

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.

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 $0.0025 \mu\text{m}$, 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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Subject Index

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

A

- Adhesive force mapping and conditioner
 - thickness, 138–141
 - conditioner-treated hair surface, 139
 - cycle of treatment, 141
 - effective stiffness, 138
 - ellipsometry, 138
 - humidity and temperature, effect of, 142
 - conditioner-treated hair surface, 142
 - damaged hair surface, 142
 - film thickness and adhesive forces, 142, 144f
 - maps/histograms, 140f, 142
 - and typical film thickness, 142, 143f
 - virgin hair, 142
 - Lifshitz theory, 139
 - 18-methyl eicosanoic acid (18-MEA), 141
 - PDMS silicone in air, 138
 - silicon tip, 139
 - snap-in distance, 138
 - surface forces apparatus (SFA)
 - experiments, 139
 - van der Waals attractive force, 138–139
- AFM, *see* Atomic force microscopy (AFM)
- “Along cuticle,” 72, 91, 125, 127
- Amino silicone-based conditioners,
 - 156–157, 161f, 162–163, 166f, 167f, 168
- Angle-resolved X-ray photon spectroscopy (XPS), 137
- Atomic force microscopy (AFM), *passim*

B

- Bleaching, 19, 21, 108

C

- Care
 - beauty care technology, 10
 - cleaning and conditioning treatments
 - conditioner, constitution/functions, 15–18
 - shampoo, constitution/functions, 13–15
 - damaging processes, 18–19
 - features/tribological attributes of conditioners, 13t
 - hair alignment, 11
 - macro/micro/nanoscale functions, 12f
 - mechanical processes, 11
 - shampoos, 11
 - tribology of hair, 11
- Chemical relaxation, 19, 61, 63, 87, 108
- Chemo-mechanically damaged hair, 41, 58, 68, 73, 76, 94, 97, 99, 102, 104, 105, 111
- Coloring, 18–19, 41, 58, 108, 165
- Commercial conditioner (physisorbed) treated hair, 38, 40f, 41, 108, 120, 135–136, 138, 144–145, 147, 149, 150, 162, 168, 171
- Conditioners, 153
 - amino silicone, 156–157, 161f, 162–163, 166f, 167f, 168
 - antistatic effects, 168
 - constitution/functions, 15–18
 - benefits, 16
 - chemical structure and purpose/function of ingredients, 17t
 - combinations of ingredients and benefits, wet and dry feel, 16t

- conditioner formation from emulsion to gel network, 16f
 - “flyaway” behavior, reduction, 15
 - gel network chassis, 15
 - negatively charged hair and deposition of positively charged conditioner on cuticle surface, 15f
 - mechanisms
 - lubricating effect, 168
 - surface conductivity, increased, 168
 - PDMS silicone, 156, 166f, 168
 - reduction of potential, 168
 - thickness distribution, 137–151
 - and adhesive force mapping, 138–141
 - conditioner/hair surface, binding interactions, 147–151
 - effective Young’s modulus mapping, 144–147
 - treatment, effects
 - chemically damaged hair, 166f
 - chemically damaged treated hair (amino silicone), 167f, 168
 - chemically damaged treated hair (PDMS silicone), 166f, 168
 - voltage biased tip for mechanically damaged hair, 167f
 - Correlation length, 99, 102, 111, 122
 - Cortex and medulla, 6–7
 - cell membrane complex, 6–7
 - microfibrils, 6
 - SEM images of virgin hair cross section, 9f
 - TEM of hair cross section, 9f
 - Coulombic bonding, 85
 - Cuticle, 3–6
 - AFM images of various virgin hair, 8f
 - cell membrane complex (CMC), 3
 - layers, *see* Cuticle layers, structure of
 - 18-methyl eicosanoic acid (18-MEA), 3
 - multiple cells, nanoscratch on, 70–75
 - coefficient of friction and scratch depth profiles, 69f
 - reduction in scratch depth/post-scratch depth, 69
 - SEM images
 - of Caucasian, virgin and treated hair, 7f, 7t
 - of various hair, 4f
 - of virgin Caucasian hair at three locations, 6t
 - single cell, nanoscratch on, 68–69
 - chemo-mechanically damaged Caucasian/Asian hair after scratch, 72f
 - coefficient of friction and scratch depth profiles/SEM images, 70f, 71f–72f
 - directionality effect, 72
 - surface profiles observation, 71–72
 - various failure mechanisms, 74f
 - sublamellar structure
 - fiber structure and, 2f
 - surface
 - interactions between AFM tip/conditioner, 36f
 - negatively charged hair and deposition of positively charged conditioner, 15f
 - variations in adhesive force on, 112f
 - variation in cross-sectional dimensions of human hair, 5t
 - various layers of cuticle, 4t
 - Cuticle layers, structure of, 48–55
 - chemically damaged hair, 50–52, 51f
 - cuticle edge “ghost,” 50
 - images of surface of chemically damaged Caucasian hair, 51f
 - schematic of progress of hair damage, 52f
 - conditioner-treated hair, 52–54
 - AFM TR mode, 54
 - images of surface of chemically damaged treated Caucasian hair, 53f
 - effect of humidity on morphology and cellular structure of hair surface, 54–55
 - cross section and longitudinal section of virgin Caucasian human hair, 56
 - surface height of virgin Caucasian hair cross section at different humidities, 56, 56f
 - TR mode phase contrast images of Caucasian virgin/chemically damaged/damaged treated hair surfaces, 55, 55t
 - virgin hair, 48–50
 - images of surface of virgin Caucasian hair, 49f
 - individual sublamellar layer, 50
- D**
- Damaged hair, effects, 165
 - before and after rubbing, 165
 - chemically damaged hair, 166, 166f
 - mechanically damaged hair, 165
 - and virgin hair, comparison, 165
 - Damaging processes
 - chemical relaxation, 18

- coloring and dyeing, 19
- mechanical damage, 18
- permanent wave treatment, 18
- Directionality effect, 31, 70, 72, 89, 107, 124–127
- Disulfide linkage, 1
- Durability
 - effects on friction force for various hair, 117f
 - measurements
 - relative humidity/temperature/soaking, AFM, 38
 - study of Caucasian/virgin and chemically damaged hair, 116–117
 - tests, results, 135
- Dyeing, 11, 19, 21
- E**
- Ellipsometry, 137–139
- Ethnicities, various, 97–107
 - adhesive force values of virgin, 102t, 105f
 - Caucasian virgin hair
 - surface roughness/friction force/slope, 107, 108f
 - chemo-mechanically damaged hair, 102t, 105f
 - coefficient of friction, 102t, 105f
 - for chemo-mechanically damaged hair, 103t, 104
 - for virgin treated hair, 103–104, 103t
 - correlation distance, 99–102
 - directionality effects of friction on micro/nanoscale, 107
 - force-volume maps
 - of chemo-mechanically damaged hair, 105, 106f
 - of virgin treated hair, 106f, 107
 - Gaussian height distribution, 99
 - height standard deviation, 99
 - surface roughness, 102t, 105f
 - of chemo-mechanically damaged hair, 97, 98f
 - and friction images for chemo-mechanically damaged hair, 99, 100f, 102
 - and friction images for commercial conditioner hair, 99, 101f
 - and friction images for virgin, 99, 100f, 102
 - of virgin, 97, 98f
 - virgin treated hair, 102t, 105f
 - “scale edge ghosts,” 97
- Experimental apparatuses, 23–26
 - AFM operating modes, tapping mode and torsional resonance (TR) mode, 23
 - comparison of methods used to characterize hair on micro/nanoscale, 24t
 - depth-sensing nanoindentation, 25
 - friction test apparatuses at macro- and micro/nanoscales, 26f
 - nano-Kelvin probe, 23
 - schematic diagram of AFM operation with human hair sample, 25
 - surface metallization and vacuum exposure, 23
- Experimental methods
 - Adhesive force mapping, 21–22
 - AFM, 21
 - combing, 22
 - experimental apparatuses, 23–26
 - friction test apparatuses at macro/micro/nanoscales, 26f
 - hair and skin samples, 41–43, 41t
 - nanointender, 22
 - nanoscale characterization, 21
 - procedure, 26–41
 - roughness parameters, 22
 - tensile loading experiments, 23
- Experimental procedure
 - macroscale tribological characterization
 - using friction test apparatus, 33–35
 - schematic of reciprocating tribometer, 34f
 - simulating wet conditions, 35
 - micro/nanotribological characterization
 - using AFM, 35–41
 - adhesive force measurements, 36
 - conditioner thickness, 38–41
 - force calibration plot for Caucasian virgin hair, 37
 - force calibration plot for commercial conditioner-treated hair, 40f
 - interactions between AFM tip/conditioner on cuticle surface, 36f
 - region around AFM tip/conditioner/hair surface, 39f
 - relative humidity/temperature/soaking/durability measurements, 38
 - specimen mounting, 35
 - surface roughness/friction
 - force/adhesive force measurements, 35–37
 - surface roughness images, 36
 - Young’s modulus of sample, 39–40

- nanomechanical characterization using nanoindentation, 30–32
- in situ* tensile deformation characterization using AFM, 32–33
- beam-type strain gauge force sensor, 33
 - setup used to conduct *in situ* tensile testing, 32f
 - stage motion, 32
- structural characterization using AFM, 26–29
- cantilever–tip assembly, 28–29
 - contrast in TR amplitude and phase angle images, 29
 - optical lever method, 28
 - surface height images, 27
 - three different AFM settings, 27f
 - TR mode, 28
 - TR mode II, 29
 - various operating modes of AFM for surface imaging, 28t
- surface potential studies using AFM-based Kelvin probe microscopy, 29–30
- first pass of Kelvin probe technique, 30
 - macroscale tribological characterization using friction test apparatus, 33–35
 - nanoscratch, 31–32
- in situ* tensile deformation characterization using AFM, 32–33
- F**
- Failure modes of various hair samples, 88t
- Fiber
- failure, 33, 81, 88t, 89
 - inner hair fiber composition, 6
 - keratin, 25, 50, 78–79, 89, 164
 - structure and cuticle sublamellar structure, 2f
- Flat-on-flat tribometer, 33, 91
- Force–volume (FV), 37–38, 105–106
- Fourier transform infrared spectroscopy (FTIR), 137
- Friction and wear studies of various hair, 91–94
- coefficient of friction measured
 - from bundle of hair sliding, 91, 92f
 - from hair strands, 91, 92f
 - coefficient of friction of polyurethane film
 - vs. Caucasian virgin/treated hair at dry/wet conditions, 92, 93f
 - vs. Caucasian virgin/treated hair/hair vs. hair, 92, 93f
 - vs. chemo-mechanically damaged, 94f
 - vs. various Caucasian virgin, 94, 94f
 - vs. virgin and virgin treated Caucasian hair during wear test, 94, 95f
 - vs. virgin Caucasian hair, 93f
 - vs. virgin treated hair, 94f
 - effect of normal load/velocity/film size, 92–94, 93f
 - hair–hair interaction, 91–92
 - macroscale hair friction, 94
 - optical micrographs
 - of virgin and virgin treated Caucasian hair before/after wear test, 95f
- Friction force microscopies (FFM), 21–24, 50, 99, 107, 108, 125, 135
- Friction/temperature/humidity, effects, 95–97
- on coefficient of friction of polyurethane film
 - vs. virgin and virgin treated Caucasian hair, 95–97, 96f
- H**
- Hair structure
- cellular sublamellar structures in cuticle, 48
 - cross section of hair, 45
 - images of virgin Caucasian hair, 46f
 - longitudinal section, 45–48, 47f
 - macrofibril, 48
- Hair types, treated with various conditioner matrices, 117–122
- adhesive force maps
 - for Caucasian chemically damaged hair, 118–120, 119f
 - histograms, 119f, 120
 - plots, 121f
 - coefficient of friction, 121f
 - and adhesion for various hair treatments, 122t
 - surface roughness and friction force images
 - maps of Caucasian chemically damaged hair, 118, 118f
 - plots, 121
- Hardness, Young’s modulus and creep, 57–68
- cross section, 63–64
 - hardness and elastic modulus, 64, 65f, 66t
 - effect of humidity and temperature, 64–68, 66f, 67f
 - treated hair samples at different temperatures, 68f
 - hair surface, 57–63
 - creep displacement vs. time curves, 61, 62f, 63f
 - hardness and elastic modulus of virgin/chemo-mechanically damaged/virgin treated hair, 62f

- hardness and elastic modulus
 - vs. indentation depth, 58, 59f
 - image of indents on hair surface made using nanoindenter, 58f
 - load–displacement curves, 59f
 - Nano Indenter II system, 57
- Hertz analysis, 39, 137
- Hookean region, 78
- I**
- In situ* tensile deformation studies on human hair using AFM
- characterization using AFM, 32–33
 - beam-type strain gauge force sensor, 33
 - setup used to conduct *in situ* tensile testing, 32f
 - stage motion, 32
 - effect of ethnicity on tensile deformation, 81–82
 - AFM topographical images and 2D profiles, 83f
 - African hair cuticle, 82
 - mechanical properties of ethnic hair, 82t
 - stress–strain curves, 81
 - effect of soaking on tensile deformation of Caucasian virgin/damaged/treated hair, 82–85
 - Coulombic interaction bonds in α -helix, 85
 - mechanical properties of unsoaked and soaked Caucasian hair, 84t
 - stress–strain curves, 84
 - fatigue studies of Caucasian virgin/damaged/treated hair, 85–88
 - effect of soaking on hair morphology, 86f
 - mechanical properties of fatigued Caucasian hair, 87t
 - stress–strain curves, 87f
 - tensile deformation of Caucasian virgin/damaged/treated hair, 78–80
 - AFM topographical images and 2D profiles, 80f
 - comparing mechanical damage and chemical damage, 79
 - images of chemically and mechanically damaged hair, 79, 80f
 - stress–strain curves for five types of hair, 78f
- K**
- Kelvin probe microscopy
- nano-Kelvin probe, 23
 - surface potential studies using, 153–169
 - latex, effects physical wear/rubbing, 153–158
 - rubbing load on nanoscale charging characteristics, effects, 163–168
 - voltage/humidity, effect of external, 158–163
 - surface potential studies using AFM-based, 29–30
 - first pass of Kelvin probe technique, 30
 - macroscale tribological characterization using friction test apparatus, 33–35
 - nanoscratch, 31–32
 - in situ* tensile deformation characterization using AFM, 32–33
- Keratin**
- fiber, 25, 50, 78–79, 89, 164
 - α -keratin to β -keratin, 78, 78f, 81, 89
 - layer, 9–10
 - non-keratinous protein, 7, 58
 - protein, 1, 3t
- L**
- Latex, effect of physical wear/rubbing, 153–158
- after rubbing data, 154
 - before rubbing data, 154
 - chemically damaged treated (amino) hair samples, 156–157, 157f
 - mechanically damaged hair, 157–158, 158f
 - natural latex finger cot, 153
 - surface potential, measurement, 153
 - virgin and virgin treated hair samples, 154–156, 154f–156f
 - wear scars, 153
- M**
- Macroscale tribological characterization
- friction/wear studies of various hair, 91–94
 - temperature/humidity on hair friction, effects, 95–97
 - using friction test apparatus, 33–35
 - schematic of reciprocating tribometer, 34f
 - simulating wet conditions, 35
- Melanin, 1, 3t
- 18-Methyl eicosanoic acid (18-MEA), 3, 3t, 4, 4t, 141–142
- Microfibrils, 6
- Micro/nanotribological characterization using AFM, 35–41
- adhesive force measurements, 36
 - conditioner thickness, 38–41
 - force calibration plot for Caucasian virgin hair, 37

- force calibration plot for commercial conditioner-treated hair, 40f
- interactions between AFM tip/conditioner on cuticle surface, 36f
- region around AFM tip/conditioner/hair surface, 39f
- relative humidity/temperature/soaking/durability measurements, 38
- specimen mounting, 35
- surface roughness/friction force/adhesive force measurements, 35–37
- Young's modulus of sample, 39–40
- Multi-scale tribological characterization, 91–136
 - macroscale tribological characterization friction/wear studies of various hair, 91–94
 - temperature/humidity on hair friction, effect of, 95–97
 - nanotribological characterization using AFM
 - skin, 122–124
 - various ethnicities, 97–107
 - various hair types treated with various conditioner matrices, 117–122
 - virgin and chemically damaged Caucasian hair, 108–113
 - scale effects
 - on coefficient of friction/adhesive force of various hair, 127–134
 - directionality dependence of friction, 124–127
- N
 - Nanomechanical characterization using nanoindentation, 30–32
 - coefficient of friction, 31
 - effect of soaking on hair, 32
 - nanoindentation, 30–31
 - Nanoscale rubbing load, effects
 - Co/Cr-coated conducting Si tapping mode tip, 163
 - conditioner treatments, 168
 - damaged hair, 165
 - virgin hair, 163–165
 - voltage-biased tip, 163
 - Nanoscratch
 - on multiple cuticle cells, 70–75
 - coefficient of friction and scratch depth profiles, 69f
 - reduction in scratch depth/post-scratch depth, 69
 - on single cuticle cell, 68–69
 - chemo-mechanically damaged Caucasian/Asian hair after scratch, 72f
 - coefficient of friction and scratch depth profiles/SEM images, 70f, 71f–72f
 - directionality effect, 72
 - surface profiles observation, 71–72
 - various failure mechanisms, 74f
- Nanotribological characterization using AFM
 - hair types treated with conditioner matrices, 117–122
 - skin, 122–124
 - various ethnicities, 97–107
 - virgin and chemically damaged Caucasian hair, 108–113
- Non-keratinous protein, 7, 58
- P**
 - PDMS silicone-based conditioners, 17t, 41t, 42–43, 118, 120, 122t, 135, 138–139, 145, 150, 156, 166f, 168–169
 - Polyurethane film (simulated skin), 33–35, 41t, 91, 92f, 93f, 94, 94f, 95f, 96f
- R**
 - Relative humidity (RH)
 - amino silicone conditioner and, 162–163
 - on hair friction, 34–35, 95
 - temperature/soaking/durability measurements, AFM, 38
 - virgin and chemically damaged Caucasian hair, 113–114, 114f
 - Roughness, surface
 - of chemo-mechanically damaged hair, 97, 98f
 - and friction force images, 108–111
 - and adhesive force measurements, 35–37
 - for Caucasian virgin, 110f
 - for chemically damaged/damaged treated hair, 110f
 - maps of Caucasian chemically damaged hair, 118, 118f
 - plots, 121
 - and slope, Caucasian virgin hair, 107, 108f
 - for virgin treated, 110f
 - and friction images
 - for chemo-mechanically damaged hair, 99, 100f, 102

- for commercial conditioner hair, 99, 101f
 - for virgin, 99, 100f, 102
 - parameters, experimental methods, 22
 - plots, 112–113, 113f, 113t
 - skin
 - and friction force images for collagen and polyurethane films, 122, 123f
 - parameters σ and β^* for collagen/polyurethane films/skin, 122, 124t
 - of virgin, 97, 98f
- S**
- Samples, hair and skin, 41–43, 41t
 - collagen film, 42
 - conditioner–skin contact in AFM experiments, 43
 - contact angle and surface energy of hair, 42t
 - simulating conditioner–skin contact, 43
 - Wilhelmy balance method, 43
 - Scale effects
 - adhesive force comparison
 - micro/AFM tips/force calibration plot technique, 128f–129f
 - of virgin and virgin treated hair, 128f–129f
 - on coefficient of friction/adhesive force
 - of various hair, 127–134
 - for Caucasian virgin, 130f, 131
 - for chemically damaged, 130f, 131
 - for damaged treated, 130f, 131
 - force calibration plots, 129
 - hair–conditioner–tip interaction, 129
 - for macro-/micro-/nanoscales, 127–131, 133–134, 133f
 - macroscale coefficient of friction (COF) data, 131
 - for virgin treated, 130f
 - directionality dependence of friction
 - on macroscale, 125, 126f, 127
 - on microscale, 125, 127, 127f
 - on nanoscale hair friction, 125–127
 - on various scales, 126f
 - friction force vs. normal force curves
 - for chemically damaged hair, 128f–129f, 129
 - for damaged treated hair, 128f–129f, 129
 - for micro/nanoscale coefficient of friction of Caucasian virgin, 128f–129f, 129
 - for virgin treated hair, 128f–129f, 129
 - microscale coefficient of friction data
 - for Caucasian virgin, 126f
 - for chemically damaged hair, 126f
 - for damaged treated hair, 126f
 - for virgin treated hair, 126f
 - virgin Caucasian hair friction on various scales, 125, 126f
 - Scanning electron microscope (SEM), 4, 4f, 5, 6f, 7f, 9f, 21–23, 24f, 45, 54–56, 63, 70–73, 70f, 71f, 125
 - Scratch resistance
 - nanoscratch on multiple cuticle cells, 70–75
 - coefficient of friction and scratch depth profiles, 69f
 - reduction in scratch depth/post-scratch depth, 69
 - nanoscratch on single cuticle cell, 68–69
 - chemo-mechanically damaged
 - Caucasian/Asian hair after scratch, 72f
 - coefficient of friction and scratch depth profiles/SEM images, 70f, 71f–72f
 - directionality effect, 72
 - surface profiles observation, 71–72
 - various failure mechanisms, 74f
 - soaking effect, 75–76
 - coefficient of friction and scratch depths
 - of Caucasian (unsoaked and soaked) and Asian (unsoaked) hair, 76t, 77t
 - comparison of nanoscratch results, 75f–76f
 - Shampoo, constitution and main functions, 13–15
 - aesthetic additives, 14
 - cleansing agents, 13
 - components of common shampoos and functions, 14t
 - conditioning agents, 14
 - dandruff, treatment of, 15
 - functional additives, 14
 - medically active ingredients, 15
 - modern shampoos, 13
 - preservatives, 14
 - surfactant molecules, 14
 - Skin, 7–10, 122–124
 - coefficient of friction, 121f
 - values for collagen and polyurethane, 122, 124, 124f
 - epidermal hyperplasia, 10
 - feel of hair, 7
 - human skin structure with different layers, 10f

- keratin-rich corneocytes, 9–10
 surface roughness
 and friction force images for collagen
 and polyurethane films, 122, 123f
 parameters σ and β^* for collagen/
 polyurethane films/skin, 122, 124t
 water, 10
- Soaking
 coefficient of friction and scratch depths
 of Caucasian (unsoaked and
 soaked) and Asian (unsoaked) hair,
 76t, 77t
 in de-ionized water, 115–116
 of Caucasian virgin, 116f
 of chemically damaged hair, 116f
 of damaged treated hair, 116f
 effect on hair morphology, 86f
 effect on hair nanotribological and
 nanomechanical properties, 32
 effect on tensile deformation of Caucasian
 virgin/damaged/treated hair,
 82–85
 and relative humidity/temperature/
 durability measurements, AFM, 38
- Structural characterization using AFM,
 26–29
 cantilever–tip assembly, 28–29
 contrast in TR amplitude and phase angle
 images, 29
 optical lever method, 28
 surface height images, 27
 three different AFM settings, 27f
 TR mode, 28
 TR mode II, 29
 various operating modes of AFM for
 surface imaging, 28t
- Surface forces apparatus (SFA) experiments,
 139, 148
- Surface potential studies using AFM-based
 Kelvin probe microscopy, 29–30
 first pass of Kelvin probe technique, 30
 macro-scale tribological characterization
 using friction test apparatus, 33–35
 nanoscratch, 31–32
in situ tensile deformation characterization
 using AFM, 32–33
- T**
- Transmission electron microscope (TEM), 7,
 9f, 21, 23, 24t, 45, 48, 54, 56
- Tribology, 11, 21–22, 91
 TR mode II technique, 48, 50
- V**
- van der Waals attractive force, 138–139
 Virgin and chemically damaged Caucasian hair
 adhesive force maps, 115
 variations in adhesive force on cuticle
 surface, 112f
 adhesive force plots, 112–113, 113f, 113t
 coefficient of friction, 112–113, 113f,
 113t
 cuticle surface damage/deposition of
 conditioner, effects, 108, 109f
 durability study of friction force,
 116–117, 117f
 relative humidity on nanotribological
 properties, 113–114, 114f
 soaking in de-ionized water, 115–116,
 116f
 surface roughness and friction force
 images, 108–111, 110f
 surface roughness plots, 112–113,
 113f, 113t
 temperature on nanotribological properties,
 114–115
 with and without commercial conditioner
 treatment, 108–113
- Virgin hair, 99, 163–165
 virgin and virgin treated hair samples,
 154–156, 154f–156f
 with voltage-biased tip at two different
 normal loads, 163–164, 164f
 bar charts of change in surface potential,
 164–165, 165f
- Voltage/humidity, effect of external, 158–163
 chemically damaged treated (amino
 silicone) hair samples, 161f–162f,
 162–163
 chemically damaged treated hair samples,
 159–162, 159f–160f
- W**
- Wave treatment, 11, 18, 41
 Wear studies of various hair, *see* Friction
 and wear studies of various hair
- Y**
- Young's modulus mapping, effective, 144–147
 amino silicones, 150
 biolubrication studies, 151
 of chemically damaged hair surface, 147
 and damaged treated hair samples, 148f
 of conditioner-treated hair surface, 145,
 147–149
 and film thickness/adhesive force, 148t
 force calibration plot, 144

physisorbed/bound conditioner,
comparison, [149](#), [150f](#)
of silicones (PDMS), [150](#)
soft bound silicone layer and stiff hair
surface, [150](#)

tip-sample separation for hair
samples, [144–145](#), [146f–147f](#)
van der Waals attractions,
[149–150](#)
of virgin hair surfaces, [149](#)

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 (NLB²) 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

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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.

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