High Speed Atomic Force Microscope
Nicolas Mauran, Denis Lagrange, Xavier Dollat, Laurent Mazenq, Lucien Schwab, Jean-Paul Salvetat, Bernard Legrand

To cite this version:

HAL Id: hal-01529673
https://hal.laas.fr/hal-01529673
Submitted on 31 May 2017

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
High Speed Atomic Force Microscope

Nicolas Mauran1, Denis Lagrange1, Xavier Dollat1, Laurent Mazaen2, Lucien Schwab2, Jean-Paul Salvetat3, Bernard Legrand4


Summary

Atomic Force Microscope (AFM) is now a common tool for material analysis in the academic and industrial areas because it enables non-destructive high-resolution images of nanometric objects. However, a main drawback is the slow scan rate that hinders many potential applications. Recently, breakthroughs have been achieved in AFM sensors based on MEMS technology, allowing to extend AFM operation in terms of measurement bandwidth and data acquisition. The present work focusses on developing an electronic controller for AFM featuring the wide bandwidth and the fast data processing rate required to enable the exploitation of the full potential of MEMS AFM sensors.

High frequency AFM probes (MEMS technology)

AFM probes used in the present work were developed at EEMN-CNRS (Lille, FRANCE) and are now available from Vmicro SAS. A silicon ring holding a nanotip vibrates according to the elliptical resonance mode shape at about 13 MHz. Capacitive electromechanical transducers are integrated for driving and sensing the nanotip vibration. Typical measurement resolutions are 1.5 nm/√Hz in displacement and 0.5 pN/√Hz in force.

Software architecture

PC – LabVIEW 2016, QMH project

UI@ 10 ms
- R/W network streams from RT
- Unbundle datas
- Convert data to physical units (m,V)
- Averaging per pixel

UI@ 100 ms
- Display scaled data
- Display scan images

UI management
- Save image files
- Control USB motor for approach

Real-Time Controller – LabVIEW RT, QMH model

RT@ 5 ms non determ.
- R/W stream to UI
- Data 80 Mbit/s
- Messages

RT@ 1 ms deterministic
- Read data from FPGA

FPGA – LabVIEW FPGA

Z control loop @1µs pipelining
- Probe signal acquisition
- PID calculation with gain schedule
- Piezo Z command (20-bit word to external DAC)

Scan control @10µs or more
- Scan X, Y via Analog Outputs
- Read X, Y position sensors (AIs)
- Watchdog @40MHz

Piezo Z control Loop timing

DAC command 20-bit word

FPGA: microscope Z feedback operations take about 4 µs to complete. It executes every µs 1 with pipelining method.

Software performance

Small image
- 1k pixels
- Biggest image
- 3M pixels
- Scan duration
- 0.02s (50 images/s)
- 60s
- Binary file size
- 47 KB
- 140 MB

Topography images of d-block copolymers in the AFM mode

(a) Image 1 x 1 µm (256 x 256 pixels) acquired in 60 s. (b) and (c) images forward and backward 200 x 200 µm (1,000 x 1,000 pixels) acquired in 5 s.

The topographic contrast is due to elasticity contrast of copolymers strips.

Contact and informations at:
https://www.laas.fr/projects/olympia

This work is supported by the projects:
ANR OLYMPIA ANR-14-CE26-0003
- CRPP DYNMIC

Data 80 Mbit/s
Scan control @10µs or more

Images of graphite HOPG steps in AM-ADF mode

(a) Image 2.5 x 2.5 µm (512 x 512 pixels) acquired in 130 s. (b) Image 1 x 1 µm (300 x 200 pixels) acquired in 40 s. (c) Image 1 x 1 µm (300 x 200 pixels) acquired in 20 s.