HybriD Mode Webinar Questions and Answers *(collected during webinars which took place on 21-st and 23-rd of May)*

1. **Q: Which of your microscopes currently offer HybriD Mode?**

As I briefly mentioned during the presentation, the HybriD Mode is currently available as an option for NEXT and NTEGRA microscopes, where the sample excitation is realized. The HybriD Mode is also realized with SMENA head where probe excitation is used in instead. Furthermore, as NTEGRA is also the base platform for the AFM-Raman Spectra microscope, HybriD Mode has been successful used with this microscope configuration.

2. **Q: What is the difference between HD mode and Peak Force mode of Bruker?**

Our knowledge about Peak Force of Bruker is limited to the few applications briefs of this manufacturer, therefore besides the general understanding that Peak Force is one of the many possible implementations of using the cantilever deflection in a non-resonant oscillatory AFM mode, which was described earlier in the jumping mode patent by V. Elings and G. Gurley filed in 1989. With respect to a fair comparison of capabilities of different practical implementations of such non-resonant approach, which in addition is also realized in pulsed force and digital pulsed force from Witec, jumping mode and jumping mode + from Nanotec and a newly demonstrated mode from Anasys Instruments, there is a strong need fora set of benchmark samples thatreveal the pros and cons of each mode. We'll be happy to contribute to this process and some of the data presented in my presentation obtained on PDES and SBS samples, which were introduced for AFM studies in my earlier practical work are a good starting point for comparisons.

3. **Q: what cantilever spring constants and scan rates do you typically use in HybriD Mode?**

This is a very important question that I can only partially answer due to my relative short-term, but continuously developing, experience with HybriD Mode applications. As regarding the imaging in air I have successfully applied Si probes with a broad range of stiffness (0.3 N/m – 400 N/m), which I believe is slightly broader than in Amplitude modulation mode. Also of importance in the HybriD Mode is the range of the cantilever deflections (from 1 nm to hundreds of nm) and they depend strongly on a nature of sample, particularly, the sample stickiness. Concerning the use of HybriD Mode under *liquid, where my experience is more limited, the softer probes with k smaller than 0.1 N/m can be applied.*

4. **Q: Is it possible to measure surface potential, conductivity and current in HybriD Mode?**

With respect to the current imaging in HybriD Mode, the situation is clear, and the images obtained on the carbon nanotubes, which are included in the presentation, show high-sensitivity and high-spatial contrast of the current maps obtained by recording the tip-sample current (with a rather small bias of 0.1 V) during the touching part of the periodic deflection profile. As I have demonstrated in the talk, the long-distant electrostatic force variations, which can be translated into variations of surface potential, can be detected by measurements of the conducting probe deflection. Such measurements are similar to recording the electrostatic force variations in EFM and KPFM in double-pass mode when the probe is away from the sample during such measurements. Such applications are useful but limited by sensitivity and spatial resolution. It will be advantageous to perform such measurements with the probe remaining in the immediate vicinity of the sample like in the single-pass KPFM measurements in amplitude modulation mode.

5. **Q: Is it possible to couple the Raman imaging to obtain nanomechanical properties as well as chemical imaging simultaneously?**

The answer is yes!

6. **Q: Does the contrast in Stiffness map dependent on applied force?**

Naturally, the stiffness map, which actually can be constructed from the slopes of either loading or unloading parts of the deflection profile, can depend on the level of the set-point deflection. For example, at small set-point deflections the deformation of polystyrene is typically elastic and the unloading and loading parts coincide. At higher set-point deflections the deformation becomes inelastic, or plastic, with different and dissimilar loading and unloading traces. Therefore, the stiffness maps, which are also defined by what interval of the traces is used for stiffness evaluation, can be quite different. Furthermore, this situation also shows that it is rather difficult to assign the particular value of elastic modulus in case if the data is treated without knowledge of deformation type (elastic, viscoelastic or plastic).

7. **Q: Do we lose contrast when applying low force?**

Yes, it might happen when the sample deformation is small possibly making it more difficult to differentiate the softer and harder regions.

8. **Q: I think you mentioned pulsed force and peak force modes, can you contrast HD mode with those?**

With respect to a fair comparison of capabilities of different practical implementations of such non-resonant approach, which in addition is also realized in pulsed force and digital pulsed force from Witec, jumping mode and jumping mode + from Nanotec and a newly demonstrated mode from Anasys Instruments, there is a strong need for a set of benchmark samples that reveal the pros and cons of each mode. We'll be happy to contribute to this process and some of the data presented in my presentation obtained on PDES and SBS samples, which were introduced for AFM studies in my earlier practical work are a good starting point for comparisons.

9. **Q: How is HD mode different from force volume or force modulation mode?**

A key difference between HybriD Mode and force volume is primarily in the rate at which force curves are collected. This range for force volume is typically between 0.1 to 10Hz and for the HybriD Mode it is between 0.5 kHz and 10 kHz. As regarding the Force Modulation mode, this mode was introduced by Digital Instruments and it was based on monitoring the cantilever deflection at the resonance of the Z-piezo-actuator. Therefore, this mode was a type of resonant operation that makes the quantitative analysis of the probe deflection more difficult in terms of local properties.

10. **Q: How does the HybriD Mode work in fluid?**

As regarding the HybriD Mode operation in liquid, our developing experience shows that this mode has definite advantages compared to the amplitude modulation mode because the search for the cantilever resonance is excluded and the effect of force baseline drift is eliminated

11. **Q: HybriD Mode seems to be aggressive with the tip. What about tip degradation during the scan?**

As regarding the tip wear, we have not noticed any abnormalities for the HybriD Mode as compared to the Amplitude Modulation mode. The reason, might be, that we are particularly careful about the tip handling, especially in the engagement procedure. Most of the measurements reported in the presentation were made with the initial engagement of the probe in the Amplitude modulation mode, which has followed by switching to the HybriD Mode with the probe disconnected from the surface. The gentle engagement procedure, which we are using in the Amplitude Modulation mode, is based on the monitoring of the probe phase jump caused by the transition of the probe from the non-contact to the intermittent contact mode.

12. **Q: How did you get the same nano and macro moduli of PDMS using DMT model? With such a high adhesion, it should be JKR based on limits of applicability of these models?**

Sorry, I made a mistake by attributing the quantitative AFM-nanoindentation data obtained for PDMS rubbers to DMT model. Instead JKR model was applied in this case as seen from the following paper: Lacrout, H., Ginzburg, V., Meyers, G., McIntyre, B., Belikov, S., Erina, N., Huang, L., Magonov, S., and Prater, C. Proceed. "Quantitative AFM-based nanoindentation of PDMS films" Annu. Meet. Adhesion Society ***2008****, pp. 392-394.*

13. **Q: Does HybriD Mode wear out tips (especially with conductive coatings) faster than just amplitude modulation mode, and how can you keep your tips in good condition longer?**

As I mentioned answering Question 11, we didn't find any specifics of the probe wear in the HybriD Mode compared to the Amplitude Modulation mode and the same is true for the use of the conducting probes. An increase of the bias voltage sometimes was needed to bring current contrast in the current imaging with HybriD Mode but it happened rarely compared to the current imaging in the contact mode.

14. **Q: Do stiffness measurements assume the AFM probe is contacting a flat plane representing the sample?**

So far we are using simple models which assume local flatness of sample within the contact area. From the other side, we have developed the approach which is based on the KBM asymptotic solution of Euler-Bernoulli equation describing the tip-sample force interactions (using the real tip geometry derived from SEM and TEM images) in framework of different solid-state deformation models and already using the latter in off-line quantitative analysis of the AFM-based nanoindentation (see our application note). In due course we are pursuing the simulation of the HybriD Mode experiments in the interplay with the experiment.

15. **Q: Do you see errors in stiffness or adhesion measurements due to sample topography?**

Definitely, one can expect that both, stiffness and adhesion contrast, which are influenced by the tip-sample contact area, can depend on a local geometry of the probe and surface roughness of the sample. Although, we have not yet thoroughly explored this issue, the comparative stiffness and adhesion experiments with the probe having different size of the tip apex are on our list to-do.

16. **Q: Could HD mode be useful for analysis of surface functional groups?**

Although the direct chemical analysis in AFM is not accessed and a combination of AFM-Raman is a proper choice of the instrumentation, the differences in sample adhesion, which is detected with HybriD Mode, can be used for the indirect assignment of its contrast variations to the specific chemical nature of surface location as it was done much earlier in so-called Chemical Force Microscopy based on the lateral force variations in the contact mode scanning. The example of the HybriD Mode imaging of the assemblies of semifluorinated alkane (see the presentation last slide with the images) might be appropriate because the adhesion contrast on the assemblies with vertically oriented molecules having their –CF_3 terminal groups exposed to air was inferior to the adhesion contrast of the lamellar layers of these molecules where the surface is formed from –CH_3 and –CF_3 end groups.

17. **Q: Can you please mention which cantilevers are used, which cantilevers work for HD mode?**

The answer is similar to one for Question 3.

18. **Q: But how does the HybriD Mode compare to the PF QNM mode (Bruker) or Pulsed Force mode (WITec)?**

See the answers to Questions 2 and 8.

19. **Q: Could please compare the HybriD Mode with the PF QNM mode?**

See the answers to Questions 2 and 8.