

# ***Aulana and NgaPure* : Novel Nanogold Coloured and Antimicrobial Nanosilver Woollen Textiles: The Journey of Discovery, the Nanoscience and Pathway to Commercialisation**

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## **ABSTRACT**

*Aulana* and *NgaPure* products innovatively combine the nanoscience of gold and silver with wool fibre proteins to nanofunctionalise wool and produce a boutique colour range of novel nanogold-wool textiles (*Aulana*) and also through the use of silver to impart durable and highly effective antimicrobial properties to woollen textiles (*NgaPure*) respectively. *Aulana* has captured the exciting and unique opportunity whereby the prestige and high value of gold are linked to the high quality of New Zealand wool through the use of the surface plasmon resonance effects of nanogold, to provide novel stable colourfast colourants. The nanogold and silver entities are chemically bound to the wool fibres. Noble Bond Ltd which own the *Aulana* and *NgaPure* brands, is commercialising *Aulana* products for use in luxury apparel, upholstery textiles, rugs and carpets, and the *NgaPure* antimicrobial treatment technology for woollen products for use in transport and public seating upholstery, furnishing textiles and carpets. This utilises Noble Bond's network of businesses concerned with the wool industry and high value woollen products.

**Keywords:** *Aulana*, *NgaPure*, nanogold, silver, wool, colourants, antimicrobial

## **1 AULANA AND NGAPURE**

Over recent years we have developed a unique and exciting new proprietary nanotechnology and product suite of high value textiles involving the use of nanogold and silver as colourants and antimicrobial entities respectively for New Zealand wool [1, 2]. For nanogold wool which we have branded *Aulana*, this innovatively links the high value and prestige of gold with the sought after natural qualities and attributes of New Zealand wool, for high value international markets in fashion apparel, upholstery furnishing textiles, premium carpets and bespoke rugs. *Aulana* comprises only pure New Zealand wool and minute quantities of pure gold. We have also captured the well known and effective antimicrobial properties of silver with the desirable durability and feel of New Zealand wool fibres to yield *NgaPure* treated antimicrobial woollen yarns and textiles. These exhibit long lasting, stable and effective antimicrobial properties and are well suited for leisure and

sports apparel, upholstery textiles and carpets, particularly those in the early childhood education and healthcare service industries.

The technology and brands are owned by Noble Bond Ltd, a new company that was established to take our rare and exquisite *Aulana* and *NgaPure* products to the elite international luxury and functional textiles and carpet markets. Our market appraisal and business agreements have confirmed a strong demand for such luxurious and functional woollen products that uniquely combine premium natural fibres and precious metals, producing opulent coloured fabrics or durable, long lasting antimicrobial textiles. Noble Bond Ltd is now commercialising *Aulana* and *NgaPure*.

Gold and other noble metals in bulk form exhibit their well known characteristic metallic colour. However, when their particle size is reduced to nano dimensions they exhibit different colours due to the collective oscillation of conduction band electrons resulting from their resonance interaction with the electric field vector of the incoming visible light. This effect is known as localised surface plasmon resonance. The resulting colours depend on the size and shape of the nano entities and the dielectric constant of the surrounding material [3-6].

Interestingly, colloidal gold nanoparticles have been used to colour glass dating back to about the 17<sup>th</sup> century. Also, the Lycurgus Cup dating back to around the late 4<sup>th</sup> century used gold and silver nanoparticles as colourants. The science was not understood until 1869 when Michael Faraday recognized and explained the role of gold as a colourant in general terms. In 1908 Mie [5] provided a theoretical explanation by solving Maxwells equations for the absorption and scattering of electromagnetic radiation by very small metallic particles – nanoparticles.

Spherical nanoparticles of gold exhibit a single transverse surface plasmon resonance absorption peak at about 525 nm which shifts to longer wavelengths and is broadened with increasing particle size and agglomeration respectively. Particles about 10-20 nm are pink-red in colour. As the particle size increases or agglomeration occurs, the colour changes progressively through shades of

pink, red, purple, blue-grey to grey (Figures 1 & 2). Gold nanorods and core-shell gold nanoparticles exhibit both transverse and longitudinal surface plasmon resonance absorption peaks. These absorptions essentially span the visible spectral range and some of the NIR range [6]. Hence they offer various shades of blue, green and red colours, depending upon the aspect ratio of the gold nanorods and the thickness of the gold shell respectively. Nanogold colourants cannot fade or denature in sunlight like traditional organic dyes do and hence the nanogold coloured wool products exhibit excellent lightfastness.

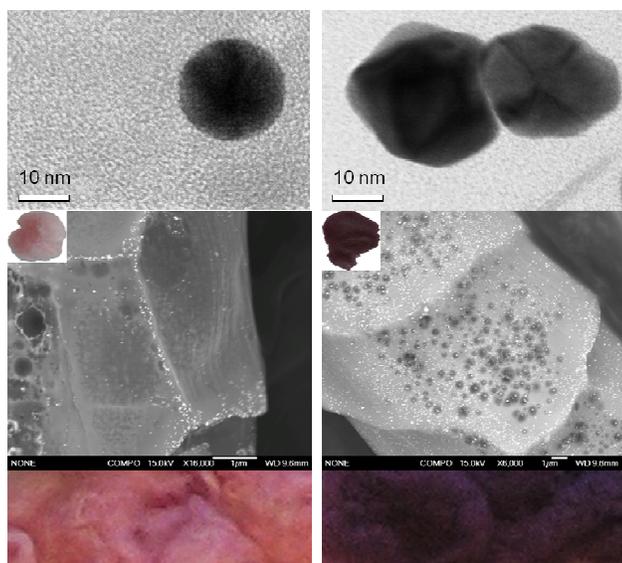


Figure 1: TEM and SEM images of gold nanoparticle on pink and purple nanogold coloured *Aulana* wool. (Copyright Kerstin Lucas)



Figure 2: Examples of *Aulana* top wool. (Copyright Noble Bond Ltd)

The nanogold entities for *Aulana* are formed by the controlled reduction of  $\text{Au}^{3+}$  to  $\text{Au}^0$  and the attachment of these to the wool fibres using our proprietary knowhow and technology [1, 2]. Electronmicroscopy (Figure 1) and associated X-ray elemental mapping, and X-ray photoelectron spectroscopy studies show the nanogold is

primarily bound to the cuticle edges and is also present within the fibre [2]. A key feature is that these nanogold entities are strongly chemically bound to the wool fibres and do not leach out or rub off. This provides a further competitive advantage.

The antimicrobial properties of silver are well known and date back to Chinese Dynasties and early medicine, and are effective against some 600+ microbes [7] notably bacteria, fungi and algae. Ancient Greeks used silver containers to store purified water and wine. Silver has been used in wound management as early as the 18<sup>th</sup> century where silver nitrate was used in the treatment of ulcers, wounds and burns. During the early 19<sup>th</sup> century silver ions were approved for wound management by the US Food and Drug Administration. However, the introduction of antibiotics in 1940 largely replaced silver for medical purposes. In the 1960s silver regained popularity in the treatment of burns and continues to be used to date in silver-based antibacterial creams. Over the last two decades silver nanoparticles which provide a ready source of silver ions due to their high specific surface area, have found substantial increasing use in a wide variety of consumer products, notably plastics, synthetic and cotton textiles, paints and medical dressings. A major concern here is that the silver nanoparticles are not chemically bound to these particular substrates and readily wash or abrade off and enter the environment. This is of concern and also significantly decreases antimicrobial effectiveness of these silver-containing products [7].

For *NgaPure* we utilise the chemical affinity of silver for N in the wool proteins and strongly bind the antimicrobial active silver entities to the wool fibres. This has been confirmed by detailed electronmicroscopy and photoelectron spectroscopy studies as well as extensive leaching tests. The resulting *NgaPure* woollen textiles, carpets and rugs exhibit excellent, long lasting and durable antimicrobial properties as the silver entities do not leach out. This provides a significant environmental and competitive advantage for *NgaPure*.

The *Aulana* and *NgaPure* technologies and product suites have been protected by branding, trademark and patent applications, and are being commercialised by Noble Bond Ltd. These have been developed on the laboratory scale and successfully progressed to pilot scale production for loose wool, combed top wool, yarn and fabric, using our respective technologies. Commercial scale production is ensuing.

## 2 DEVELOPMENT AND PATHWAY TO COMMERCIALISATION

***Aulana*:** The research was commenced by us in 2006 with a detailed laboratory study of the controlled formation of gold nanoparticles and their binding to wool fibres in order to produce a range of attractively coloured wool

fibres on the 0.1 g scale [1, 2]. The initial research was carried out using New Zealand merino wool with a fibre diameter of about 19 microns, which is suitable for apparel and fine furnishing textiles, and also using strong wool (crossbred) wool with a fibre diameter of about 32 microns which is suitable for carpets. Both wools were in top or sliver form. During the ensuing research and development work, a large number of different wool types selected from various points in the conventional wool processing and treatment stages post the farm gate, were also used. A range of different fibre diameters between 14.5 and 32 microns were used. The process chemistry and technology was modified and optimised accordingly to produce the desired colours. A selection of the initial colours produced in the early stage development are shown in Figure 2. The research here involved a detailed study of the factors controlling gold nanoparticle synthesis and the interaction and chemical binding of the nanogold entities to the wool fibres [1, 2]. The next task which was indeed a very major challenge, was then to progressively scale the process chemistry and technology up to produce kilogram quantities of nanogold wool in a range of colours with the consistency and uniformity for commercial products. The initial focus here was to again use the merino and crossbred wools in top form. Once this was accomplished successfully, the process chemistry and technology were further advanced to colour yarn in larger amounts and in both hank and package form. Figure 3(a) shows an early example of merino wool *Aulana* in top form where the where the colouring is undesirably non-uniform. A later example of this top wool and the subsequent yarn where the colouring is very uniform following further development and refinement, is shown in Figure 3(b).

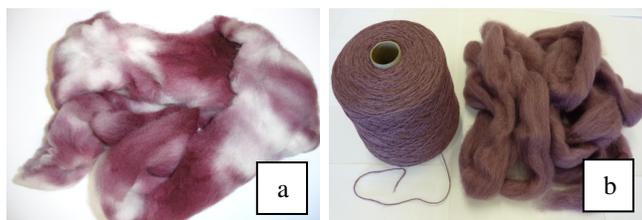


Figure 3: Examples of top wool coloured with nanogold. (a) non-uniform colouring; (b) uniformly coloured *Aulana* top wool and subsequent yarn. (Copyright Noble Bond Ltd)

*Aulana* merino wool in top form and in a range of attractive colours have been spun into yarn of the required specifications for fine knitted apparel and accessories and then fabricated into fine knitted jersey, scarves and pin striped suiting, which Noble Bond and its partner companies Wools of NZ Ltd and Ascend Rugs Ltd have presented to the international luxury markets for these products. Examples of these are shown in Figures 4. In a similar way, deep regal purple coloured *Aulana* crossbred wool and mid micron wool in different colours have been made into carpet samples and rugs for the high value

sectors of these markets. Examples of these are also shown in Figure 4.

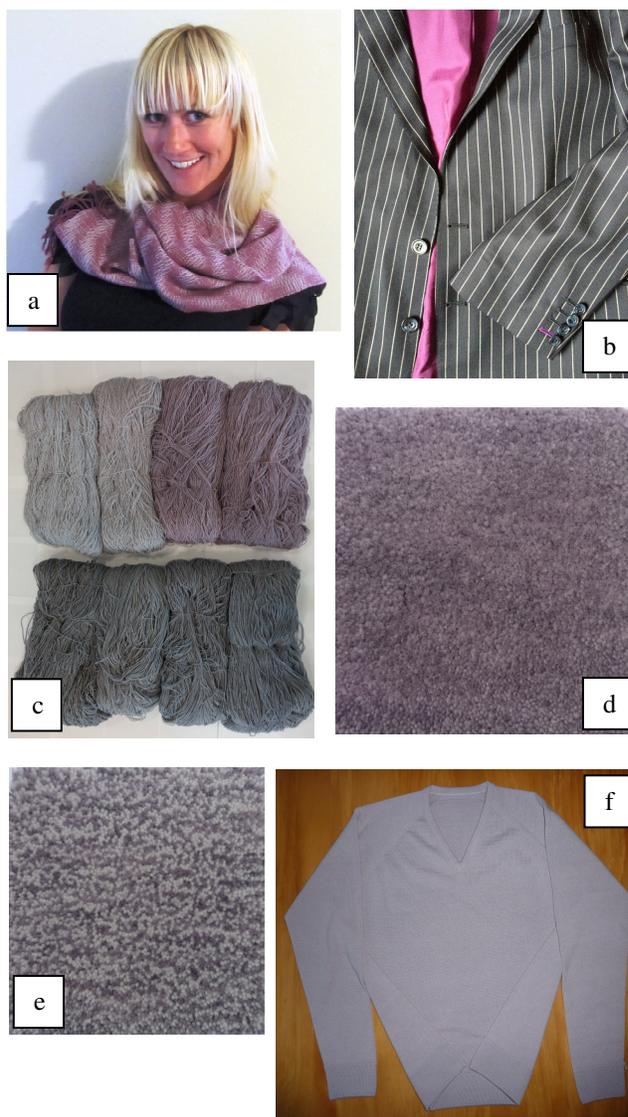


Figure 4: Examples of *Aulana* products. (a) scarf in two colours; (b) pin striped suit; (c) rug and carpet wool; (d) purple bespoke rug; (e) grey and purple bespoke rug; (f) fine knitwear jersey. (Copyright Noble Bond Ltd).

*NgaPure*: A range of textiles for different market segments have been treated with our *NgaPure* technology and their antimicrobial activity and durability tested accordingly. These showed excellent results. Noble Bond Ltd has successfully developed and shown that *NgaPure* is a very versatile technology. It uses very small amounts of silver and can be used to impart highly effective, durable and long lasting antimicrobial to a wide range of woollen textiles. The treatment can be applied before or after conventional dyeing and there is no change to the colour of the *NgaPure* treated textile. *NgaPure* has applications in

leisure and sports apparel, upholstery textiles and carpets, particularly those in the early childhood education and healthcare service industries. Examples of *NgaPure* treated upholstery fabrics are shown in Figure 5.

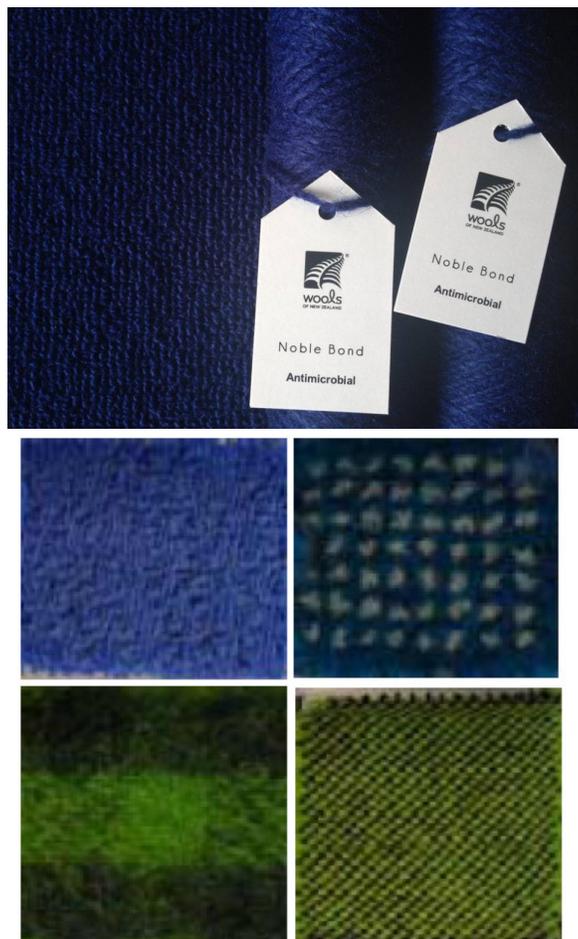


Figure 5: *NgaPure* treated blue woollen yarn and carpet (top), and a selection of woollen textiles. All these products exhibit excellent antimicrobial effectiveness.

The quantified antimicrobial effectiveness of a typical *NgaPure* treated textile against *E. Coli* is shown in Figure 6. The blue bar represents the starting bacteria colony count on the untreated textile, the red bar represents the reduction in the bacteria colony count on the untreated textile after 4 days due to natural attrition. The arrow shows the negligible bar for the bacterial colony count on the *NgaPure* treated textile after 4 days, where the count was reduced by 99.97%. This shows that the *NgaPure* treatment imparts very effective antimicrobial properties to the woollen textile using very low levels of silver. Subsequent washing tests confirmed the durability and hence the long lasting nature of the *NgaPure* antimicrobial treatment.

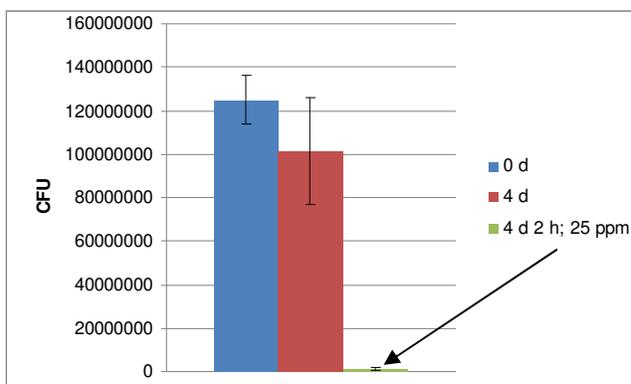


Figure 6: The antimicrobial effectiveness of *NgaPure* upholstery textiles against *E. coli* as shown by the reduction of these microbes after 4 days (arrow) compared with the untreated textile. (Copyright Noble Bond Ltd).

**Noble Bond Ltd** is commercialising this exciting new technology and product suite which is a world leading innovation and a world first. It is currently inviting capital investment in this attractive new business opportunity in the high value fashion apparel, carpets and functional textiles markets, where high quality, uniqueness, functionality and environmental attractiveness are the value drivers and product hallmarks. Expressions of interest should be made to the authors at the above contact address.

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