African-American Hair Damage Study

Diana Tang, PhD

The L'ORÉAL Institute for Ethnic Hair and Skin Research, Chicago, IL

Introduction

Hair fragility is a major concern to most people of African decent due to frequent chemical treatments, thermal appliance use and environmental exposure. It is extremely important to both cosmetic scientists and African-American consumers to understand the internal and external hair damage caused by these factors.

Hair damage, such as internal chemical bonding distortion, loss of mechanical tensile properties and hair cuticle surface disruption, can be characterized by internal and external surface changes. Both internal and external disruption to hair can occur when hair is impaired. Since the mechanisms and degrees of the damage may vary from different practices, several types of instrumental measurements are required. The characterization and quantification of African-American hair properties with respect to morphological, physical and chemical characteristics by various instrumental techniques will be discussed in this presentation.

Instrumental Techniques

1. Field-Emission Scanning Electron Microscopy of Hair Surface Morphology

Hair is known to undergo changes in morphological, physical, and chemical characteristics after chemical treatments and mechanical impact. Field emission scanning microscopy (FESEM), Hitachi FEG SEM S-4700, was used to monitor the hair fiber surface morphological changes after the hair has been relaxed, colored, and heated with a blow dryer.

The use of FESEM for hair fiber study other than the conventional SEM has advantages such as: 1). FESEM produces clearer, less electrostatic distorted images with spatial resolution down to 1-2 nm, that is at least 4 times better than conventional SEM; 2). Low voltages and non-coating is utilized in FESEM, while the coatings of 5-10 nm with high voltages in conventional SEM lead to an inferior image due to the artifacts.

The surface morphological characterization and topographic details of virgin and chemical treated hair was determined by FESEM and will be discussed

during the presentation.

Figure 1. SEM Images of Different Hair Types

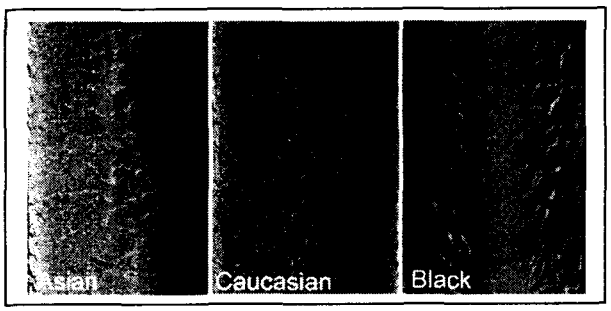
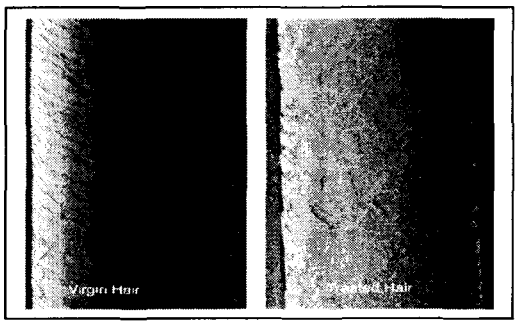


Figure 2. SEM Images of Damaged Hair



2. Tensile Properties by Single Fiber Tensile Testing

Single fiber tensile analysis was performed using a Dia-Stron Miniature Tensile Tester. Before the fiber tensile analysis, the cross sectional area of each fiber was measured by a Laser Fiber Dimensional Analysis System. Hair fibers were then extended using the MTT600 automated tensile tester. A typical force load extension curve of a single hair fiber is demonstrated in Figure 1.

Figure 3. Typical Load Elongation Curve

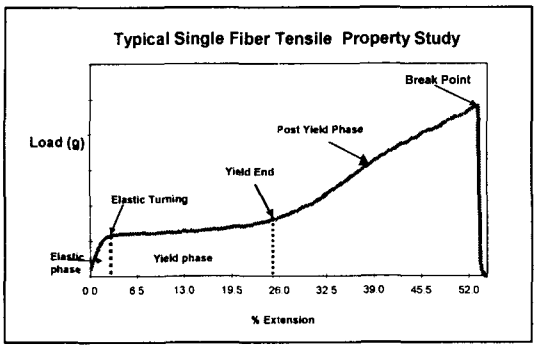
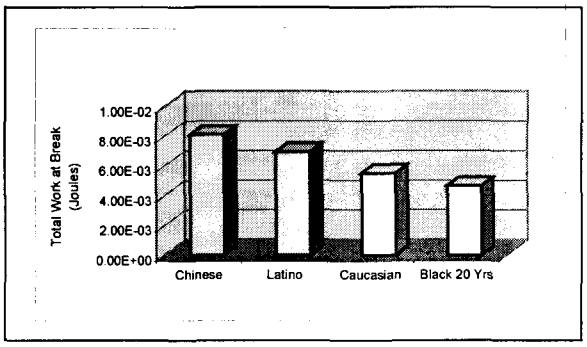


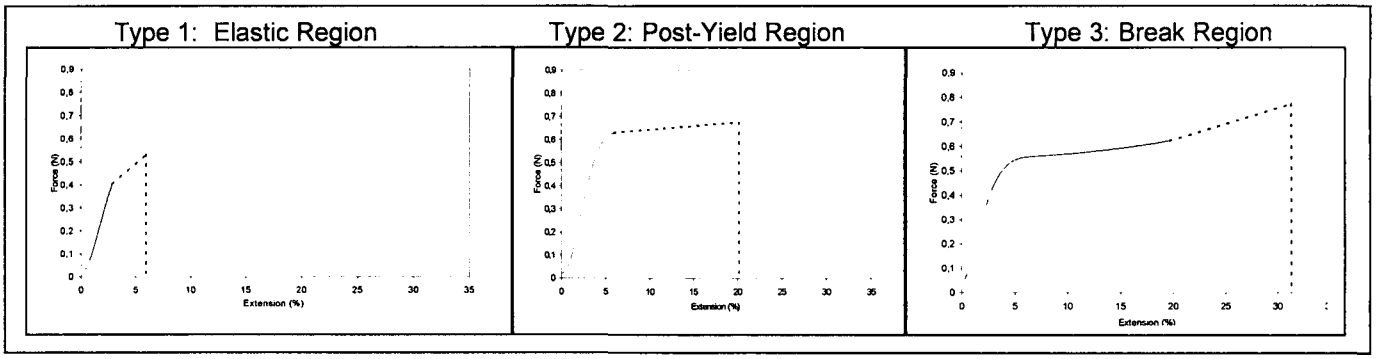
Figure 4. Tensile Property Measurement



The most important parameters in above tensile elongation curve are tensile strength and post yield gradient. The tensile strength is the stress required to break the hair fiber and the magnitude of the post yield modulus reflects the number of intact disulfide linkages in the hair fiber. It is evident that the tensile strength of different types of virgin hair is different: because of the unique structure configuration and morphological properties, Black hair exhibits the weakest tensile strength in comparison to any other ethnic groups. In addition, the African-American hair fragility can be observed by their "Premature" tensile profile.

In addition to the hair tensile strength, the fragility of African-American hair can also be characterized by the premature breaking pattern from the fiber elongation curve. From Figure 5, it was found that about 25% of African-American hair imparts a fragile mechanical character in the type 1 and 2 of premature breaking phase.

Figure 5. Premature Breaking Patterns of Black Hair



The mechanical tensile properties and internal disulfide bond linkage by various chemical treatments of Black hair are exhibited Figures 7 and 8.

Figure 7. % Reduction of Disulfide Bond

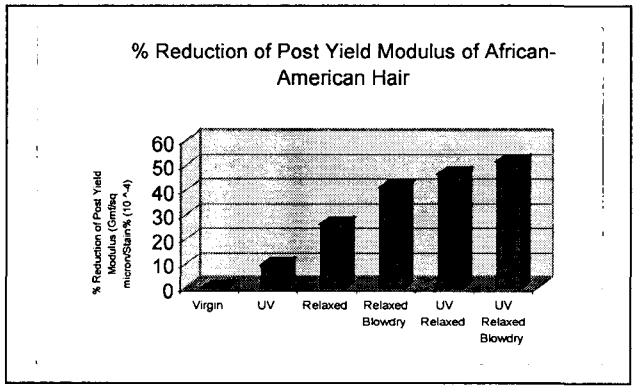
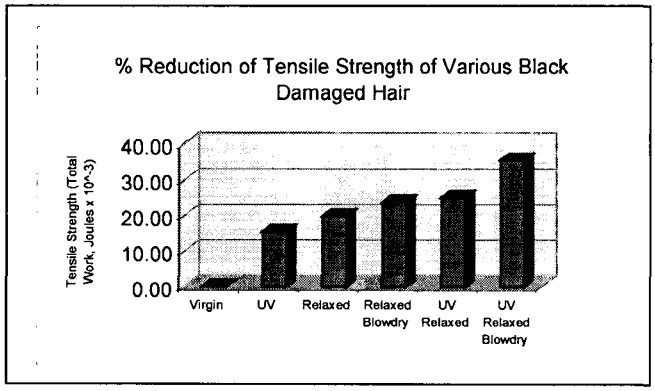


Figure 8. % Reduction of Tensile Strength



3. Hair Fatigue Analysis

Cyclic fatigue testing is used to simulate the repeated tensile stress that occurs while combing and brushing. Cyclic fatigue data and survival probability, present both internal fiber flaws and external cuticle layer rupture. In other words, cyclic fatigue testing provides a unique instrumental tool to demonstrate the progressive levels of impaired hair fibers. Each hair fiber of a sample has certain flaws of varying magnitude, which under accumulated stress will initiate the failure. Fibers with relatively large flaws probably will break at lower

numbers of cycles of applied stress than fibers with minor defects. The distribution of the failure cycles, x, of the hair fibers of a given sample can be represented using the Weibull probability of failure distribution:

$$F(x) = 1 - e^{-\left(\frac{x}{\alpha}\right)^{\beta}}, for: x > 0$$

The basic theory of cyclic fatigue test, the calculation of characteristic life and survival probability of various chemically damaged hairs in comparing with virgin hair will be discussed during the presentation.

Conclusion

African-American hair is naturally more fragile than other ethnicities because of its unique structure and morphological characteristics. Furthermore, African-Americans often utilize chemical treatments, especially chemical relaxing, for better hair manageability. Different types of chemical treatments cause different degree of hair breakage. Understanding the damaging effect of any given factors provides an accurate assessment of hair morphological, physical and chemical alterations caused by those factors.