

## Batch fabrication and characterization of nanostructures for enhanced adhesion

Michael T. Northen<sup>a,\*</sup>, Kimberly L. Turner<sup>b</sup>

<sup>a</sup> Materials Department, University of California at Santa Barbara, Santa Barbara, CA 93106, USA

<sup>b</sup> Mechanical and Environmental Engineering Department, University of California at Santa Barbara, Santa Barbara, CA 93106, USA

Available online 27 December 2005

---

### Abstract

This paper describes the realization and characterization of nanofabricated organic looking polymer nanorods, “organorods,” for use in a biomimetic adhesion system. The adhesion system is inspired by the fine hair adhesive motif found in nature and best exemplified by the gecko. The meso- to nanostructure of the gecko’s foot is designed to maximize inelastic surface contact to enhance van der Waals interactions. In this work, cleanroom-based processing techniques have been used for fabrication and characterization of nanostructures for inclusion in a multi-scale system mimicking the natural adhesive. The multi-scale system consists of flexible silicon dioxide platforms, supported by a single silicon pillar, coated with  $\sim 200$  nm in diameter and  $\sim 4$   $\mu$ m tall polymeric organorods. The organorod surface is altered between hydrophilic and highly-hydrophobic. The adhesive properties between the artificial surface and a 3.175 mm aluminum sphere are measured in a modified nanoindenter. Initial results indicate improved adhesion with the hydrophobic surface over the hydrophilic, further corroborating van der Waals interactions to be the operative force of adhesion and suggesting a reduced cut-off distance in the van der Waals theory.

© 2005 Elsevier B.V. All rights reserved.

**Keywords:** Organorods; Polymer; Nanoindentation; Nanorods; Adhesion

---

### 1. Introduction

The emergence of microsensors has come about due to increased microfabrication abilities and the gain in understanding of microscale mechanics. Sensors for chemical, mass, pressure, and inertial sensing are among the most common thus far [1–4]. Significant developments in microscale sensors have enjoyed interest because they possess important properties, including high sensitivity and the ability to be fabricated in large arrays of thousands to millions. However, there still exists a question in the deployment of these arrays. Adhesion of sensor arrays is one area necessary for many applications that require the deployment of microdevices. In addition chip-scale recognition and adhesion systems will be of great interest for

use in fabrication, self-assembling microdevices and emerging miniature aerospace applications.

Found in nature, and best demonstrated in the pad of the gecko’s foot, the fine hair adhesive system is an excellent example of convergent evolution in biology [5–12]. Researchers have puzzled over the phenomenon since the days of Aristotle. Recently much work has been done to better understand the mechanism behind the adhesion [10–15], and convincing data has shown that the adhesion is primarily due to short-range weak van der Waals interactions between the fine hairs on the adhering surface and the external surface [11]. In order for these weak interaction forces to become significant a large amount of inelastic surface contact must be made between the surfaces. If the adhesive were to elastically conform to the surface then there would be a repulsive force present from the strain in the material. To avoid this the gecko has a multi-level conformation structure which allows for a large amount of surface contact without creating a repulsive force. The

---

\* Corresponding author. Fax: +1 805 893 8651.

E-mail address: [north@engineering.ucsb.edu](mailto:north@engineering.ucsb.edu) (M.T. Northen).

multi-level structure consists of toes containing blood sinuses supporting rows of imbricated lamellae of densely packed keratinous setae, approximately 100  $\mu\text{m}$  in length and 20  $\mu\text{m}$  in diameter, which then split into finer 200 nm in diameter bristles [6].

Previous work in this area has focused on creating the final terminal bristles [11,16–18]. While individual nanorods demonstrated expected amounts of adhesion, larger arrays failed to produce larger amounts of adhesion—unless removed from the substrate and placed on a compliant backing [17]. This illuminates the need for a multi-level conformation scheme. Additionally, due to processing constraints, prior work has not fully duplicated the nanostructure, it has not used mass production means and has not emulated the super-hydrophobic nature of the gecko pad (until now only thought to aid in self-cleaning of the surface). In this paper a new fabrication technique to produce, in a massively parallel fashion, sub-micrometer polymeric organorods, will be discussed. To test the relative functionality of the nanostructures, an adhesion test technique utilizing nanoindenter instrumentation will be described, and the results compared with a simple analytical adhesion model.

## 2. Experimental

### 2.1. Fabrication

For incorporation into the multi-scale system, a compatible nanorod fabrication technique was developed to create

50–150 nm diameter and  $\sim 4\ \mu\text{m}$  tall organorods (Fig. 1). The process is compatible with standard microelectromechanical fabrication utilizing a modified reactive ion etch (RIE) process. To create the organic looking nanorods a 4 in. silicon wafer is first soaked with HMDS for 30 s and spun ‘dry’ at 3500 rpm. The wafer is then coated with photoresist (Shipley<sup>TM</sup> SPR 220-7, a diazoquinone ester and a phenolic novolak resin resist) spinning at 3500 rpm and baking at 95  $^{\circ}\text{C}$  for 90 s. The wafer is then placed into an inductively coupled plasma (ICP) reactive ion etcher using an oxygen plasma with an applied bias between the sample and the plasma (Fig. 2). For the nanorods tested in this paper a RF power of 300 W, an oxygen flow rate of 40 sccm and a 10 min growth time is used to coat a 4 in. wafer. Further transformation of the hydrophilic organorods to a highly-hydrophobic surface is achieved by placing the sample in a fluorine plasma. The fluorine deposits a conformal coating on the organorods creating a Teflon<sup>®</sup> like surface.

### 2.2. Characterization

A Hysitron Triboindenter<sup>TM</sup> is used to measure adhesion between the test surfaces and a 3.175 mm diameter aluminum sphere (see schematic Fig. 2). In this experiment the aluminum sphere is glued to the tip of a nanoindenter probe. The device is placed in the indenter and the indenter tip pressed against the test surfaces. The nanoindenter is operated in displacement control and records the load vs. displacement. To determine the adhesion the loading and

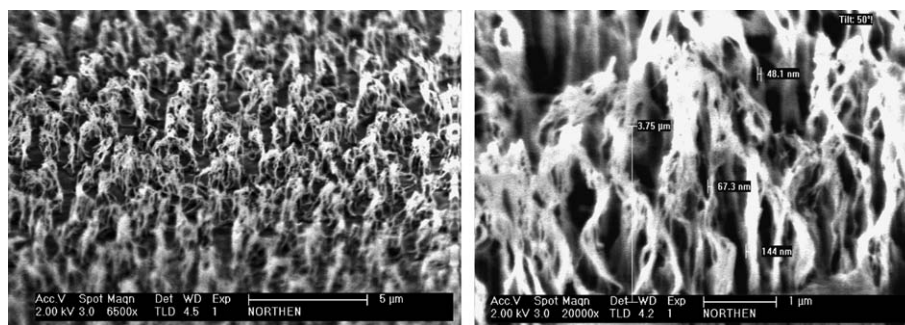


Fig. 1. Scanning electron micrographs of the organorod morphology, scale bars 5  $\mu\text{m}$  and 1  $\mu\text{m}$ , left and right, respectively.

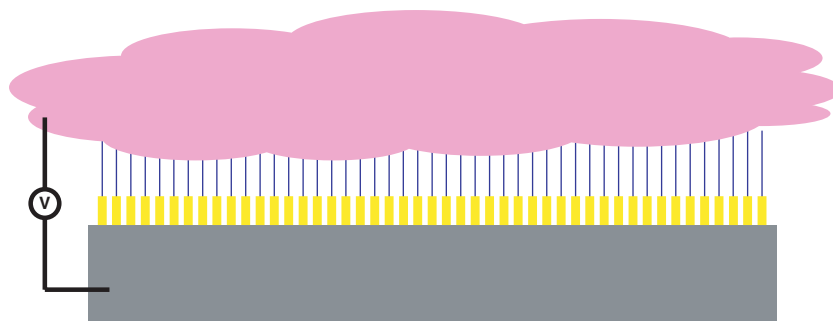


Fig. 2. Schematic of the organorod growth mechanism. A bias is applied between oxygen plasma and the substrate, creating an electric field gradient, which acts on the dielectric polymer draws it in the direction of the gradient.

Download English Version:

<https://daneshyari.com/en/article/1787969>

Download Persian Version:

<https://daneshyari.com/article/1787969>

[Daneshyari.com](https://daneshyari.com)