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Comprehensive Nano-Mechanical and Tribological Characterization of Hair

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ABSTRACT

This paper presents test procedures and results of tribological and mechanical characterization of hair, treated with various shampoo and conditioners. They allow for a comprehensive functional comparison of hair care products.

INTRODUCTION

Mechanical and tribological analysis of human hair may provide dermatologists with several markers of considerable diagnostic importance. In cosmetic research, such analysis is important to understand how shampoo and conditioners affect the hair [1].

In this work, we developed tests to differentiate and optimize functional properties of common hair care products such as shampoos, conditioners and dyes.

A quantitative analysis of tribological and mechanical properties of hair has been performed on the Universal Nano+Micro Tester UNMT-1. Its nano-analyzer module allows for measurements of Young's modulus and hardness of hair in all directions, with precision positioning on different hair areas, such as cortex (melanocyte) and periphery (inner sheath and fibrous sheath) [2, 3]. Its tribology module allows for sensitive testing of hair tribology in both a cross-hair mode (between two perpendicular hair tresses) and a sledging mode (between a tress of hair and a counter-material), with a servo-controlled down-force. The tribology and nano-analyzer modules are easily interchangeable.

NANO-MECHANICAL DATA

The study was performed on a European blonde hair, untreated and dyed, both impregnated in an epoxy matrix.

As shown in Figure 1, the measurements were done in the longitudinal and transverse directions, the latter to distinguish the properties of the cortex and hair periphery. Figure 2 shows topographical images of the smoother untreated and rougher dyed hair.

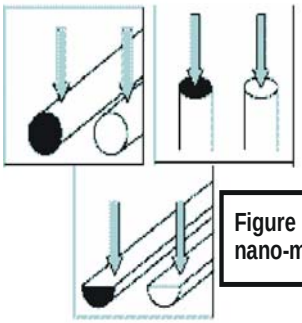

Figure 1. Schematics of nano-mechanical hair analysis;

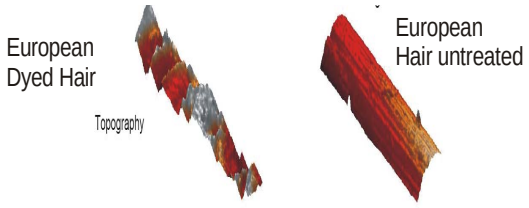

Figure 2. Topographical images of hair

Figure 3 shows stiffness maps of the untreated and dyed hair, where the former one was softer and more uniform.

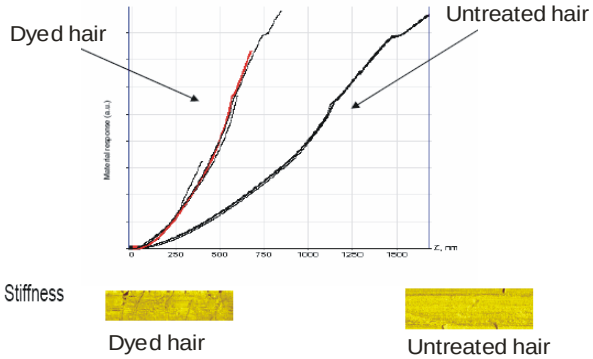

Figure 3. Stiffness maps and raw data plots for hair

Figure 4a shows an optical image of the epoxy matrix with impregnated hair. Figure 4b shows the simultaneously-obtained topographical and stiffness maps. A noticeable difference in stiffness between the core and the outer periphery of the hair is confirmed with the numerical data in Figure 4c.

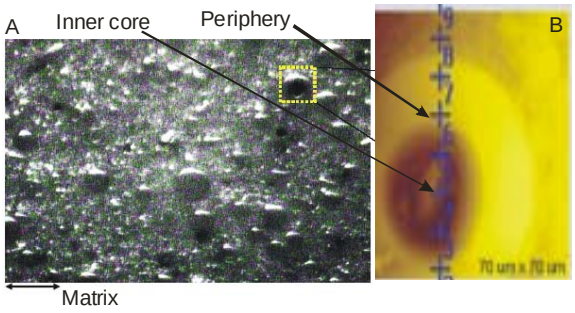

Figure 4. (a) Optical image of matrix with hair; (b) Hair stiffness map with indentation positions

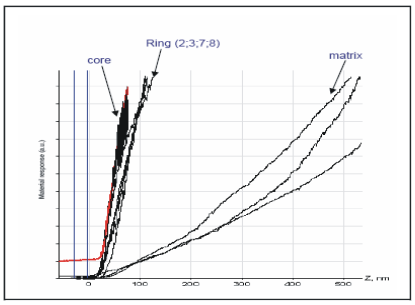

Figure 4c. Young's modulus data for hair

FRICTION DATA

Cross-hair tests were done using the UNMT setup in Figure 5. A pair of cross-hair holders was used to mount two tresses of hairs, each of 10 hair strands. The applied load was 100 mN, sliding speed was 0.5 mm/s.

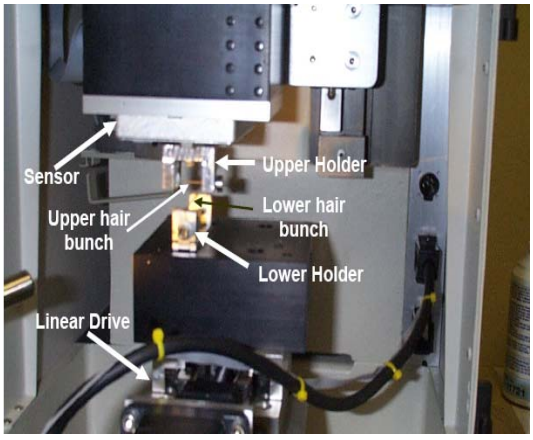

Figure 5. Cross-hair friction test

Table 1 shows the coefficient of friction (COF) data on the hair treated with four different products. The coefficient of friction was the lowest after treatment with Pantene ProV and the highest after Pantene 2-in-1.

Sledge friction tests were done against a silicon counter-surface as presented in Figure 6, under a constant load of 300 mN at the same sliding speed of 0.5 mm/s.

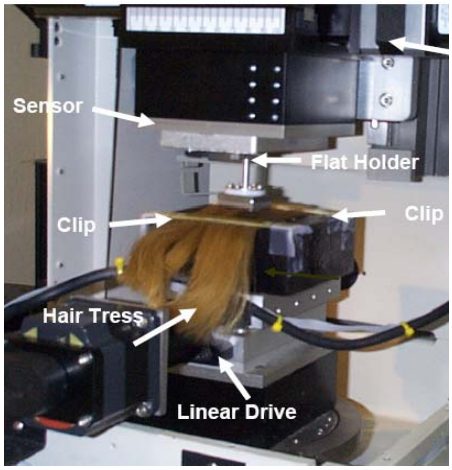

Figure 6. Sledging friction test of hair

Table 1: Cross-hair friction data on hair pre-washed and treated with hair conditioners

Hair Conditioner	Sample #	COF						
		Test 1	Test 2	Test 3	Test 4	Test 5	Mean	SD
Pantene ProV *Sheer Volume*	#1	0.070	0.066	0.065	0.064	0.063	**0.066**	0.003
	#2	0.069	0.064	0.062	0.061	0.061	**0.063**	0.003
Dove *Extra Volume*	#1	0.088	0.080	0.079	0.079	0.078	**0.081**	0.004
	#2	0.078	0.079	0.074	0.073	0.072	**0.075**	0.003
White Rain *Extra Body*	#1	0.105	0.099	0.096	0.101	0.098	**0.100**	0.003
	#2	0.090	0.090	0.090	0.091	0.093	**0.090**	0.001
Pantene 2-in-1 *Shampoo*	#1	0.099	0.098	0.099	0.102	0.104	**0.120**	0.002
	#2	0.115	0.115	0.117	0.119	0.124	**0.117**	0.004

Table 2 summarizes the sledge friction test data. Though the friction levels in the sledge tests were different from those of the cross-hair tests, the effects of conditioners were similar, with the Pantene ProV leading to the lowest friction and the Pantene 2-in-1 shampoo revealing the highest friction

Table 2: Sledge friction data on untreated hair pre-washed and treated with hair conditioners

Hair Conditioner	Hair Tress	COF						
		Test 1	Test 2	Test 3	Test 4	Test 5	Mean	SD
Pantene ProV *Sheer Volume*	#1	0.174	0.171	0.171	0.165	0.167	0.169	0.003
Dove *Extra Volume*	#1	0.191	0.184	0.181	0.180	0.181	0.183	0.004
White Rain *Extra Body*	#1	0.211	0.195	0.186	0.180	0.186	0.191	0.012
Pantene 2-in-1 *shampoo*	#1	0.233	0.227	0.222	0.221	0.220	0.225	0.005

CONCLUSIONS

A nano-mechanical analysis showed the untreated hair to be more homogeneous and more compliant than the dyed hair.

A tribological analysis showed the Pantene ProV to be more effective in reducing friction than the other hair care products tested.

The UNMT-1 is capable of comprehensive mechanical and tribological hair characterization.

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