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Trimming of Atomic Force Microscope Probe Tip by Ion Milling

M. Y. Ali[1] and B. H. Lim[2]

[1] Department of Manufacturing and Materials Engineering, Faculty of Engineering
International Islamic University Malaysia, Jalan Gombak, 53100 Kuala Lumpur, Malaysia
[2] Precision Engineering and Nanotechnology Centre, School of Mechanical and Production Engineering, Nanyang Technological University, 50 Nanyang Avenue, Singapore 639798
mmyali@iiu.edu.my

ABSTRACT

This paper discussed the trimming of atomic force microscope (AFM) probe tips to minimize measurement and imaging errors. Commonly used AFM tip was trimmed using focused ion beam (FIB) micromilling to achieve high aspect ratio and sharpness. The aspect ratio of trimmed tip was up to 10. Trimmed tip was used for measurement and imaging of high aspect ratio microstructures using tapping mode of AFM. Same microstructures were scanned with AFM under same imaging conditions using an original unmodified tip. The images and scanning results were compared. It showed that the trimmed tips were superior in imaging both shallow and deep high aspect ratio trenches.

Keywords: AFM, Probe, FIB, Micromilling, Ion milling

1. INTRODUCTION

Recently much effort has been given into miniaturization technologies and researchers around the world were aiming at higher resolutions and precision for the purpose of making things smaller [1, 2]. However, the measurement of these microstructures and systems was one of the main challenges nowadays. AFM was playing the major role in micro and nano measurement and characterization. This measurement tool also used miniaturized integrated tip cantilever. The AFM was a lens-free microscope where a sharp tip was mounted on the end of a micro-cantilever. When the tip scanned the surface of any substrate, small interaction force between the tip and the surface caused the cantilever to deflect. It finally revealed the topography of the specimen in three dimensions. Depending on the size of the tip, this imaging was able to measure down to the atomic level [3].

The commercially available standard single crystal silicon or silicon nitride pyramidal tips were commonly used in AFM measurement [4]. But these tips were not sharp enough for imaging surfaces with high precision finishing and or deep trenches with steep sidewalls. So, it was necessary to increase the aspect ratio of the AFM tip for more accurate reproduction of topographic details of scanned surfaces. In the following subsections trimming of AFM tip is discussed first. Then the evaluation of the trimmed tips is discussed.

2. ION MILLING OF SINGLE CRYSTAL SILICON

Although numerous experiments and research were done on ion milling of silicon, those were used as guidelines [5-9]. Whenever using any machine especially for micromachining, it was essential to characterize the machine first with the same substrate material. This was to select the optimal machining parameters for different cases. In this research, a 50 keV dual focused e $^{+}$Ga^{+} beam (Micrion 9500EX) integrated with an energy dispersive x-ray (EDX) system (Oxford Link ISIS300) and scanning electron microscope (SEM) was used. After estimating the optimal machining condition, AFM probe tip of silicon was micromilled for trimming and sharpening.

2.1 Preliminary Studies of Ion Milling

For any particular acceleration voltage (e.g., 50 keV in this case), the basic parameters of ion milling were ion dose, beam current, dwell time, and pixel spacing. The beam current was also expressed by aperture size. For the above machine, the aperture size of 75, 100, 150, 250, and 350 μm