Understanding the Effect on Hair Fibers of Coloring and Bleaching Formulations Using High Pressure Differential Scanning Calorimetry (HPDSC)

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High Pressure Differential Scanning Calorimetry (HPDSC) can be used to gain information on both the degree of crystalinity in the intermediate filaments (IF's) and the structural rigidity of the surrounding matrix or intermediate filament associated proteins (IFAP) of the hair cortex. A decrease in the peak denaturation temperature may result from either a change in crystalline material amount or integrity, or changes in viscosity of the matrix (IFAP's), particularly in the wet state.

We have used HPDSC to measure changes in denaturation temperature (T_d) of the crystalline components after treatment with retail colorant and bleach products. We also attempted to correlate these changes with the degree of lightening from these products (dL) and their tensile strength.

We have demonstrated that a decrease in the HPDSC peak temperature after treatment from a hair colorant or bleach is due to a combination of two effects:
(1) Oxidative breakdown of the keratin protein matrix covalent bonds. This change is permanent.
(2) Addition to the hair of formulation components such as salts, surfactants or alkalisers that change the electrostatic environment in the matrix proteins. This change is to some extent reversible either by repeat washing cycles or dialysis in deionised water.

Results

Our preliminary studies were unable to establish a significant correlation between increasing lightening (dL), tensile strength, and HPDSC denaturation temperature (T_d) for typical retail bleach or color treatments. Chart 1 shows a good correlation between the lightening of the bleach products and their tensile strength but there is no correlation between either lightening or tensile strength and the HPDSC peak temperature data.

Chart 1 - The effect of different retail colorant and bleach formulations containing different oxidant and alkaliser technologies on peak temperature T_d ^0C:-

Product	No. of treatments	Lightening dL	HPSDC Peak temp T_d ^0C	Tensile Strength Data		
				Plateau load Gmf/sq.micron	Load @ 25% Gmf/sq.micron	Break load Gmf/sq.micron
Virgin Hair	Na	na	148.3	0.0064	0.0075	0.0209
Retail Color 1	3	12	145	0.0051 (s)	0.0057 (s)	0.0190 (s)
Retail Color 2	3	12	137	0.0054	0.0065	0.0199 (s)
Retail Bleach 1	3	25	143.8	0.0040 (s)	0.0044 (s)	0.0172 (s)
Retail Bleach 2	3	26.8	138.7	0.0039 (s)	0.0044 (s)	0.0164 (s)

To test our hypothesis that the HPDSC peak temperature is influenced by both permanent changes and reversible changes we first investigated the effect of an alkaliser alone on the HPDSC peak temperature, i.e. no oxidant present. Virgin hair was soaked in an alkaliser solution (0.8M) buffered at pH 10 for 30 minutes, rinsed for 1 minute and then shampooed and rinsed for 2 cycles. The samples were then dialysed in deionised water. Chart 2 shows the results for ammonia and ethanolamine as the alkaliser. The results show that the effect of the alkaliser is to reduce the HPDSC peak temperature significantly but that the result can be reversed on dialysis with deionised water.

Chart 2 - Effect of alkalisers on HPSDC peak temperature

Treatment	HPSDC Peak temperature T_d ^{0}C
Virgin Hair	149.0
+ Ammonium Hydroxide pH 10	143.0
+ Ammonium Hydroxide Dialysed	150.7
+ Ethanolamine pH 10	147.5
+ Ethanolamine Dialysed	150.1

We then looked at the effect on the HPDSC peak temperature of multiple cycles of a bleaching product. 5 repeat cycles of treatment were performed with 10 shampoo cycles between each treatment. Samples were taken at 1, 3 and 5 cycles and dialysed in deionised water.

Chart 3 demonstrates that the HPDSC temperature is composed of a component that is reversible (likely due to incorporation of formulation components such as salts, alkalisers, surfactants etc) and a component that is irreversible (likely due to oxidative breakdown of the keratin covalent bonds).

Chart 3 - Effect of multiple treatment with a bleaching product on HPDSC peak temperature

Treatment	HPSDC Peak temperature T_d ^{0}C
Virgin Hair	149.0
1 cycle bleaching product	143.5
1 cycle + dialysis	149.1
3 cycle bleaching product	137.9
3 cycle + dialysis	145.5
5 cycle bleaching product	134.5
5 cycle + dialysis	135.1