MECHANICAL EFFECT OF CALIX[N]ARENE CAPPED SILVER NANOPARTICLES ON DNA MEASURED WITH SILICON NANO TWEEZERS

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ABSTRACT

This paper reports the use of a microelectro-mechanical system (MEMS)-based nano-tweezer in order to measure the effects of the interaction of calix[n]arene capped silver nanoparticles on the mechanical properties of DNA molecules.

KEYWORDS: Silicon Nano Tweezers, DNA, silver nanoparticles, Calix[n]arene

INTRODUCTION

The interaction between metallic nanoparticles and DNA offers great potential. A large number of studies have already shown the interest of this complexation for biological uses including diagnostics [1] and medical applications [2]. With regard to electronic and plasmonic applications, the self assembly properties of DNA can be associated with metallic nanoparticles to construct a variety of metallised and nanostructured shapes [3]. Manipulation of DNA at the molecular level is essential for understanding the effects of such interactions between specific functional nanoparticles and DNA molecules. Biophysical information concerning the interaction of DNA with other elements is usually performed using optical tweezers [4], magnetic tweezers [5] or atomic force microscopy [6]. Because of their low cost, ease of sample preparation, and use of biocompatible conditions, Silicon-Nano-Tweezers (SNT) has recently proved its great interest [7]. Here, we will present for the first time the mechanical effect of *para*-sulphonato-calix[4]arene (SC4) capped silver nanoparticles on DNA molecules.

EXPERIMENTAL

The SC4 capped silver nanoparticles solution (Fig.1-a) were prepared by the method of Xiong [8]. We have recently demonstrated their abilities to interact with nucleotides and nucleosides [9]. DNA λ-phage was purchased from TaKaRa (Japan). DNA and nanoparticles were at a final concentration of 1 µg/µL and 1.10^{-4}M respectively. DeIonized water was used as blank instead DNA. Their interactions with DNA λ-phage has been observed colorimetrically (Fig. 1-b) and spectrophometrically with a UV-visible spectrophotometer (Fig.1-c). After adding DNA into the nanoparticles solution, we observed a slight red shift (10 nm) of the plasmon resonance absorption of the hybrid nanoparticles. Moreover, AFM imaging measurements confirmed the attachment of the nanoparticles along the DNA (data not shown).

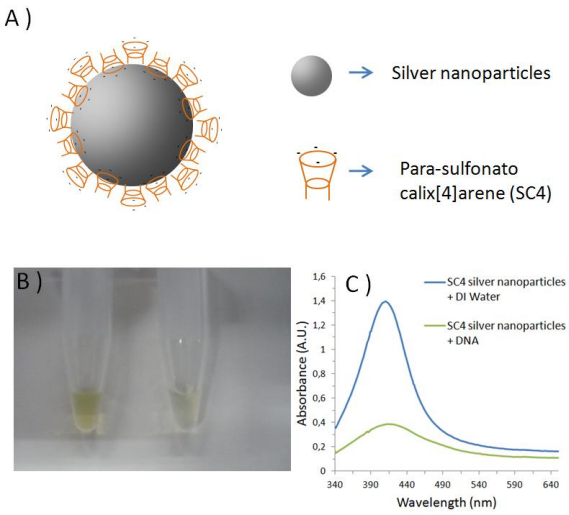

Figure 1: (1-a) Schematic representation of the organization of SC4 on silver nanoparticles (1-b) Pictures of SC4 silver nanoparticles mixed with DI water (on the left) and DNA (on the right). (1-c) UV Visible spectra of SC4 silver nanoparticles mixed with DI water or lambda DNA.

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SNT (Fig.2-a) are fabricated using standard microfabrication processes [7]. They consist of 1) a pair of opposing nanotips, 2) an electrostatic actuator for nanometer accuracy motion, and 3) a capacitive displacement sensor.

In the first step, the tweezer tips are brought to the surface of the DNA solution (droplet) on a glass slip and an AC voltage is applied between the tips (1 MHz, 16 Vpp) (Fig.2-b). By dielectrophoresis, a DNA bundle is extended and trapped between two tips of the tweezers (Fig.2-c). Next, the probes of SNT with trapped DNA bundle are introduced into the silver nanoparticles solution or DI water as negative control.
Resonance characteristics (frequency and amplitude) of the system are continuously recorded every 0.6 seconds following the 90° phase rotation at the resonance frequency.

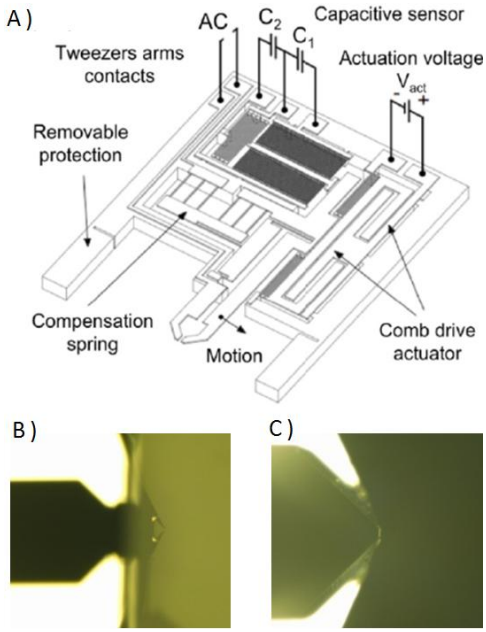

Figure 2: (2-a) Schematic diagram of silicon nano tweezers. (2-b) Tweezers tip immersed in DNA droplet. (2-c) DNA molecule bundle trapped in between tips (in air).

RESULTS AND DISCUSSION

Figure 3 shows the frequency resonance (black line) and the Q factor (red line) of the tweezers. From the immersion start of the tweezers with the DNA bundle into the nanoparticles solution and as the interaction of the nanoparticles proceeds along the DNA bundle, the resonance frequency increases and the Q factor is stable (Fig.3-b). The stability of the Q factor means that there is no difference in the amplitude of oscillations and as a consequence no energy loss. Interestingly, the increase of the resonance frequency indicates the stiffening of the DNA bundle with the nanoparticles attachment. For the witnesses, the bundle in water has shown no frequency variation in absence of nanoparticles (data not shown). The tweezers without DNA trapping proved to be very stable inside nanoparticles solution (Fig.3-a).

Transmission electronic microscopy has been performed after 5 minutes of immersion. Figure 4a confirmes that the bundle of DNA did not break up after removing the tweezer from the nanoparticle solution prior to observation by TEM. Figure 4b is focused on the bundle of DNA, confirming the attachment of the silver nanoparticles along the DNA.

CONCLUSION

SNT is a powerful tool to monitor in real-time the dynamic of silver nanoparticles attachement. SC4 nanoparticles provided extensive effect on DNA. Other calix[n]arene derivate capped silver nanoparticles will be investigated. We expect other mechanical and electronical properties according to their assemblies with DNA. This is promising for such applications as genotyping, or as news hybrid materials assemblies.

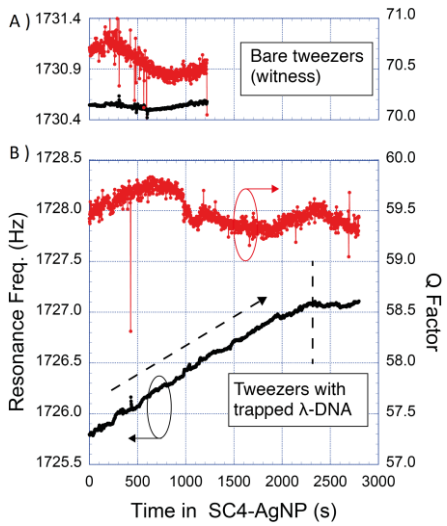

Figure 3: Frequency and factor Q vs time (3-a) Tweezers inside nanoparticles solution (3-b) Tweezers + DNA inside nanoparticles solution.

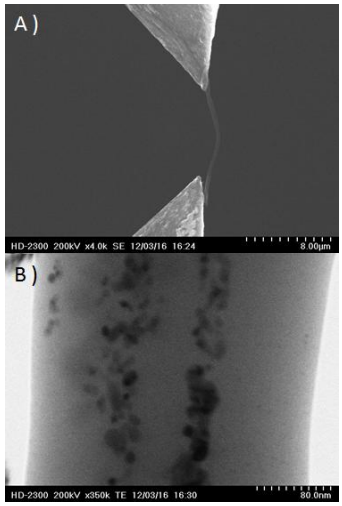

Figure 4: TEM picture of tweezer + DNA immersed inside nanoparticles solution (4-a) shows the bundle of DNA (4-b) shows silver nanoparticles along the DNA.

REFERENCES

1. "Nanodiagnostics: application of nanotechnology in molecular diagnostics," K. K. Jain, *Expert review of molecular diagnostics*, **3**, 153 (2003).
2. "Binding of functionalized paramagnetic nanoparticles to bacterial lipopolysaccharides and DNA," L. Bromberg, E. P. Chang, C. Alvarez-Lorenzo, B. Magarinos, A.Concheiro and T.A. Hatton, *Langmuir*, **26**, 8829 (2010).
3. "Connecting the nanodots: programmable nanofabrication of fused metal shapes on DNA templates," M. Pilo-Pais, E. Samano, T. H. LaBean and G. Finkelstein, *Nanoletters*, **11**, 3489 (2011).
4. "A general method for manipulating DNA sequences from any organism with optical tweezers," D. N. Fuller , G. J. Gemmen , J. P. Rickgauer, A. Dupont, R. Millin, P. Recouvreux and D. E. Smith, *Nucleic Acids Research*, **34**, 9 (2006).
5. "Single-molecule study of DNA unlinking by eukaryotic and prokaryotic type-II topoisomerases," G. Charvin, and V. Croquette, *Proceedings of the National Academy of Science*, **100**, 9820 (2003).
6. "Reversible unfolding of individual titin immunoglobulin domains by AFM," M. Rief, M. Gautel, F. Oesterhelt, J. M. Fernandez and H. E. Gaub, *Science*, **276**, 1109 (1997).
7. "Single-DNA-molecule trapping with silicon nanotweezers using pulsed dielectrophoresis," M. Kumemura, D. Collard, N. Sakaki, C. Yamahata, M. Hosogi, G. Hashiguchi and H. Fujita, *Journal of MEMS*, **21**, (2011).
8. "Synthesis of p-sulfonatocalix[4]arene modified silver nanoparticles as colorimetric histidine probes," D. Xiong, M. Chen and H. Li, *Chemical Communications*, **7**, 880 (2008).
9. "Colourimetric and spectroscopic discrimination between nucleotides and nucleosidesusing parasulfonatocalix[4]arene capped silver nanoparticles," Y. Tauran, M. Grosso, A. Brioude, R. Kassab and A. W. Coleman, *Chemical Communications*, **47**, 12307 (2011).

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