Plastic deformation magnetic assembly of out of plane structures using hydrofluoric acid vapour release

Petros Argyrakis and Rebecca Cheung
School of Engineering and Electronics, Scottish Microelectronics Centre
University of Edinburgh, King's Buildings, West Mains Road,
Edinburgh EH9 3JF, United Kingdom

Plastic deformation magnetic assembly (PDMA) is a technique used to fabricate out of plane structures [1, 2]. The PDMA process has found applications in out of plane inductors [3] and fluidic sensors [4, 5]. In our application, we have developed the PDMA technique for the construction of vertical cilium in air-flow sensors in the study of cricket behaviour [6]. In the PDMA method, a structure that includes nickel-iron permalloy film electroformed on metallic seed layer is released by etching the underlying sacrificial layer. When the released structures are exposed to magnetic field, torque across the permalloy appears, causing out of plane plastic deformation of the structures. Most applications make use of wet etching for the release of the sacrificial layer. In this work, we have developed a dry release method using hydrofluoric (HF) acid vapour that provides higher yield for the release process compared to wet release methods.

The developed process is shown in figure 1. Initially, a SiO_2 thin film has been deposited on a silicon substrate (fig. 1a), followed by photolithographic patterning and dry etch to define anchors (fig. 1b). Next, a nickel seed layer has been deposited by magnetron sputtering and patterned with lift-off process (fig. 1c). A thick SPR-220.7 photoresist mold is spun on and patterned photolithographically to prepare selective areas on the seed layer for electrodeposition (fig. 1d). 4μm thick nickel-iron permalloy film is electrodeposited on the exposed nickel seed layer (fig. 1e) and the mold is removed subsequently in photoresist stripper. Next, hydrofluoric acid vapour has been used to etch the sacrificial SiO_2 and release the structures with 100% yield. Finally, a magnetic field is applied, causing the structures to deform plastically out of plane (fig. 1g). Scanning electron micrograph of fabricated out of plane flaps can be seen in figure 2.

Surface composition of the Ni-Fe permalloy electroformed at various current densities has been characterized using X-ray photoelectron spectroscopy (XPS) (fig. 3). Details of the optimised fabrication and etch release process and its application to the construction of the wind sensor will be presented.

[1] Jack W. Judy and Richard S. Muller, The 8th International Conference on Solid-State Sensors and Actuators, pp. 332-335, 1995.
[2 Jun Zou, Jack Chen, Chang Liu, and Jóse E. Schutt-Ainé, Journal of Microelectromechanical Systems, **10,** 2, pp. 302-309, 2001.
[3] Jun Zou, Chang Liu, Drew R. Trainor, Jack Chen, Jose E. Schutt-Ainé, and Patrick L. Chapman, IEEE Transactions On Microwave Theory and Techniques, **51**, 4, pp. 1067-1075, April 2003.
[4] Chang Liu, Tom Tsao, Yu-Chong Tai, Tzong-Shyng Leu, Chih-Ming Ho, Wei-Long Tang, Denny Miu, MEMS Proceedings of the IEEE, pp. 7-12, 1995.
[5] Zhifang Fan, Jack Chen, Jun Zou, David Bullen, Chang Liu, and Fred Delcomyn, Journal of Micromechanics and Microengineering, **12**, pp. 655-661, 2002.
[6] Petros Argyrakis, Alister Hamilton, Barbara Webb, Yaxiong Zhang, Theophile Gonos and Rebecca Cheung, Microelectronic Engineering, **84**, pp. 1749–1753, 2007.

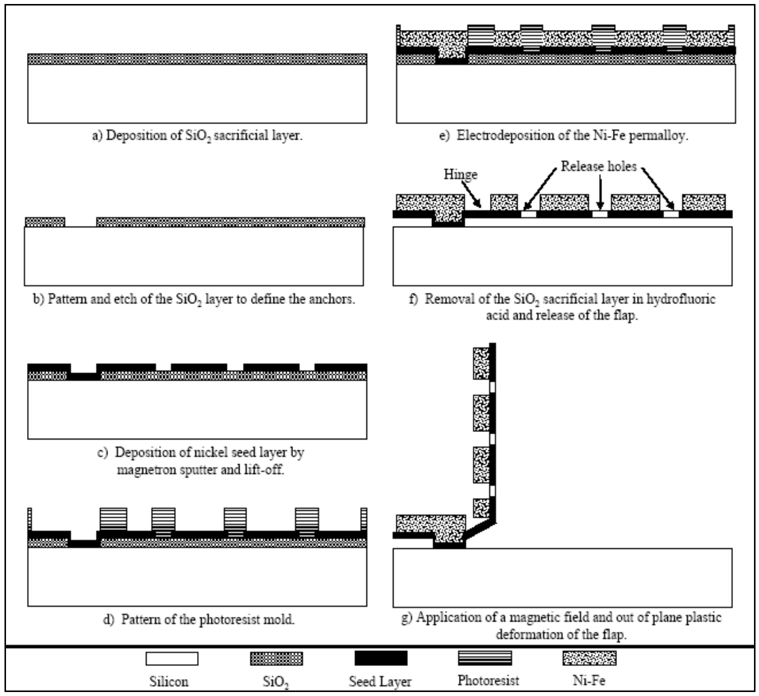


Figure 1. Schematic of the fabrication process.

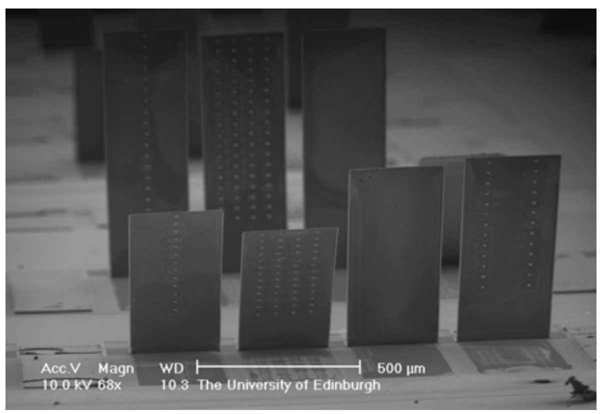
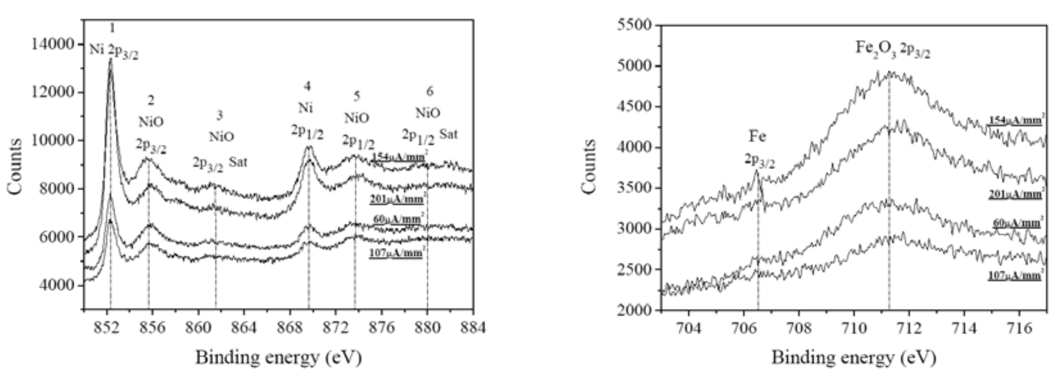


Figure 2. Scanning electron micrograph of the magnetically assembled structures.



(a) **(b)**

Figure 3. XPS spectra of electrodeposited Ni-Fe permalloy for various current densities: a) Ni 2p, and b) Fe 2p.