Characterization of Ivy Nanoparticle Adhesion Force for Biomedical Applications

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Statement of Purpose: On suitable surfaces, such as trees and rock faces, ivy has the ability to climb to levels of at least 25-30 meters above the ground and holds fast to vertical surfaces. This ability to climb onto, and strongly adhere to, a variety of solid substrates is contributed to the mucopolysaccharide-based adhesive, which is composed mainly of the uniform nanoparticles (NPs) with an average size of 70 nm based on recent discovery [1]. It is well known that micro-to-nano structures provide gecko strong attachment through van der Waals interactions. NP has recently been reported to help increase adhesion of epoxy adhesive [2]. Whether and how NPs in ivy provide strong attachment remains elusive. In this study, we first characterized and confirmed the adhesion force of NPs from cultured ivy rootlets using atomic force microscopy (AFM). The understanding of ivy NP adhesion through this study may allow us to design new generation of bioglues or sutures incorporated with NPs for future biomedical applications.

Methods: First, aerial roots (rootlets) were developed in culture plates using MS (Murashige T & Skoog F.) medium. Naturally grown fresh ivy rootlets (right before attachment) and plate-cultured rootlets were then cut close to the top and allowed to release the content onto clean silicon wafer surface. The samples were air-dried overnight for AFM scanning. Non-contact mode was used for imaging and the existence of NPs were determined in samples from both naturally and culture-plate grown rootlets. During the following force measurement studies using AFM (its tip has less than 15 nm in diameter), the culture-plate grown rootlets were cut to release the content onto the silicon wafer surface and approaching-retracting cycles were performed at different time points after settlement. The achieved force curves were later analyzed using Agilent software PicoImage, and the actual adhesion force, Young's modulus and extension length for each curves were calculated and analyzed.

Results: The released content from cultured ivy rootlet was first examined using AFM and a large amount of uniform NPs were observed (Figure 1), and their sizes agree with previously reported naturally-grown rootlets of 65-80nm in diameter with average of 70 nm. Based on this observation, we used cultured rootlets for the following studies. The exact adhesion force was first measured for freshly-released ivy NPs, which was 298 ± 8.34 nN on average, with a range of 274 to 307 nN. Change of adhesion force was tracked for these ivy NPs and a 30.2% decrease was observed during 24 hour after settlement (Figure 2), mainly in the first 7.5 hours. Next, the Young's modulus reflecting elastic / tensile property of these NPs was analyzed. The increased Young's modulus during the 24 hour study implicated the hardening process of these NPs after their exposure to air, which was also reflected by their decreased extension length measured by AFM. The hardening process is an essential step in the formation of strong attachment for liquid adhesives, which results in a closer contact and thus possibly increased van der Waals interactions among molecules in substrates.

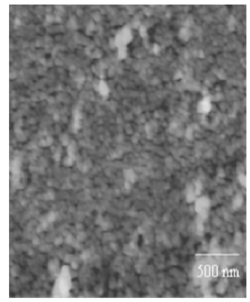

Figure 1: AFM imaging of NPs from cultured ivy rootlets.

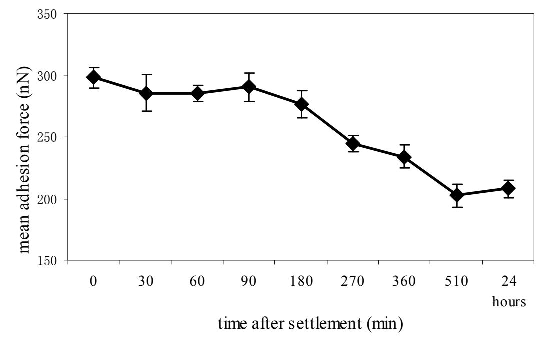

Figure 2: change of adhesion force within 24 hours after settlement.

Conclusions: The existence of NPs from *in vitro* grown ivy rootlets was confirmed using AFM with average diameter of 70 nm and range of 65-80 nm. The adhesion force of these NPs was measured to be 298 nN on average and had a 30.2% decrease during the first 7.5 hours after their exposure to air. This is significant larger than bare surface adhesion. The Young's modulus and extension length of these NPs changed with time, reflecting the hardening process of these NPs in the air. The potential medical applications of this unique feature of the ivy nanoparticles include medical adhesive, sutureless material, adhesive coating for cell growth and tissue engineering, etc.

References:

1. Zhang M. Nano Lett. 2008;8(5):1277-1280.
2. Zhai L. Mater. Lett. 2006;60:3031-3033