Electrodeposition of $Fe_{80}Ga_{20}$: from thin films to nanowires

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Magnetostrictive materials are of increasing interest for sensor and actuator applications. A promising candidate to overcome the mechanical limitations of Terfenol-D is $Fe_{100-x}Ga_x$ with 15 to 25 at.% Ga, which exhibits high mechanical strength and low saturation fields. For sensor applications an efficient, scalable preparation route is required for thin film and nanowire fabrication.

The electrochemical deposition of Fe-Ga has been studied very little. Main challenges are the rather negative deposition potentials of the involved metals and the strong tendency of gallium ions to hydrolyze causing low film quality and low reproducibility

We have investigated the Fe-Ga alloy deposition from a simple aqueous electrolyte. Detailed EQCM experiments [1] reveal a complex mechanism combined of electrochemical alloy deposition and simultaneous chemical precipitation of mainly gallium (hydr)oxide due to pH increase as the result of strong hydrogen evolution. It has also been shown that these hydroxides can be re-dissolved when the pH is partially restored. By using a pulse potential technique dense and homogeneous films close to $Fe_{80}Ga_{20}$ with an oxygen content as low as 1 at.% have been obtained [2]. The films show a (110) Fe_3Ga fibre texture and a saturation magnetization of up to 1.7 T which exceeds that of sputtered films (1.45 T) [3] and approaches the values for bulk single crystals of 1.75 T [4].

The preparation of $Fe_{80}Ga_{20}$ nanowires represents another major challenge. Irregular nanowire growth occurs even in case of pulse plating, probably due to worse mass transport conditions within high aspect ratio nanopores. A promising approach towards more homogeneous nanowires is the complexation of the metal ions in the electrolyte. This prevents the formation of hydroxides and thus makes the deposition process less sensitive to pH fluctuations.

References:

[1] D. Iselt, K. Tschulik, S. Oswald, D. Pohl, L. Schultz, H. Schlörb, J. Electrochem. Soc. 159 (2012) H633-H637.

[2] D. Iselt, U. Gaitzsch, S. Oswald, S. Fähler, L. Schultz, H. Schlörb, Electrochim. Acta 56 (2011) 5178–5183.

[3] B. Adolphi, J. McCord, M. Bertram, C.-G. Oertel, U. Merkel, U. Marschner, R. Schäfer, C. Wenzel, W.-J. Fischer, Smart Mater. Struct., 19 (2010), 055013.

[4] A.E. Clark, M. Wun-Fogle, J.B. Restorff, K.W. Dennis, T.A. Lograsso, R.W. McCallum, J. Appl. Phys., 97 (2005), 10M316