Phase Detection In Semicontact Mode

The parameters of cantilever oscillations (amplitude, frequency, phase) change when cantilever approach to sample surface. Changes of cantilever amplitude near surface are used for feedback control in semicontact or noncontact mode. During scanning in semi-contact mode the cantilever amplitude is kept constant but the phase shift between cantilever oscillations and driving ac voltage can change. Registration of this phase shift simultaneously with topography is often useful for distinguishing of small features on sample surface. This can be seen on Fig.1, which demonstrates topography (a) and phase shift distribution (b) of nigella orientalis seed (oriental spice). Both images were obtained simultaneously. Phase image (b) reveals features that are invisible on topography (a).

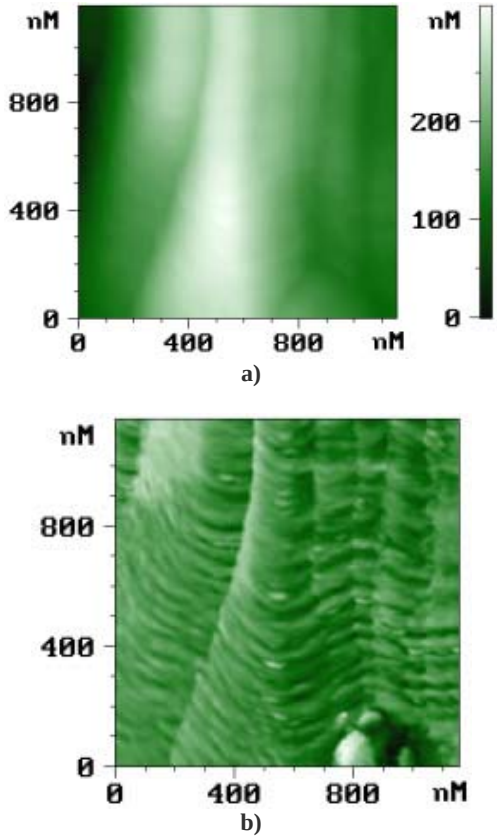
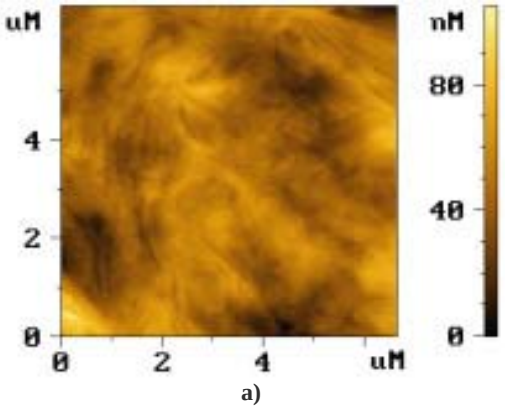
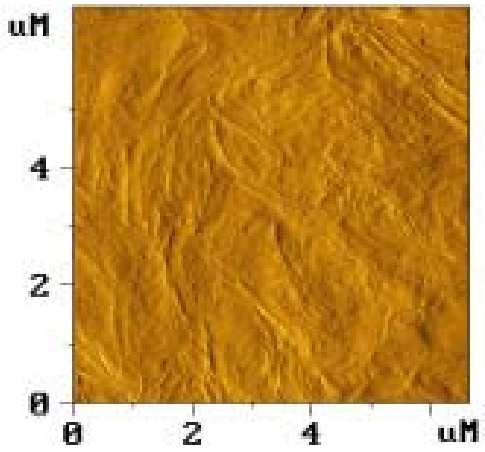


Fig. 1. Nigella orientalis seed (oriental spice): a) topography, b) phase image

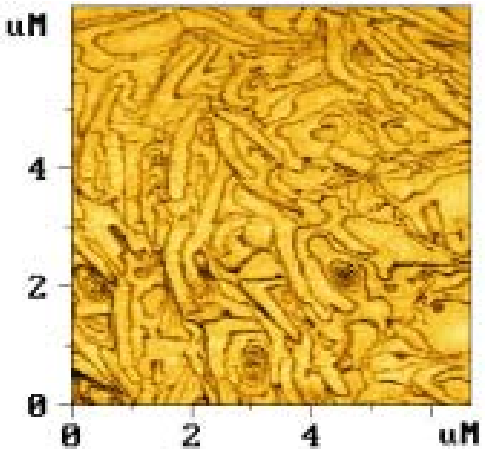
Moreover, the phase shift is defined not only by topography but also shows strong dependence on sample properties, such as adhesion, elasticity and viscoelastisity [http://www.ntmdt.ru/SPM-Techniques/SPM-Methodology/Phase_Detection_In_Semicontact_Mode/text49.html#ref_1]. Fig.2 shows this possibility of phase registration for polyethyleneoxide obtained by cooling of a melt. Phase image (c) has strong contrast unlike the topography (a) and the amplitude image (feedback error) (b). Amplitude image (b) also helps to distinguish small topography features due to absence of global roughness, but structure of surface is more clearly seen on the phase image (c). This strong contrast of the phase image is explained by differences of mechanical properties of amorphous and crystalline phases. Dark areas on Fig.2b correspond to softer amorphous polymer, which placed between hard crystalline lamellas. Phase contrast also depends on scanning conditions. Small scanning amplitude with regard to free amplitude, i.e. strong tip-sample interaction, leads to strong dependence of cantilever phase shift on sample properties [http://www.ntmdt.ru/SPM-Techniques/SPM-Methodology/Phase_Detection_In_Semicontact_Mode/text49.html#ref_1]. If scanning amplitude is close to free cantilever amplitude (small tip-sample interaction) then phase image may depend on topography features only without any influence of sample properties. In general the influence of the sample properties on the cantilever phase shift is intricate [http://www.ntmdt.ru/SPM-Techniques/SPM-Methodology/Phase_Detection_In_Semicontact_Mode/text49.html#ref_1]. But in some cases it is possible to connect phase changes with certain parameter distribution (see also polymer application).



a)



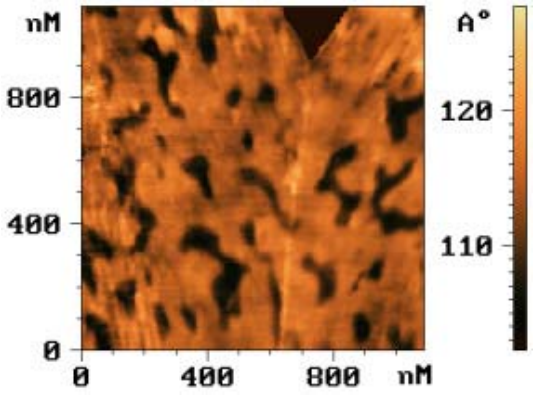
b)



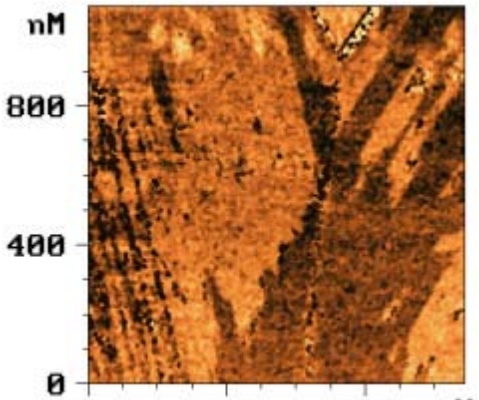
c)

Fig. 2. Topography (a), amplitude image (feedback error) (b) and phase image (c) of polyethyleneoxide obtained by cooling of a melt. Semicontact mode

Next example shows absolute difference between topography and phase images. The sample being investigated is Langmuir-Blodgett film, which was heated to 75шC and then was cooled to room temperature. During heating monolayer of azobenzene derivative forms needle-shape crystals. Fig.3 demonstrates the boundary region of two crystals (boundary looks like light line in the middle part of Fig.3a). Completely difference between topography (a) and phase image (b) is explained by various density of the top bilayer of the crystal. This leads to different mechanical properties of the surface that affect phase contrast.



a)



b)

Fig. 3 Topography (a) and phase image (b) of crystal obtained after heating LB film

Also electrical or magnetic properties of sample can influence phase image without visible topography changes when conductive or magnetic cantilever is used. Fig.4 shows surface of triglycine sulfate (TGS): a - topography, b - phase image. TGS is ferroelectric material and it contains electric domains, which are clear seen on Fig.4b. Electric tip-sample interaction leads to appearance of domain structure on topography (a). Absence of abrupt topography changes (steps on Fig.4a) on phase image proves electric character of phase contrast.

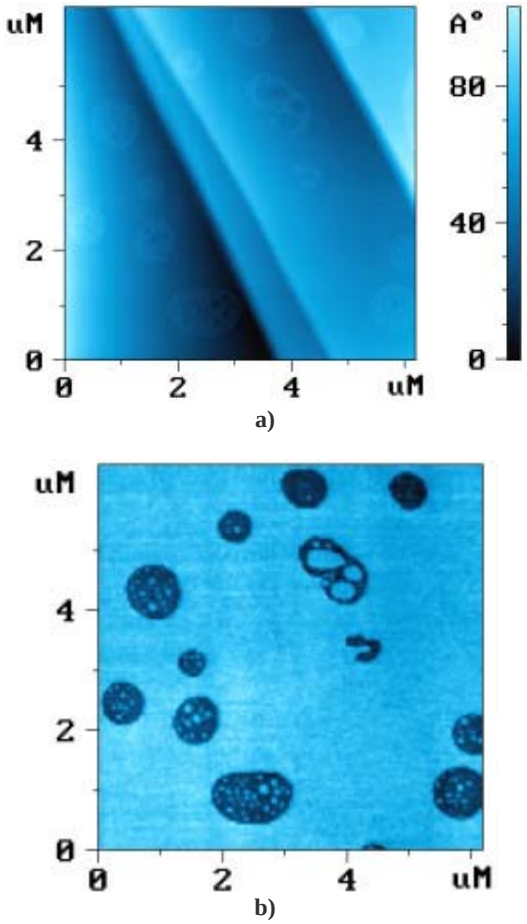


Fig. 4 Topography (a) and phase image (b) of triglycine sulfate

Detecting of the cantilever phase shift in semicontact mode simultaneously with topography measurements is available with every AFM manufactured by NT-MDT.

Conclusion

Registration of cantilever phase shift during scanning in semicontact mode synchronous with topography enables to acquire additional information about surface properties or to emphasize surface features. This technique is especially useful for materials with variable mechanical and chemical properties, such as composition or multiphase materials, materials with different structure and other complex samples.

References

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CONTACT DETAILS

Building 167, Zelenograd, 124460, Moscow, Russia
Tel: +7(095)535-0305, 913-5736
Fax: +7(095) 535-6410, 913-5739

e-mail: spm@ntmdt.ru; http://www.ntmdt.ru