Appendix A
Shampoo and Conditioner Treatment Procedure

This section outlines the steps involved in washing hair swatches with shampoo and/or conditioner.

A.1 Shampoo Treatments

Shampoo treatments consisted of applying a commercial shampoo evenly down a hair swatch with a syringe. The hair was lathered for 30 s, rinsed with tap water for 30 s, and the process was repeated. The amount of shampoo used for each hair swatch was 0.1 cm^3 of shampoo per gram of hair. Swatches were hung to dry in an environmentally controlled laboratory and then wrapped in aluminum foil.

A.2 Conditioner Treatments

A commercial conditioner was applied, 0.1 cm^3 of conditioner per gram of hair. The conditioner was applied in a downward direction (scalp to tip) thoroughly throughout the hair swatch for 30 s. The swatch was then rinsed thoroughly for 30 s. Swatches were hung to dry in an environmentally controlled laboratory and then wrapped in aluminum foil.

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Appendix B
Conditioner Thickness Approximation

We consider a cylindrical hair fiber of diameter $D = 50\ \mu\text{m}$ (radius $R = 25\ \mu\text{m}$). For conditioner thickness calculations, the following assumptions are made: (a) hair and the material being added have the same density; (b) the coating of material is uniform on the hair surface; (c) the cross-sectional area of a hair fiber remains constant along the longitudinal axis of the fiber (i.e., from root to tip); the hair fiber is perfectly cylindrical (circular cross section); and (d) the deposited conditioner remains bonded to the cuticle surface (no absorption into the cuticle layer).

The cross-sectional area of an untreated hair fiber is initially calculated. By adding a specified amount of conditioner, this area will increase and cause the radius of the treated hair fiber to increase. This increase in the radius of the treated hair will be equivalent to the thickness of the conditioner layer. The original cross-sectional area A_c of the hair fiber is

$$A_c = \pi R^2 = \pi (25\mu\text{m})^2 = 1963.4954\,\mu\text{m}^2$$

Adding 200 ppm of material to the surface (which is comparable to the amount that commercial conditioners typically deposit) will cause an increase in volume (for a unit fiber length) by 200 ppm, or by 0.0002. Thus, the cross-sectional area $A_{c,\text{conditioner}}$ of the treated hair will increase by the same amount to

$$A_{c,\text{conditioner}} = 1.0002\,A_c = 1963.888\,\mu\text{m}^2$$

which results in a new radius $R_{\text{conditioner}}$

$$R_{\text{Conditioner}} = \sqrt{A_{c,\text{Conditioner}}}/\pi = 25.0025\,\mu\text{m}$$

Therefore, subtracting the original radius from the radius after treatment increases the thickness of the hair by 0.0025 μm, or 2.5 nm.

It is important to note that the approximation of the conditioner thickness as 2.5 nm was determined for a particular hair diameter and material deposition amount (with the hair and material having equal densities). Although these are generally realistic approximations, hair diameter often varies by a factor of 2 and the deposition level can vary up to an order of magnitude. The conditioner layer has been shown in previous work to be non-uniform as well. Thus, actual conditioner thickness can deviate significantly from this number.

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Note: The letters ‘f’ and ‘t’ following the locators refer to figures and tables respectively.

D

Biography

Dr. Bharat Bhushan received an MS in mechanical engineering from the Massachusetts Institute of Technology in 1971, an MS in mechanics and a PhD in mechanical engineering from the University of Colorado at Boulder in 1973 and 1976, respectively; an MBA from Rensselaer Polytechnic Institute at Troy, NY, in 1980; Doctor Technicae from the University of Trondheim at Trondheim, Norway, in 1990; a Doctor of Technical Sciences from the Warsaw University of Technology at Warsaw, Poland, in 1996; and Doctor Honouris Causa from the National Academy of Sciences at Gomel, Belarus, in 2000. He is a registered professional engineer. He is presently an Ohio Eminent Scholar and The Howard D. Winbigler Professor in the College of Engineering, and the Director of the Nanoprobe Laboratory for Bio- & Nanotechnology and Biomimetics (NLB^2) at the Ohio State University, Columbus, Ohio. His research interests include fundamental studies with a focus on scanning probe techniques in the interdisciplinary areas of bio/nanotribology, bio/nanomechanics, and bio/nanomaterials characterization and applications to bio/nanotechnology and biomimetics. He is an internationally recognized expert of bio/nanotribology and bio/nanomechanics using scanning probe microscopy and is one of the most prolific authors. He is considered by some a pioneer of the tribology and mechanics of magnetic storage devices. He has authored 6 scientific books, more than 90 handbook chapters, more than 700 scientific papers (h-index – 45+; ISI Highly Cited in Materials Science, since 2007), and more than 60 technical reports; edited more than 45 books; and holds 17 US and foreign patents. He is co-editor of Springer NanoScience and Technology Series and co-editor of Microsystem Technologies. He has given more than 400 invited presentations in the six continents and more than 140 keynote/plenary addresses at major international conferences.

Dr. Bhushan is an accomplished organizer. He organized the first symposium on Tribology and Mechanics of Magnetic Storage Systems in 1984 and the first international symposium on Advances in Information Storage Systems in 1990, both of which are now held annually. He is the founder of an ASME Information Storage and Processing Systems Division founded in 1993 and served as the founding chair during 1993–1998. His biography has been listed in over two dozen Who's Who books including *Who's Who in the World* and he has received more than two dozen awards for his contributions to science and technology from professional societies, industry, and US government agencies. He is also the recipient of various international fellowships including the Alexander von Humboldt Research Prize for Senior Scientists, Max Planck Foundation Research Award for Outstanding Foreign Scientists, and the Fulbright Senior Scholar Award. He is a foreign member of the International Academy of Engineering (Russia), Byelorussian Academy of Engineering and Technology, and the Academy of Triboengineering of Ukraine, an honorary member of the Society of Tribologists of Belarus, a fellow of ASME, IEEE, STLE, and the New York Academy of Sciences, and a member of ASEE, Sigma Xi and Tau Beta Pi.

Dr. Bhushan has previously worked for the R&D Division of Mechanical Technology Inc., Latham, NY; the Technology Services Division of SKF Industries Inc., King of Prussia, PA; the General Products Division Laboratory of IBM Corporation, Tucson, AZ; and the Almaden Research Center of IBM Corporation, San Jose, CA. He has held visiting professor appointments at University of California at Berkeley, University of Cambridge, UK, Technical University Vienna, Austria, University of Paris, Orsay, ETH Zurich, and EPFL Lausanne.