

Resolution Limits for Investigating Layered Structures with AFMIR As A Function of Depth

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AFMIR is an analytical technique based on the photoacoustic effect: we optically monitor the deflection of the cantilever in a commercial AFM (Atomic Force Microscope) induced by a short pulse infrared (IR) laser, e.g. a QCL (quantum cascade laser), which is lightening the sample. The pulsed irradiation of an absorbing zone within the sample produces a fast local heating, which creates a thermal expansion of the heated zone and an acoustic wave propagating up to the sample surface where the AFM cantilever is positioned. The detection of the transient deflection of the cantilever gives a signal corresponding to the surface deformation, i.e. related to the local infrared absorption. In this way chemical information of the sample can be recorded with spatial resolution levels in the sub-micron-regime. The investigated samples consist of an optically absorbing layer less than 100 nm thick on a thick transparent substrate coated with a polymer of several micrometers thickness (e.g. PMMA) or with biomaterials. For such thin absorbing layers the surface displacement is not only determined by the acoustic wave but also by the thermal expansion of the heat diffusing outside the absorbing layer. Therefore thermal and acoustic equations have to be coupled to model the surface displacements measured for several coatings of different thickness. This is in contrast to conventional photoacoustic imaging, where thermal confinement allows neglecting the thermal expansion outside the absorbing layer. The coupled model is used for depth profiling: from the measured cantilever signal the coating thickness, which is the depth of the absorbing layer, should be estimated. This is an ill-posed inverse problem for which Tikhonov regularization is used, and the resolution is determined as a function of depth. The actual resolution is compared to the principle resolution limit for AFMIR, determined by using the equality of information loss and entropy production.