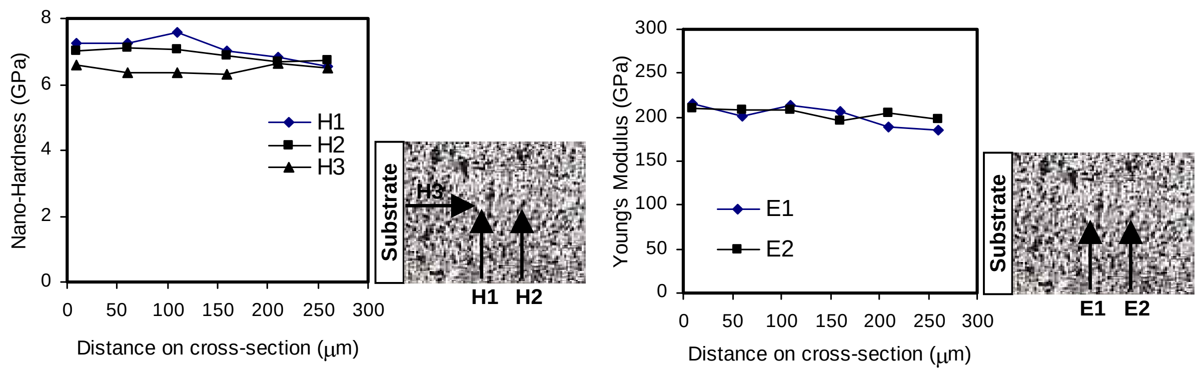
(a) (b)

Fig. 1 Cross-sectional (a) hardness and (b) Young's modulus for a polycrystalline Ni electrodeposit



(a) (b)

Fig. 2 Cross-section of a electroplated (a) polycrystalline, (b) nanocrystalline nickel microcomponent. (Adopted from [2].)



(a) (b)

Fig. 3 Cross-sectional (a) hardness and (b) Young's modulus for nanocrystalline Ni electrodeposit

References

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