
Highlights
- An atomic force microscopy mode for nondestructive analysis of electromechanical and dielectric properties is reported.
- The technique is applied to diphenylalanine peptide tubes of less than 100 nm in diameter.
- Nondestructive in- and out-of-plane piezoresponse mapping of such nanoscale objects are demonstrated for the first time.
- High-resolution maps of tube elastic properties were obtained simultaneously with the piezoresponse.

Abstract
Nondestructive scanning probe microscopy of fragile nanoscale objects is currently in increasing need. In this paper, we report a novel atomic force microscopy mode, HybriD Piezoresponse Force Microscopy (HD-PFM), for simultaneous nondestructive analysis of piezoresponse as well as of mechanical and dielectric properties of nanoscale objects. We demonstrate this mode in application to self-assembled diphenylalanine peptide micro- and nanotubes formed on a gold-covered substrate. Nondestructive in- and out-of-plane piezoresponse measurements of tubes of less than 100 nm in diameter are demonstrated for the first time. High-resolution maps of tube elastic properties were obtained simultaneously with HD-PFM. Analysis of the measurement data combined with the finite-elements simulations allowed quantification of tube Young's modulus. The obtained value of $29 \pm 1$ GPa agrees well with the data obtained with other methods and reported in the literature.

Keywords
Atomic force microscopy; Piezoresponse force microscopy; Peptide tubes; Nondestructive scanning probe imaging; Young's modulus