Intermodulation atomic force microscopy

A novel nonlinear dynamics approach to atomic force microscopy
Intermodulation AFM

• Dynamic multifrequency AFM method
• Utilization of nonlinear frequency mixing
• Increased number of information channels
• High signal-to-noise ratio
• Various analysis methods
Intermodulation

- Cantilever driven with two pure drive tones close to resonance
- Nonlinear tip-surface force creates new components in the spectrum (Intermodulation products)
Each intermodulation product has amplitude and phase which can be used for imaging.

Phase images on a stack of different metals
Force measurements

- Reconstruction of the tip-surface force by combining all measured IMP amplitudes and phases.
- The force is approximated as a polynomial.
- Conservative forces and position dependent viscosities are reconstructed separately.
- Reconstruction at fixed probe height allows force reconstruction in every pixel of an image.
Force measurements

Force reconstruction on two points of blend of polystyrene and poly(acrylic acid)
Parameter maps

- Measured IMPs used to directly extract surface force parameters
- Any force model can be assumed
- Numerical solver extracts the model parameters that fit best the measured IMPs
- Generation of high resolution surface property maps
Parameter maps

Extracted Young’s modulus and adhesive force from a van-der-Waals DMT model

Sample courtesy of Eva Malmström (KTH) and Henrik Hillborg (ABB)
Summary

• IMAFM is a new dynamic multifrequency mode
• Increased tremendously the number of available information channels
• Surface force reconstruction in every pixel of an image
• High resolution parameter mapping with arbitrary force models
• Real-time intermodulation lockin analyzer available

www.intermodulation-products.com
References

• D. Platz et al. Ultramicroscopy 110, 573 (2010)
• E. Tholén et al., Rev. Sci. Instrum. 82, 026109 (2011)