Localized Electrochemical Deposition Process and Mechanical Property Measurements for One-Dimensional Structure

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ABSTRACT

In general, electrochemical deposition has been employed to deposit metal on the metallic surface (plating) or to deposit metal for duplicating the patterns prepared by photolithographic process (electroforming). However, if by locally controlling the induced electric field to deposit metal, the lithography process for prepare the pattern by marks can be spared. Thus, it can reduce fabrication cost and error of masks or molds. Furthermore, using a localized electrochemical deposition can deposit micro-sized structures with high aspect ratio easily. Usually, the structure which is fabricated by micro-process, demonstrates mechanical properties different from its bulk materials counterpart. In this study, we use a localized electrochemical deposition to fabricate a cantilever beam of Cu which is in the dimensions of micrometers. The effects of various control parameters of the deposition process are also studied. The first resonance frequency of the deposited structure is measured by the forced vibration at its base. The Young ’ s modulus of the micro-structure is then inferred from the resonance frequency and several possible factors which affect the apparent stiffness are discussed. Because a stepping mode is used to deposit micro-structure in the experiment, a nodular micro-structure has been obtained. Therefore, this study also design a magnification mechanism which is composed of linkages connected by flexure hinges and is driven by a piezoelectric actuator. The continuous movement instead of stepped movement of the electrode with feedback control, should overcome the shortcoming of the previous study.

Keywords : Localized electrochemical deposition, Cantilever,Young ’ s modulus, Piezoelectric actuator, Flexure hinges.

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REFERENCES

[1] J. D. Madden, S. R. Lafontaine, and I. W. Hunter, “ Fabrication by -Electrodeposition: Building 3D Structures and Polymer -Actuators, ” Sixth International Symposium on Micro Machine -and Human Science, (1995). IEEE, pp. 77-81.

[2] J. D. Madden, and I. W. Hunter, “ Three-Dimensional -Microfabrication by Localized Electrochemical Deposition, ” -Journal of Microelectromechanical System, Vol. 5, No. 1, March -(1996), pp.24-32.

[3] E. M. El-Giar, U Cairo, and D. J. Thomson, “ Localized -Electrochemical Plating of Interconnectors for -Microelectronics, ” Proceedings of 1997 Conference on -Communications, Power and Computing; Winnipeg, MB; May -22-23, (1997), pp.327-332.

[4] L. T. Romankiw, “ A Path: From Electroplating Through -Lithographic Masks in Electronics to LIGA in MEMS, ” -Electrochimica Acta. 41, (1997), 2985-3005.

[5] E. M. El-Giar, R. A. Said, G. E. Bridges, and D. J. Thomson, - “ Localized Electrochemical Deposition of Copper -Microstructures, ” Journal of the Electrochemical Society, 147 (2) -(2000), pp. 586-591.

[6] A. J. Bard, F. Fan, J. Kwak, and O. Lev, “ In Situ Scanning -Tunneling Microscopic Study of the Corrosion of Type 304L -Stainless Steel in Aqueous Chloride Media , ” Journal of the -Electrochemical Society, (1989), 61(2), pp. 132-138.

[7] D. Muller, F. Muller, and M. Hietschold, “ Localized -Electrochemical Deposition of Metals Using Micropipettes, ” Thin -Solid Films, 366(2000) 32-36.
[8] S. H. Yeo and J. H. Choo, “ Effects of rotor electrode in the -fabrication of high aspect ratio microstructures by localized -electrochemical deposition, ” Journal of Micromechanics and -Microengineering. 11, (2001) 435-442.
[9] S. H. Yeo, J. H. Choo and K. H. Sim, “ On the effects of ultrasonic -vibrations on localized electrochemical deposition, ” Journal of -Micromechanics and Microengineering. 12, (2002) 271-279.
[10] Y. Li, Y. Zheng, G. Yang, and L. Peng, “ Localized -electrochemical micromachining with gap control, ” Sensors and -Actuators A 108(2003), pp. 144-148.
[11] B. Cappella, and G. Dietler, “ Force-distance curve by atomic -force microscopy, ” Elsevier Science, Surface Science Reports, 34 -(1999) 1-104.
[12] K. R. Virwani, A. P. Malshe, W. F. Schmidt and D. K. Sood, - “ Young ’ s modulus measurements of silicon nanostructures using -a scanning probe system: a non-destructive evaluation approach, ” -Smart Materials and Structures. 12 (2003) 1028-1032.
[13] X. Li, B. Bhushan and P. B. McGinnis, “ Nanoscale mechanical -characterization of glass fibers, ” Materials Letters. 29 (1996), -215-220.
[14] Hsin-Chang Tsai, Weileun Fang, “ Determining the Poisson's ratio -of thin materials using resonant method ”, Sensors and Actuators -A 103(2003), pp.377-383.
[15] J. W. Dini, Electrodeposition, 1st ed., Noyes Publications, New -Jersey, (1993), pp.195-216.
[16] F. E. Scrie, and E. C. Teague, “ Pizeodriven 50- μ m range stage -with subnanometer resolution, ” Rev. Sci. Instrum, Vo1.49, (1978). -pp. 1735-1740.
[17] T. King, M. Pozzi, and A. Manara, “ Piezoactuators for - ‘ real-world ’ applications, ” Power Engineering Journal, (2000), -pp105-110, June.
[18] W. Vu, and T. King, “ Flexure hinges for piezoactuator -displacement amplifiers: flexibility, accuracy, and stress -considerations, ” Precision Engineering, Vol.19, (1996), pp.4-10.
[19] Xu and Qu, “ Some Analytical Problems of High Performance -Flexure Hinge and Micro-motion Stage Design, ” Proceedings of -the IEEE International Conference on Industrial Technology, (1996), pp.771-775.
[20] 許錫鑫，“ 奈微米載具平台動態性能分析 ”，碩士論文，國立 彰化師範大學機電工程學系，(2003)。
[21] 朱志良、范盛豪，“ 奈米定位平台之研製 ”，中華民國第二十 七屆全國力學會議。
[22] W. T. Thomson, Theory of Vibration with Applications, 2nd ed., -Santa Barbara, California, (1981), pp. 218-220.