# Electrostatic Properties of Hair Building Fibres

An independent study[1] for the scientific community

In recent years, the technology of cosmetics has begun to harness the science of electric charge. Recently I became intrigued by a new British product “Nanogen” that aimed to camouflage thinning hair. It was claimed that each strand of normal hair was thickened in appearance by ‘attaching’ microscopic coated keratin fibres using electrostatics to place them in a perpendicular pattern. These fibres are applied simply by shaking the fibres from a specially developed container. On further investigation of the product category, I discovered three other brands of note with Nanogen thought by many users to perform the best. As an expert in electrostatics I decided to investigate the claims and relative effectiveness of each product and produce an independent report with quantitative data.

## Charged Fibres

The most persistent claim from hair fibre manufacturers is that their products are more charged than any other, and this charge binds the fibres to the hair. Hair charges differ and can change in different conditions; however the charge on the fibres appears to be an important factor in binding.

It was found that fibres were charged most significantly during dispensing, and therefore the available products were compared immediately after they were dispensed in order to simulate their behaviour when applied to the hair. 10 repetitions were used and then averaged as there was little variation between repetitions.

| | Charge to Mass Ratio/ μC kg$^{-1}$ | | | |
|---|---|---|---|---|
| Test | Nanogen | Toppik | Super Million Hair | Megathik |
| 1 | 17.143 | -7.308 | -10.000 | 1.667 |
| 2 | 20.000 | -6.667 | -6.000 | 3.571 |
| 3 | 11.556 | -6.129 | -7.941 | 5.000 |
| 4 | 11.818 | -5.882 | -5.710 | 3.333 |
| 5 | 20.588 | -5.753 | -8.462 | 3.529 |
| 6 | 30.000 | -3.636 | -4.167 | 6.111 |
| 7 | 25.789 | -5.952 | -6.500 | 3.500 |
| 8 | 16.000 | -4.571 | -2.867 | 6.522 |
| 9 | 13.913 | -6.000 | -7.667 | 7.250 |
| 10 | 22.500 | -4.421 | -4.286 | 1.000 |
| Average | **18.931** | **-5.632** | **-5.846** | **4.148** |

**Figure 1.** Table comparing charge densities of various hair building fibre brands after dispensing.

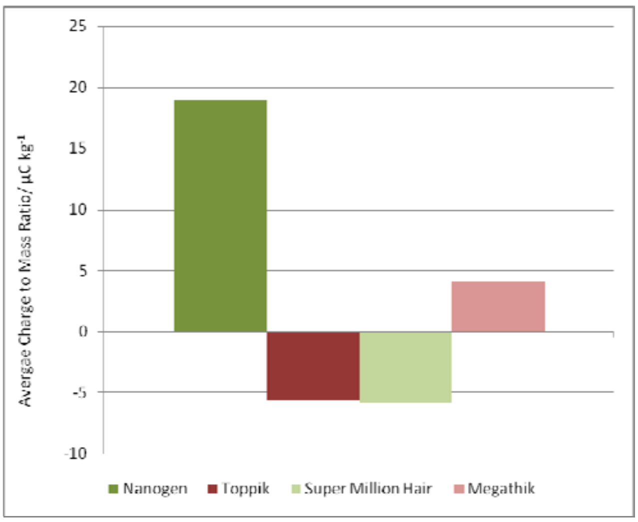


**Figure 2.** Graph to compare the average charge density of various hair building fibre brands after dispensing, over 10 repetitions.

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The results in Figures 1 & 2 clearly show that all of the fibres tested do charge electrostatically when dispensed. Some fibres charged positively giving a positive charge to mass ratio, others charged negatively giving a negative charge to mass ratio. Of all the brands tested Nanogen exhibits 4.5 times more positive charge than the nearest competitor and in excess of 3 times more polarity-independent charge than any other brand tested.

It was expected that the capacity for hair fibre charging was predominantly affected by the basic composition material and that material's position on the Triboelectric Series. The fibres were variously composed with Keratin, Rayon & Nylon as a base, which all have different positions on the Triboelectric Series chart. Since both Toppik and Nanogen fibres were comprised of Keratin, it was expected that they would charge with the same polarity and to the same amplitude. However Nanogen fibres had the opposite polarity of charge to Toppik and a higher charge magnitude, leading me to conclude that properties and/or characteristics of the product other than the basic fibre composition is significant in donating charge.

### Dispensing Jar

Investigating each product further, one of the main points of difference other than fibre composition is the dispensing jar. Nanogen in particular make bold claims as to their jar design and its ability to enhance the charging of their fibres. In order to test these claims, a variety of tests were performed. Since the fibres differ between manufacturers, it was neither practical, nor scientific to test and compare the jar and fibres between brands as this would introduce two variables. The Nanogen dispensing jar includes a metallic strip which purports to ground the jar contents via the user.

| Test | Charge to Mass Ratio/ $\mu C\ kg^{-1}$ Dispensing without metallic strip | Dispensing with strip grounded |
|---|---|---|
| 1 | 6.875 | 17.143 |
| 2 | 11.250 | 20.000 |
| 3 | 6.000 | 11.556 |
| 4 | 6.000 | 11.818 |
| 5 | 11.000 | 20.588 |
| 6 | 10.000 | 30.000 |
| 7 | 13.333 | 25.789 |
| 8 | 7.143 | 16.000 |
| 9 | 9.286 | 13.913 |
| 10 | 9.200 | 22.500 |
| Average | **9.009** | **18.931** |

**Figure 3.** Table comparing charge densities in Nanogen's fibres after dispensing when the metallic strip was and was not grounded.

To test this claim, the metallic strip was removed on one Nanogen jar and left on a second as the control, so that the product could be grounded during dispensing. Both jar variants were dispensed ten times with results in the Figure 3.

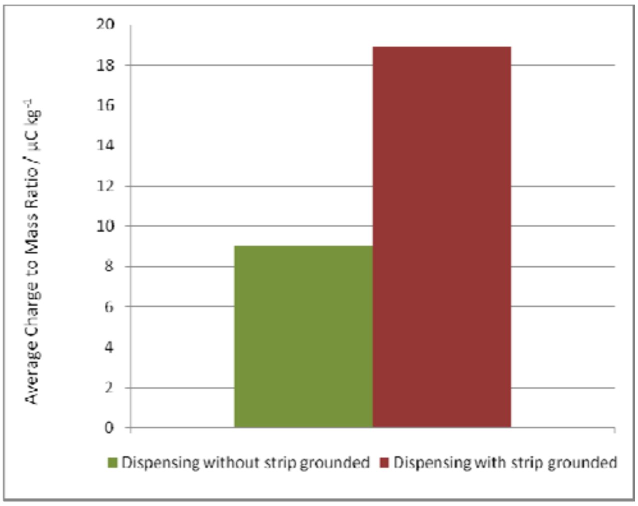


**Figure 4.** Graph to compare average charge density in Nanogen's fibres after dispensing when the metallic strip was and was not grounded, over 10 repetitions.

Figures 3 & 4 show that the grounding of the metallic strip does have a significant effect in increasing the charge developed on the fibres.

This may be due to the grounding provided by the metallic strip regulating the charge of the fibres before dispensing, removing any randomly built up charges and allowing repeatable charging from dispensing.

It is worth noting that even without the metallic strip, the Nanogen charge was still 2 times greater than competitors (and 50% more – charge polarity independent) indicating that fibre material composition and the metallic strip on the dispensing jar are not the sole factors influencing charge intensity.

As regulating the charge of the fibres before dispensing seems to have a positive effect on the charge developed, it is plausible that use of amphoteric chemicals such as certain chemical surfactants that leave materials effectively neutral may have a similar effect on the end result.

These chemicals could be used on the fibres themselves, either in the manufacturing stages or immediately before or during dispensing; or on the hair as a preparation for applying the fibres. However the preliminary background research found no such chemical treatment available, and so the possibility cannot be confirmed as this stage.

Small particles often gain charges as they collide, whether with each other or a suitable material. It seemed plausible that collisions between fibres resultant from dispensing-by-shaking caused the fibres to charge.

| Test | Charge to Mass Ratio/ μC kg$^{-1}$ | |
|---|---|---|
| | Dispensing with no pre-shake | Dispensing after 15s pre-shake |
| 1 | 6.875 | 12.500 |
| 2 | 11.250 | 14.000 |
| 3 | 6.000 | 14.889 |
| 4 | 6.000 | 21.429 |
| 5 | 11.000 | 18.333 |
| 6 | 10.000 | 18.462 |
| 7 | 13.333 | 22.222 |
| 8 | 7.143 | 20.000 |
| 9 | 9.286 | 15.000 |
| 10 | 9.200 | 17.500 |
| Average | 9.009 | 17.433 |

**Figure 5.** Table comparing charge densities in Nanogen's fibres after dispensing with and without pre-shaking. The same jar with the metallic strip removed was used in both tests to eliminate any earthing variable.

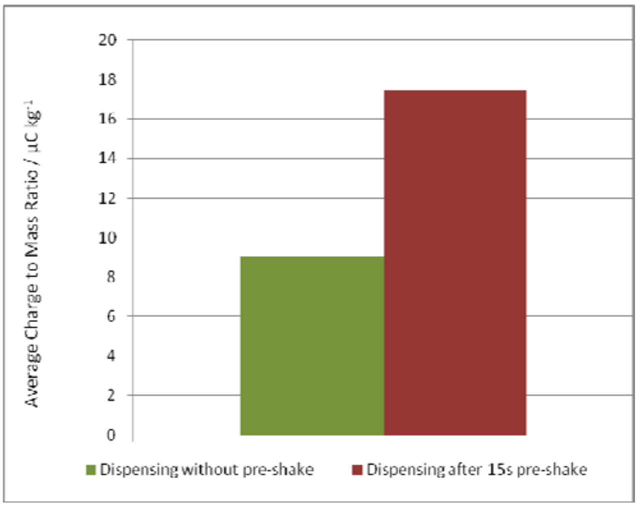


**Figure 6.** Graph to compare the average charge density of Nanogen fibres after dispensing with and without pre-shaking, over 10 repetitions.

The results of the tests in Figures 5 & 6 show that increasing the number of collisions between fibres, such as by shaking the jar when it is closed, increases the charge developed when dispensed. It is therefore probable that a method for further increasing the number of collisions between fibres before or during dispensing would increase the charge developed.

## The Perpendicular Effect

Another common claim by manufacturers was that after dispensing, the fibres bound to hair in a perpendicular fashion. The brands claimed that this arrangement would produce the most thickening effect which seemed logical. However, in theory, a positively charged fibre in contact with a negatively charged hair would bind in parallel, and a negatively charged fibre would repel the hair and not bind. Therefore a series of tests were performed to determine in practice, whether hair building fibres could bind to hair in a perpendicular arrangement to a statistically significant degree.

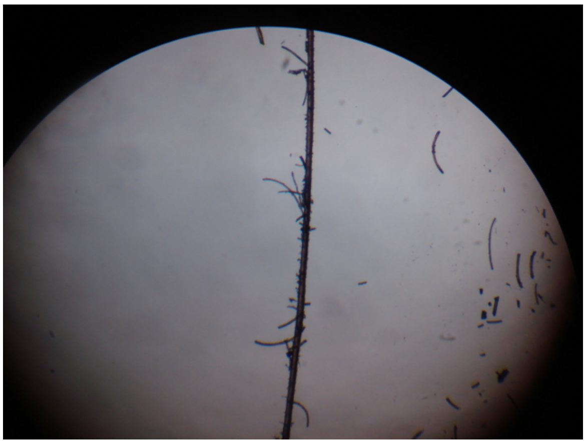

**Figure 7.** Microscope slide showing mostly parallel binding of fibres to a human hair.

As shown in Figure 7, most of the fibre brands tested appear to bind as expected, a few individual fibres protrude perpendicular to the filament they are attached to, but most do not. Therefore there does not appear to be any statistical significance in the direction of binding.

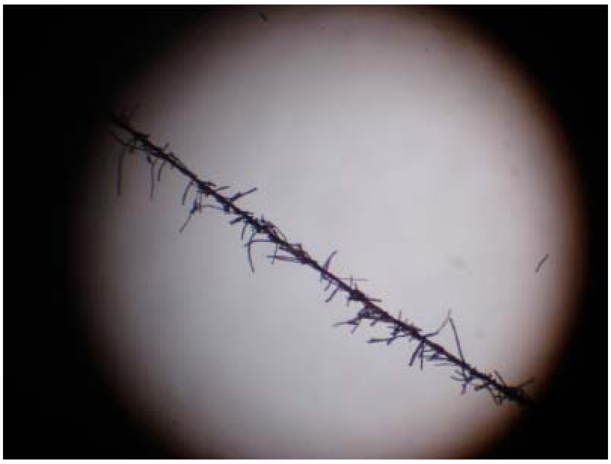

**Figure 8.** Microscope slide showing significant perpendicular binding of fibres to a human hair.

Figure 8 shows that one brand, Nanogen, did actually perform as claimed, with most of the fibres bound perpendicularly to the hair shaft, a statistically significant increase on the number of fibres that would have randomly bound in a perpendicular manner.

Since only Nanogen exhibited statistically significant perpendicular binding, it was decided to investigate what mechanism was producing this effect. Since Nanogen's fibres were producing the strongest charge, it would have been especially likely that they would more tightly bind in a parallel fashion, making the result especially interesting. It is probable that there is a secondary electrostatic effect at work that overrides the effect of the positive charge to create this perpendicular binding.

One possible explanation for the simultaneous high positive charge yet perpendicular binding is if the Nanogen fibres were designed to be relatively conductive. This property would correlate with the inclusion of Nanogen's metal grounding strip which must also rely on fibre conductivity. Accordingly it was decided to test fibres for conductivity.

| Brand | Polarity | Average Charge Density/ μC kg$^{-1}$ | Relative Conductivity |
|---|---|---|---|
| Nanogen | + | 18.931 | < 2 |
| Megathik | + | 4.148 | 7 |
| Toppik | - | -5.632 | 10 |

**Figure 9.** Table comparing polarity, charge density, and conductivity in hair building solids. Conductivity is measured with the lowest value as the most conductive.

As shown in Figure 9, Nanogen's fibres are the most conductive as well as the most charged. It is plausible that conductivity could contribute to the perpendicular binding effect. If the fibres could partially conduct charge along their length, they would form a dipole. Dipole formation would mean that every fibre was charged differently at opposite ends, and so one end of the fibre would bond to the hair whilst one would be repelled, holding the fibre in the perpendicular arrangement seen in Figure 8.

Once again, conductivity was expected to be mostly affected by composition of the fibre, but Toppik and Nanogen, which are both keratin-based, differ widely in conductivity. There must be either another physical property or a coating on the fibres that affects conductivity as well as the charge polarity and amplitude.

## Non-Electrostatic Effects

As hair changes electrostatic state dependant on many factors including environmental conditions such as humidity, and is sometimes even neutrally charged, a hair building solid would perform better if it also adhered to a neutral surface as well as charged surfaces.

The two most widely sold brands were selected for this test. Approximately one gram of fibre was dispensed from each respective container onto a smooth brass plate which was then grounded for 20 seconds to remove all charge from the plate. The plate was then turned to the vertical and knocked 10 times with the force of two fingers over 5 seconds so that the uncharged fibres would be under the influence of gravity plus inertia.

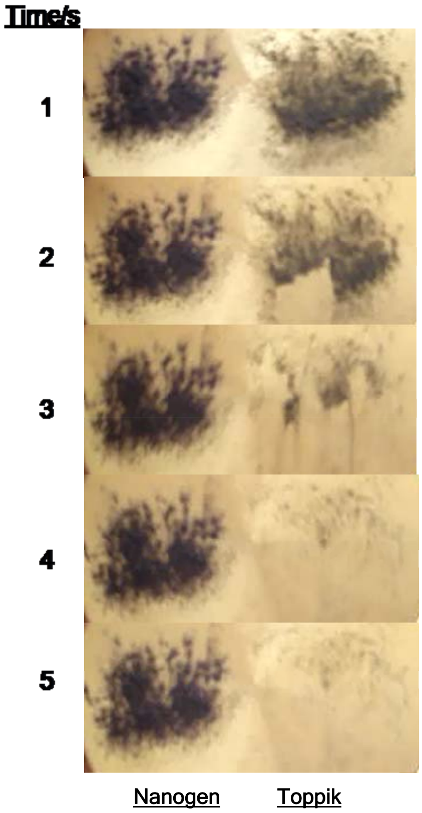


**Figure 10.** Video stills from a comparison of 2 brands of keratin hair building solid binding to a vertical uncharged surface

The images were then analysed with ImageJ picture analysis software to accurately quantify the amount of the fibres on the brass plate at every second during the test, and the amount of fibre adhered at every second calculated.

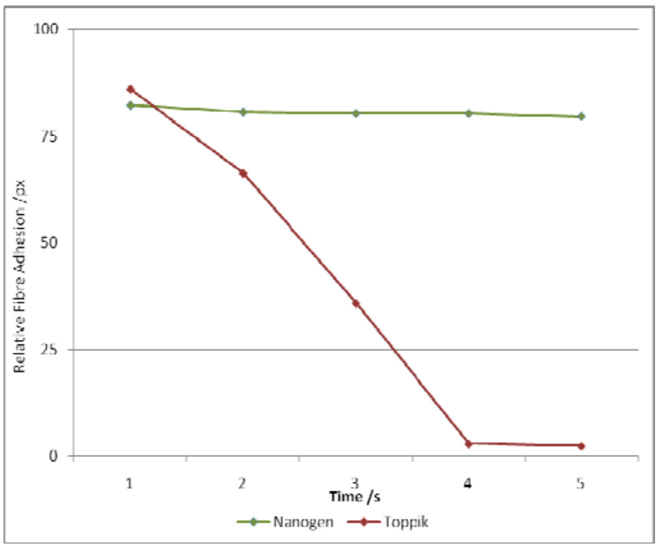


**Figure 11.** Quantitative data from the comparison of 2 brands of keratin hair building solid binding to a vertical uncharged surface.

As can be seen in Figures 10 & 11, some of both fibres adhered to the plate by non-electrostatic means demonstrating the adhering properties of both brands rely on more than just electrostatics alone.

Nanogen's fibres adhered much more strongly to the brass plate, indicating they must also have non-electrostatic properties that aid in binding the fibres to hair; these may be physical properties or a coating of the fibres. It should be noted that both manufacturers advise using a fixing polymer when applying the products to hair, but this test did not incorporate a fixing spray.

## Conclusion

The combination of a strong positive charge and the relatively high conductivity appears unique to Nanogen's fibre product. This may be caused by a physical or chemical property of the fibres, a fibre coating, a feature of the jar design, or most probably a combination of these.

Certainly the combination of a strong positive charge and relatively high conductivity allow a higher percentage of Nanogen's fibre product to bind to hair, and binding to be significantly perpendicular, unlike the other products tested.

It is also probable that the conductivity of Nanogen fibres would allow them to bind to hair even where the hair may have been given a different charge to normal. This may be due to an ability to form dipolar charges.

## Conflict of Interest

I confirm that I have received no financial reward or reimbursement for the compilation of this report and the results are independent of any commercial interest.

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## Positions

Academic-related staff in Electrical Power Engineering at the University of Southampton (2007-Present).

Senior member of staff in the Electrical Power Engineering Research Group at the University of Southampton (1981-2007).

Member of the CENELEC European Technical Committee CLC/TC31/WG20 to develop a new European Standard on ‘Electrostatics – Code of practice for the avoidance of hazards due to static electricity’ PD CLC/TR 50404:2003.

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Honours degree in `Physics and Technology of Electronics', University of North London (1975).

Chartered Engineer and Corporate Member of the Institute of Electrical Engineers.

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Millennium Award for the 'Tribopen'

Ford of Europe Technical Achievement Award for work in asbestos/aramid recycling technology.