Viscoelastic Properties of Living Cells Investigated by Time-Domain AFM Analysis

T. Okajima, M. Tanaka. S. Tsukiyama, T. Kadowaki,
S. Yamamoto, M. Shimomura, H. Tokumoto

Nanotechnology Research Center, Research Institute for Electronic Science, Hokkaido University, Creative Research Initiative "Sousei", Hokkaido University, N21W10 Kitaku, Sapporo, 001-0021, Japan
E-mail: okajima@es.hokudai.ac.jp

Since living cells have high anisotropy as a consequence of their complex internal architecture, it is crucial to explore the relationship between structure and function at the micro- and nanoscale under physiological conditions. In this study, we measured mechanical relaxation of living cells by a time-domain AFM analysis, in which an indentation force was applied to the cell by the AFM tip, and then a time series of the cantilever deflection signal was measured at the fixed position of cantilever displacement (Fig.1 (left)). We used a commercial AFM apparatus, MFP-3D AFM (Asylum Research, Santa Barbara, CA), which was mounted on an inverted optical microscope (IX71, Olympus Co.) and a silicon cantilever "BioLever Mini'' (BL-AC40TS, Olympus Co) whose spring constant and resonance frequency were l~0.1 N/m and ~ 30 kHz in liquids. Mechanical relaxation, i.e., a decay of the applied force, was clearly observed on human hepatoma cell line, HepG2 cells [1] and mouse fibroblast cell line, NIH3T3 cells [2]. The relaxation was well fitted to a stretched exponential function known as the Kohlrausch-Williams-Watts (KWW) function, which is empirically employed to represent dispersion processes of the system. The stretching exponent was estimated to be around 0.5, implying that the relaxation observed in HepG2 cells consisted of multiple relaxation process. The relaxation of cells was also measured by colloidal probe AFM, in which a silica bead with the diameter less than 2um was attached on the tip apex. The relaxations observed by the colloidal probe AFM were consistent with those by the sharp tip. This work was partly supported by Industrial Technology Research Grant Program in 2006 from New Energy and Industrial Technology Development Organization (NEDO) of Japan.

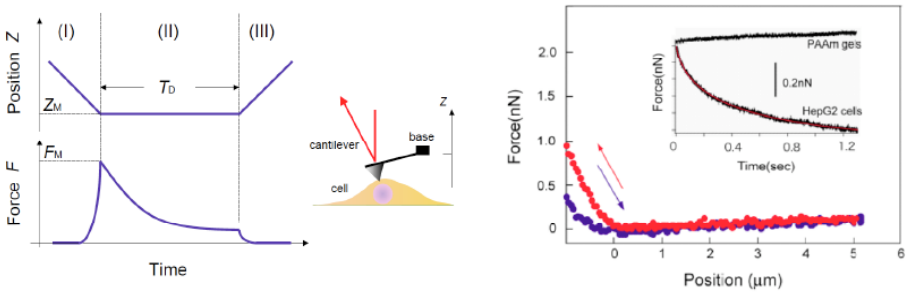

Fig. 1 (left) Schematics of stress (mechanical) relaxation measurement with AFM. The tip contacted the cell surface (region I), the position of the cantilever base Z was kept at a constant value (region II), and the tip was retracted (region III). (right) Typical approach and retraction force–distance curves measured in HepG2 cells. Inset shows the time series of the deflection signals observed on the HepG2 and a polyacrylamide (PAAm) gel.

[1] T. Okajima, M. Tanaka, S. Tsukiyama, T. Kadowaki, S. Yamamoto, M. Shimomura and H. Tokumoto, Nanotechnology in press.
[2] T. Okajima et al. JJAP in preparation.