INVESTIGATING PHYSICAL PROPERTIES OF BIOPOLYMERS IN HAIRS

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INTRODUCTION

Hair is of outmost importance for the human body. Hair is composed of 1–8% external hydrophobic lipid epidermis, 80–90% α-helix or β-sheet conformation of parallel polypeptide chains to form water-insoluble keratin, less than 3% melanin pigment, and 0.6–1.0% trace elements, 10–15% moisture (Figure 1) [1]. Keratin proteins are insoluble in water and play a protective role. They possess a heterogeneous morphology that classifies them to the fibrous structural proteins.
We received samples of hair that had undergone treatment with a hair mask prepared by a cosmetic company (Figure 2). The samples were taken in different timelines (table 1) to assess not only the reconstruction of keratin induced by the cosmetic formulation but also the possibility of a long-term effect on the hair.
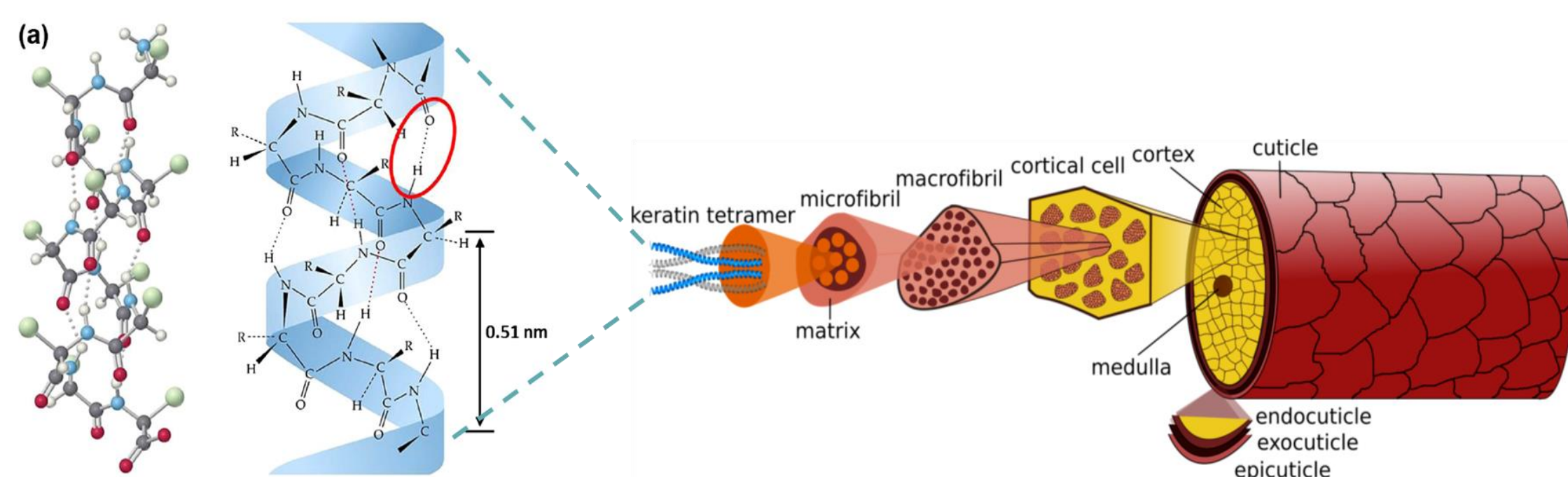

Figure 1. Cross-section of a hair fiber
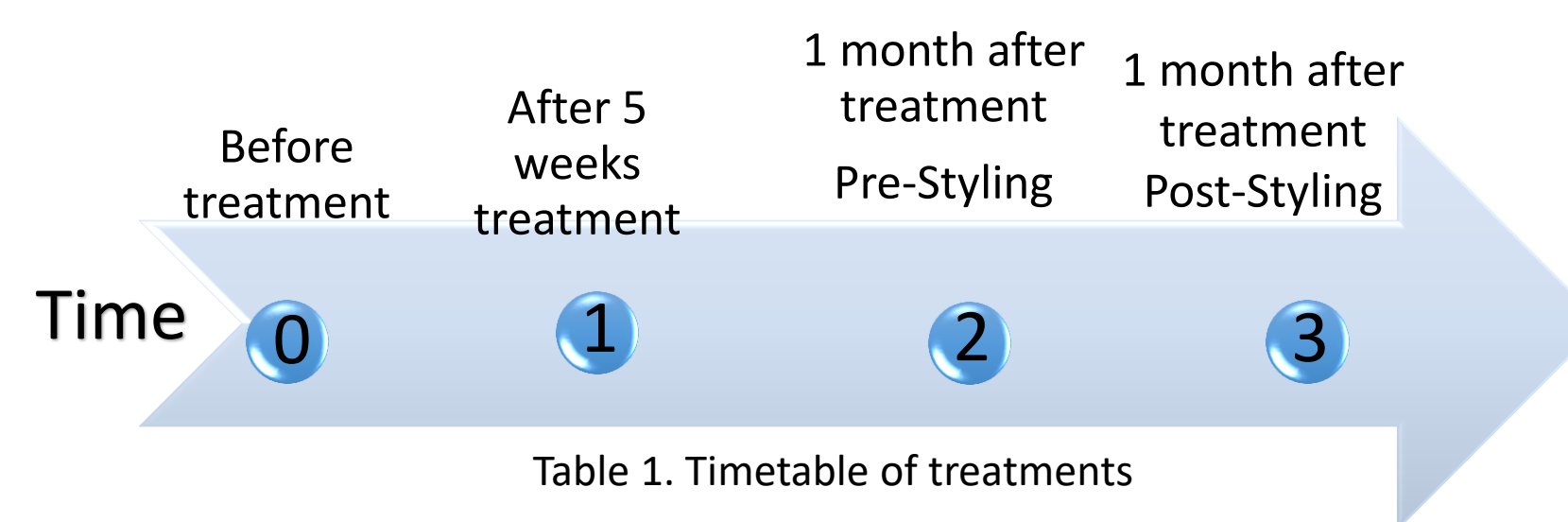

Figure 2. The hair of the models before the treatment

Intech   Bleached   Natural

Table 1. Timetable of treatments

Time: 0 Before treatment; 1 After 5 weeks treatment; 2 1 month after treatment Pre-Styling; 3 1 month after treatment Post-Styling

Main goal: qualitative and quantitative assessment of the reconstructive effect of the cosmetic formulation on keratin

Techniques:

1. SEM-FEG

2. Solid + Liquid NMR

RESULTS

NATURAL HAIR SAMPLE

Solid-state NMR was applied to compare the hair that underwent different treatments. Liquid NMR was used to analyse the lipids extracted from natural hair samples in a chloroform:methanol solution (Figure 3).

A — ¹H-NMR on lipid extracts
B — ¹H-MAS after lipid extraction
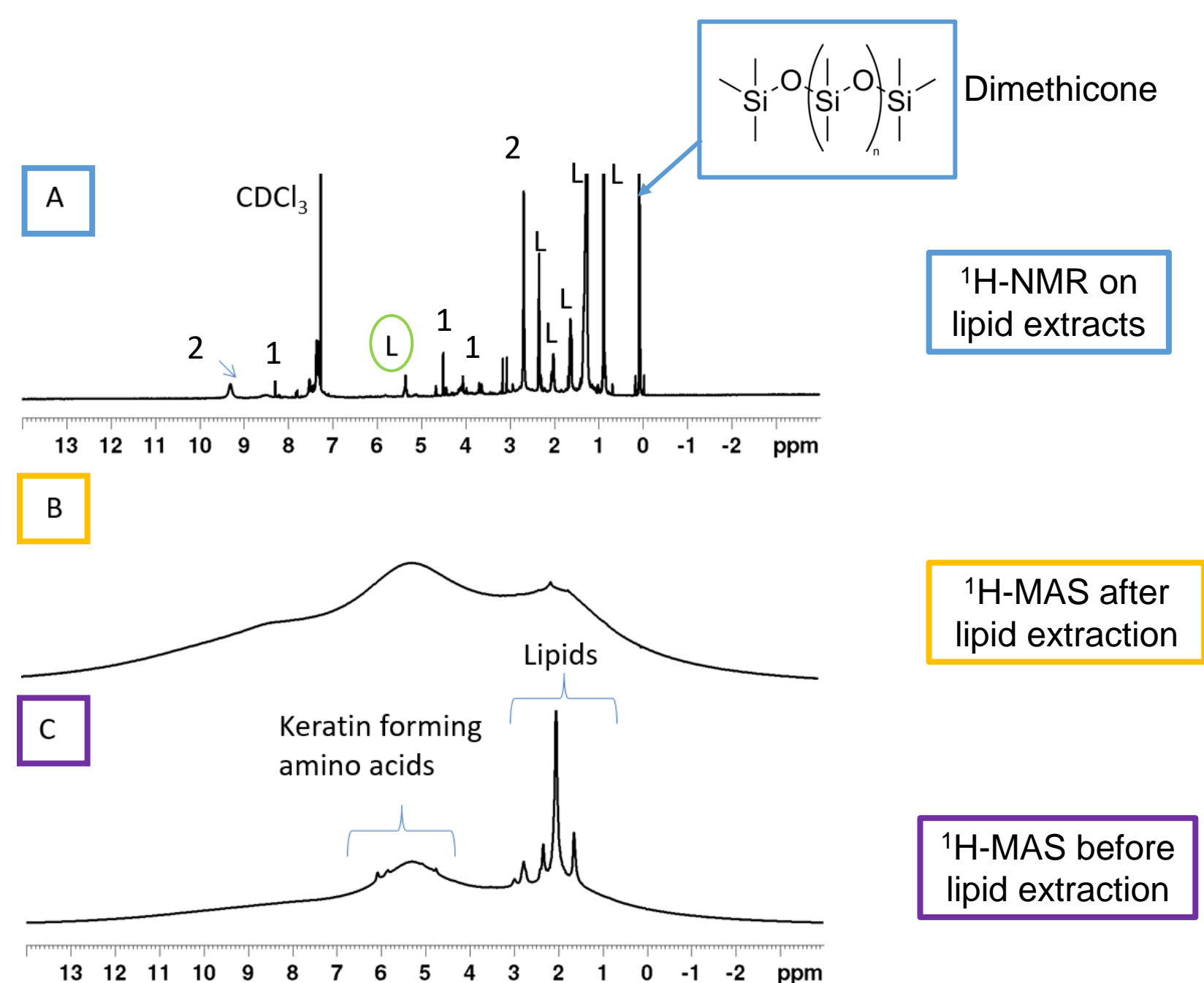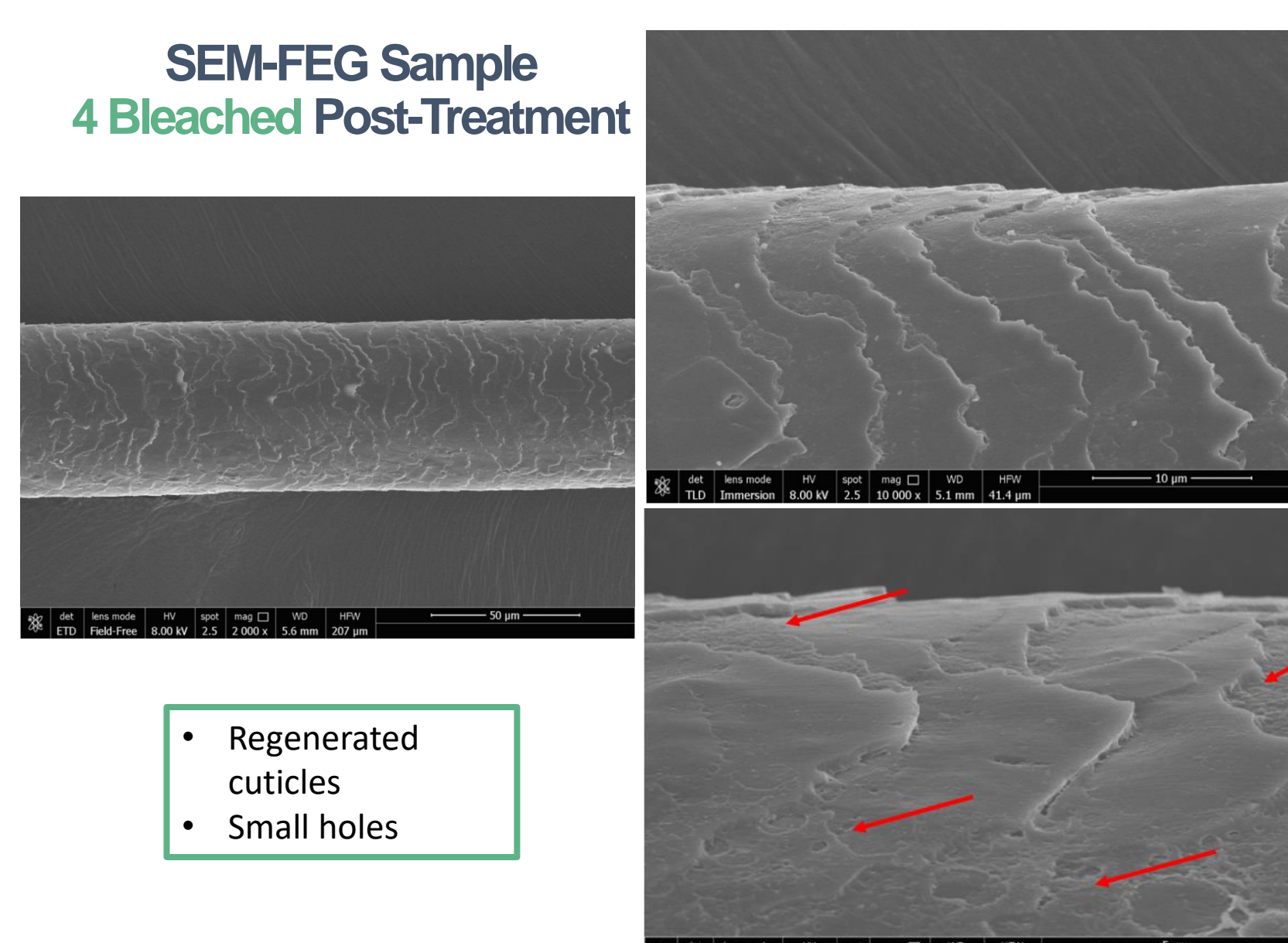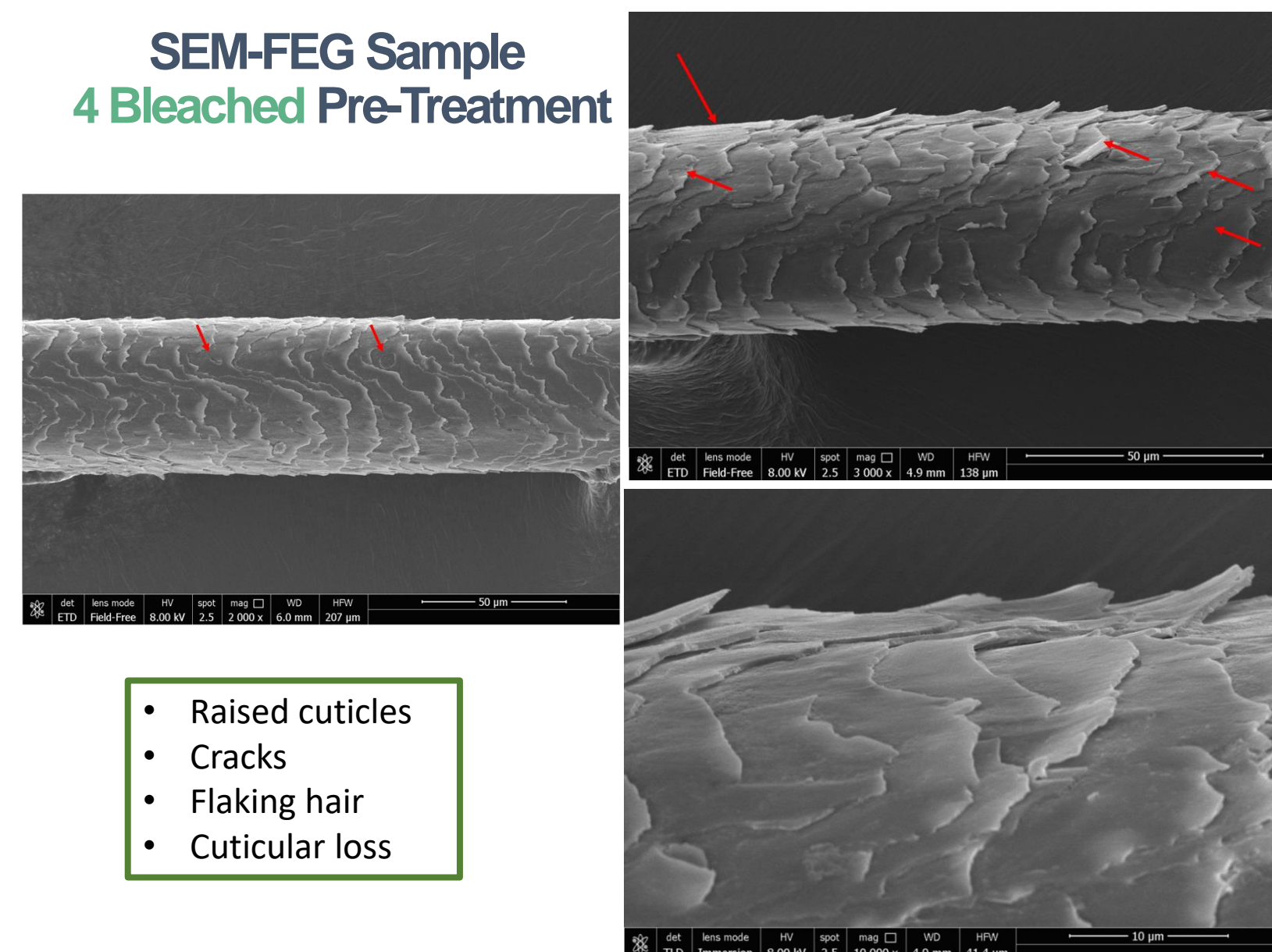C — ¹H-MAS before lipid extraction

Figure 3. (A) ¹H NMR on lipid extracts (1=benzyl formamide, 2=(CH₃)₂NH₂⁺, L=Lipid), (B) ¹H MAS NMR on hair after extraction, (C) ¹H MAS NMR on hair before extraction.

Dimethicone is the most widely used silicone in hair care industry and the main ingredient of the two-in-one shampoos. It is responsible for protecting the hair shaft from abrasive actions while siloxysilicates increase hair body [2]

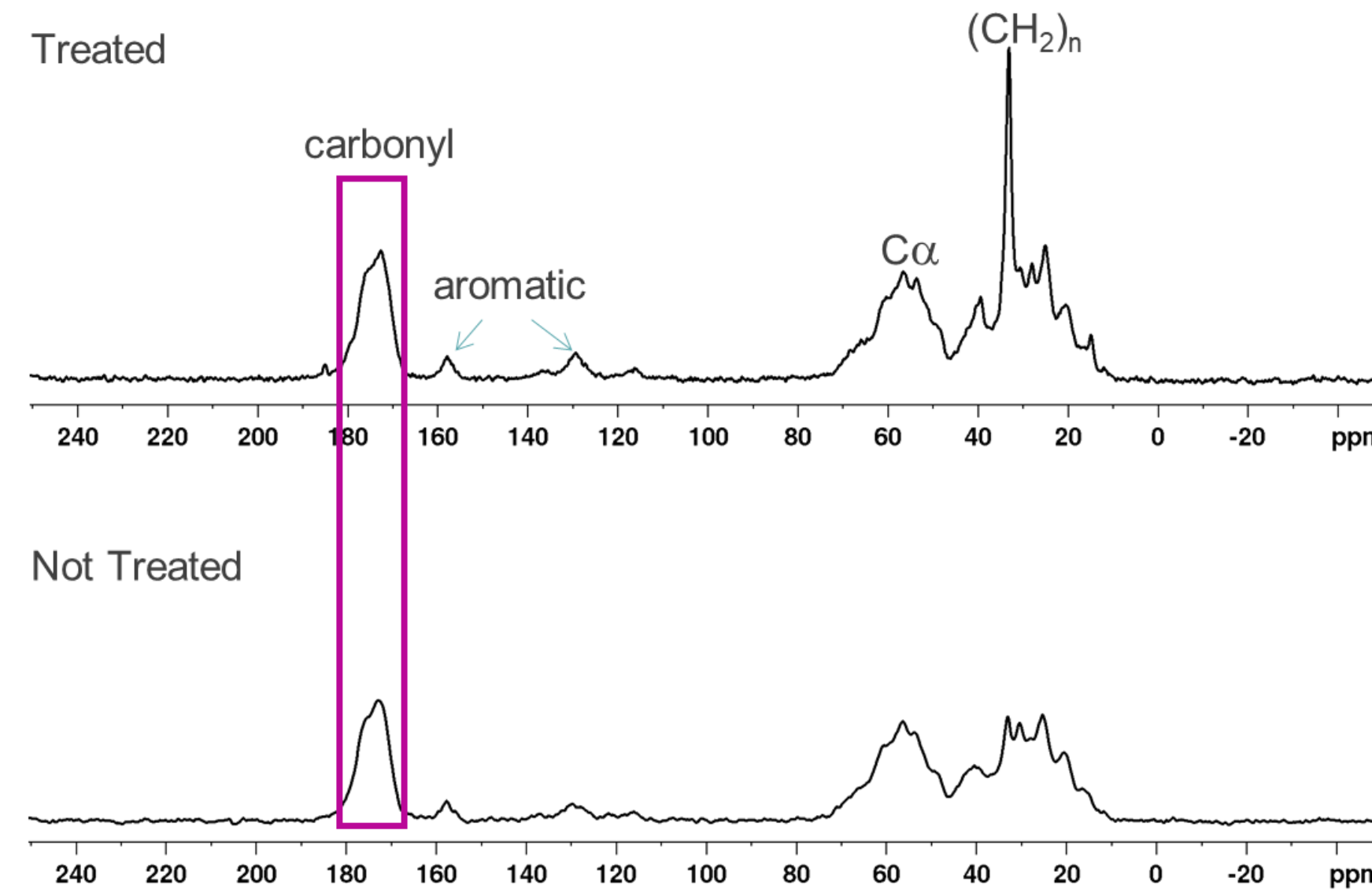### Solid ¹³C CP MAS NMR – Sample 1 Intech

Figure 4. ¹³C CP MAS spectra of Treated and Not Treated samples of Model 1.

In Figure 4 the broad peak from 56 to 42 ppm was indicative of the more open conformation attributed to the α- and β carbon, respectively, present in the leucine residues and crosslinked cysteine. The sharp signal at around 38 ppm present only in the treated spectrum was contributed to lipids.

Sample	Area C=O
Not Treated	25 10⁴
Treated	81 10⁴

Summary of the induced keratin regeneration on Model 1.

Solid ¹³C CP MAS NMR – Sample 7 Natural

- Similar spectra
- Treatment not very effective
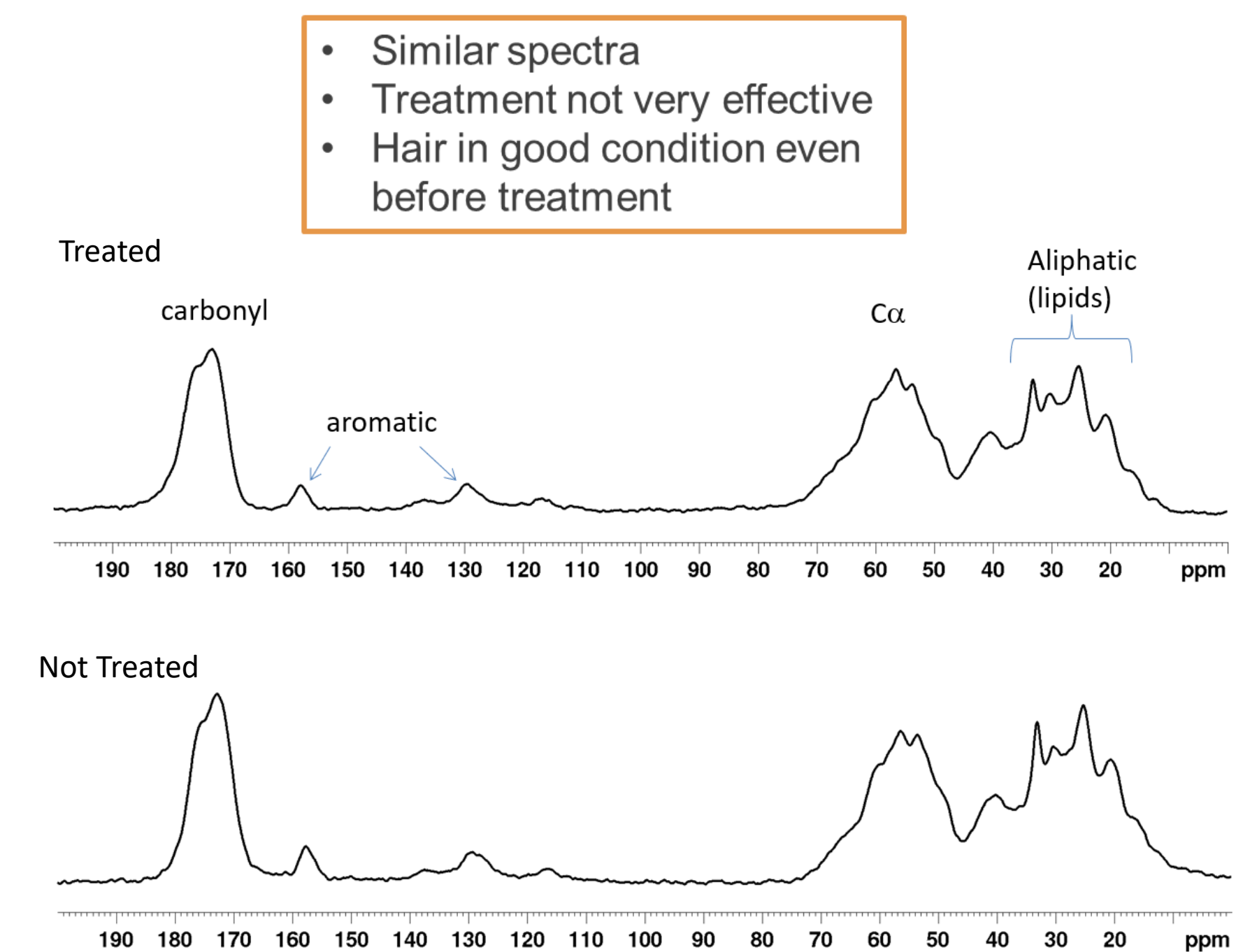- Hair in good condition even before treatment

Figure 5. ¹³C CP MAS spectra of Treated and Not Treated samples of Model 7.

The spectra of Figure 5 before and after the treatment did not display any significant differences, thus the treatment was not very effective on this model. The cosmetic formulation did not induce any distinctive effect.

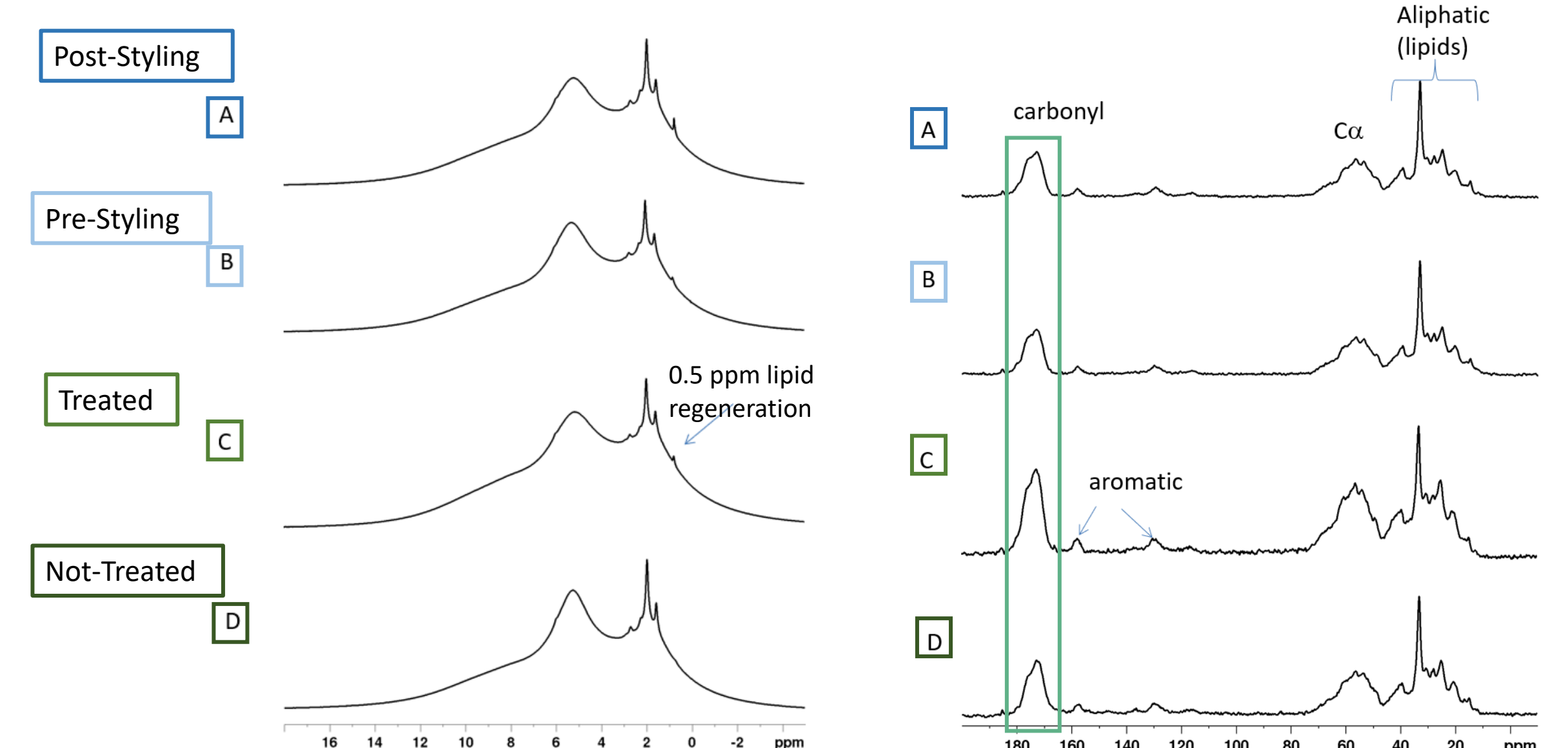### Solid ¹H NMR – Sample 4 Bleached   ¹³C CP MAS NMR – Sample 4 Bleached

Figure 8. ¹H solid state spectra of A) Post Styling and B) Pre Styling C) Treated D) Not Treated for Model 4

Figure 9. ¹³C CP MAS spectra of A) Post Styling, B) Pre Styling, C) Treated and D) Not Treated samples of Model 4.

In Table 2 it is evident that the cosmetic treatment fully reconstructed the carbonyl associated hair components. Moreover, the product had a long-term effect since the regeneration was decreased only by 14.8% from the last treatment.

Table 2

Sample	Area C=O
Not Treated	36 10⁴
Treated	72 10⁴
Pre Styling	62 10⁴
Post Styling	65 10⁴

SEM-FEG Sample 4 Bleached Pre-Treatment

- Raised cuticles
- Cracks
- Flaking hair
- Cuticular loss

SEM-FEG Sample 4 Bleached Post-Treatment

- Regenerated cuticles
- Small holes

CONCLUSIONS

- Keratin reconstruction was expressed in different ways even though the samples underwent the same treatment.
- The cosmetic treatment was not very effective on Natural and Intech samples that were less damaged.
- Whereas severely damaged Bleached hair displayed the greatest keratin regeneration and heat resistance.
- The cosmetic formulation was more suitable for very damaged hair.
- Future research: specific interaction of cosmetic ingredients with molecules present in particular hair conditions.
- Solid-state NMR information on hair are limited.

References

[1] Man QY, Zhang LT, Cho YI. Efficient Hair Damage Detection Using SEM Images Based on Convolutional Neural Network. *Lect Notes Comput Sci (including Subser Lect Notes Artif Intell Lect Notes Bioinformatics).* 2021;12883 LNCS:323-330.
[2] Gavazzoni Dias MFR. Hair cosmetics: an overview. *Int J Trichology.* 2015;7(1):2-15. doi:10.4103/0974-7753.153450