Green synthesised silver nanocomposite for thermoregulating e-textiles

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1. Introduction

•E-textiles form the ideal foundation for Personal thermal management (PTM) devices due to their concurrence with thermal comfort adaptation behaviours, i.e. using clothing to manage temperature.
• PTM, or thermoregulating, devices aim to address the environmental impact of heating and cooling systems in buildings.
• Silver nanoparticles (AgNPs) are highly electrically and thermally conductive, industrially scalable within the textile industry, and are biocompatible for next to skin wear [1]. Polypyrrole has high conductivity and stability so has been selected to enhance the adhesion through electrostatic forces with the silver nanoparticles whilst hydrogen bonding to the linen [2,3]. Linen was selected due to its renewability, low energy requirements and greenhouse gas emissions as compared to petrochemical-based textiles, and low water consumption compared to cotton whilst being a commercially accessible and popular textile worldwide.

2. Aims

- To develop a **highly efficient** joule heating and temperature sensing e-textile using **environmentally-benign** methods and materials.
- The e-textile is to deliver heat suitable for skin contact with **minimal power requirements**.
- The composite design is to facilitate a **low percolation threshold to keep production costs low.**
- The development will focus on **comfort, durability and biocompatibility** with sufficient hydrophobicity to mitigate the crosstalk effects of humidity.

3. Silver nanoparticle green synthesis

Silver nanoparticles (AgNP) were synthesised from silver nitrate using **lime peel extract** as a reducing agent. A 5 factor, 2 level **Plackett-Burman method** of experimental design was used to optimise the green synthesis parameters.

UV-vis spectroscopy confirms the synthesis of AgNPs with peaks between **408 and 432 nm** (Figure 1). The surface plasmon resonance of AgNPs gives a characteristic absorbance peak between 390 – 470 nm. Morphology of the nanoparticle will shift the exact wavelength of the peak.

Zeta size analysis confirms a homogenous collection of nanoparticles that are approximately **45 nm** in diameter (Figure 2).

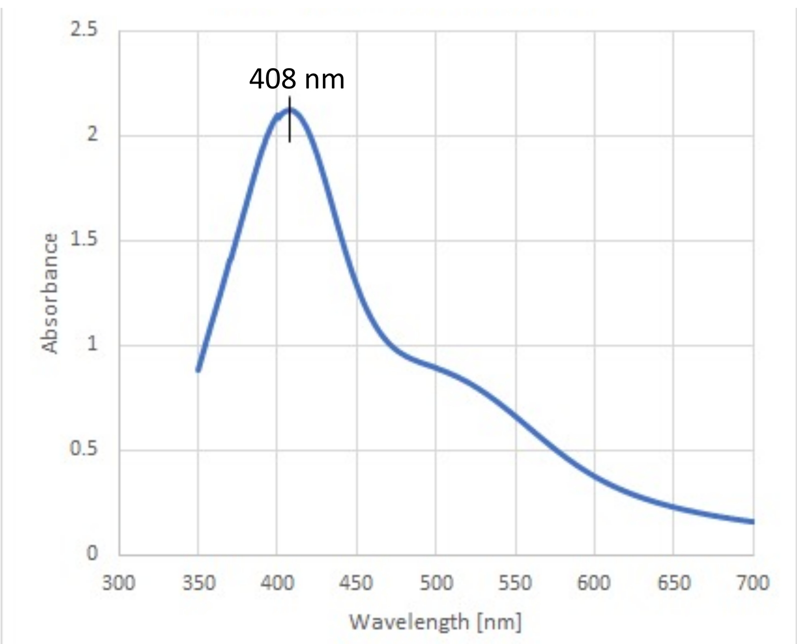

Figure 1: UV-vis spectrophotometry results showing the characteristic peak at 408 nm.

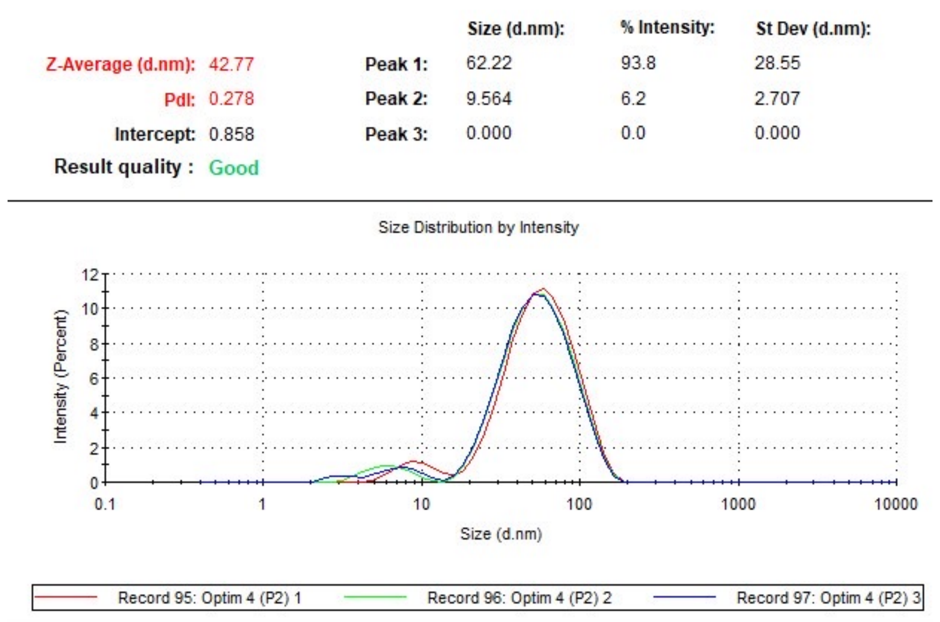

Figure 2: Zeta size analysis of optimised green synthesised silver nanoparticles

4. Preparation of polypyrrole –silver nanoparticle linen

Samples have been prepared using a **wet chemistry** method. The linen is added to a solution of green synthesised silver nanoparticles and pyrrole monomer. The polymerisation initiator, ferric chloride or silver nitrate, is subsequently added.

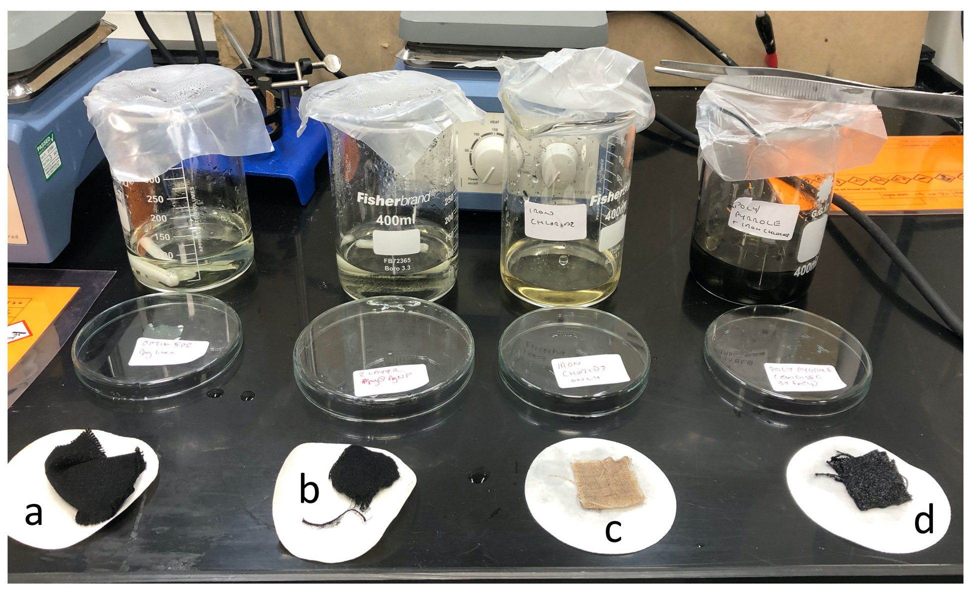

Figure 3: Linen samples with (a) silver nanoparticles and polypyrrole (b) 2 coatings silver nanoparticles and polypyrrole (c) iron chloride only (d) polypyrrole only

5. Electrothermal Results

With a large excess of ferric chloride, low resistance of 10 – 35 Ω and **joule heating of 58°C at 6V** power input was achieved. However, it is hypothesised that this has been caused by iron rather than the polypyrrole capped AgNPs since thus far, the same results have not been achieved in other samples.

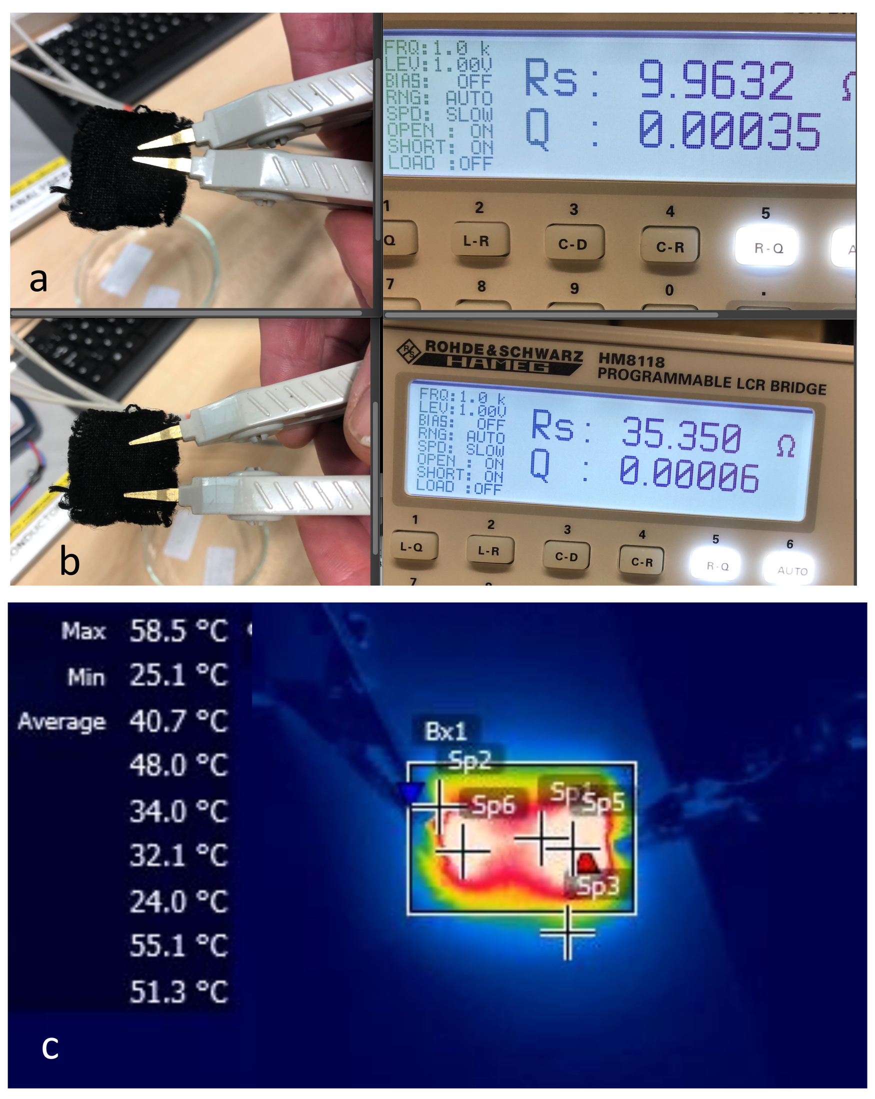

Figure 4: (a, b) Electrical resistance of AgNP, polypyrrole e-textile polymerised in excess iron (Sample 3) at two contact point distances (c) Joule heating properties of Sample 3

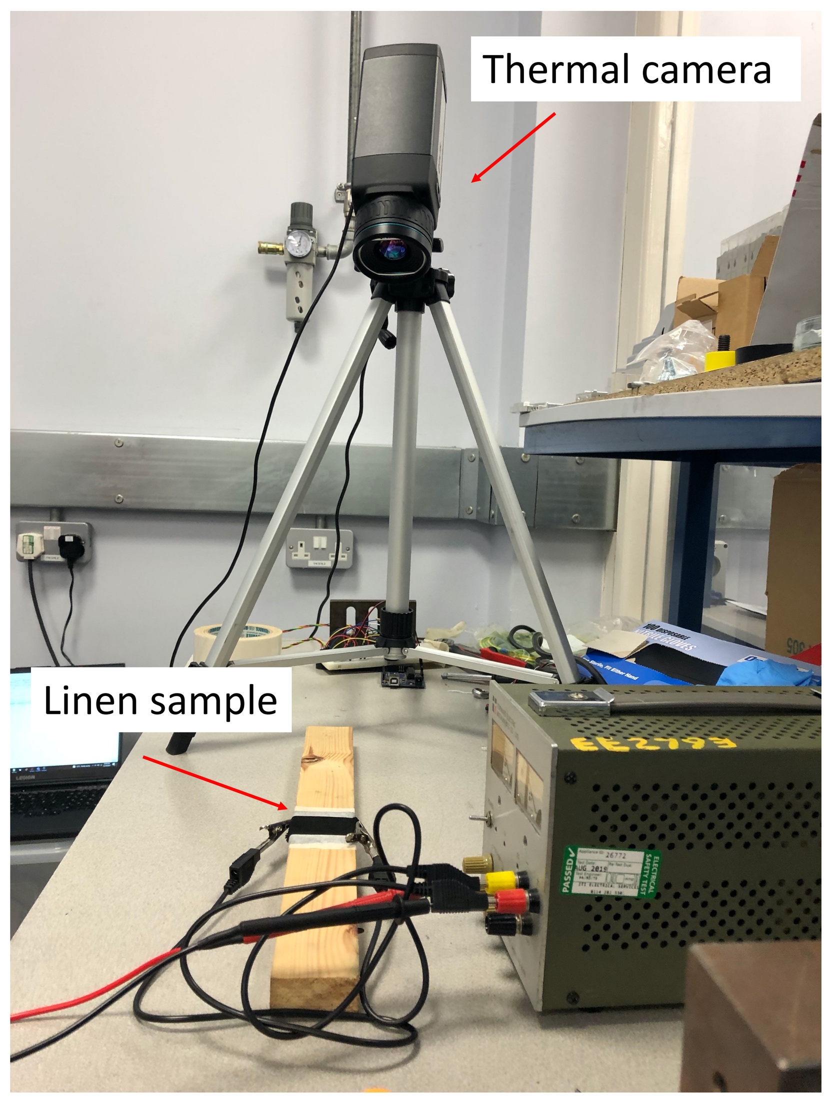

Figure 5: Thermal camera set up to analyse joule heating properties

Preliminary results for other samples have resulted in high resistance of 115 kΩ and above. **Thermal analysis of these samples have confirmed no joule heating** is occurring demonstrating a lack of thermal and electrical conductivity in these samples. It can be hypothesised that $FeCl_3$ is preferentially oxidising silver nanoparticles into silver ions before polymerising pyrrole in these samples.

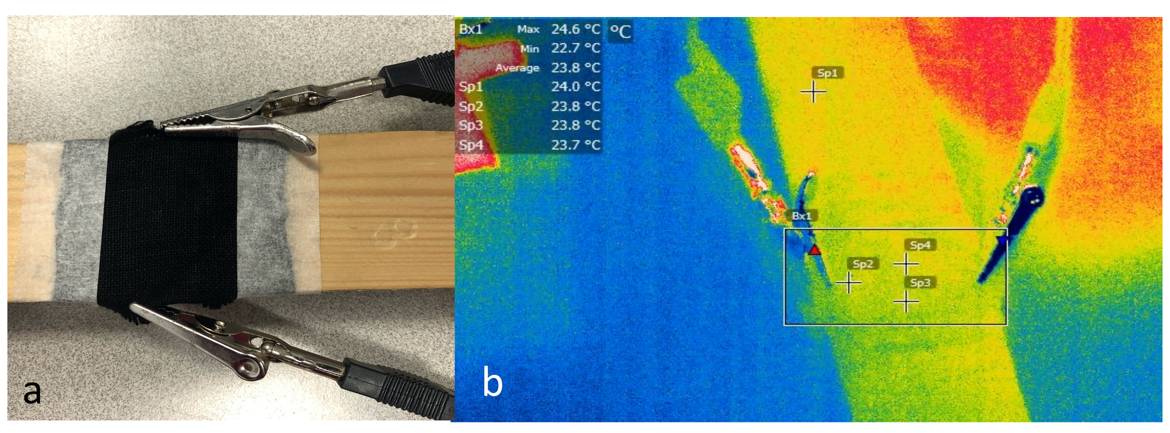

Figure 6: (a) AgNP, polypyrrole e-textile polymerised in 1:2.3:5 molar ratio pyrrole:iron chloride:AgNPs (Sample 5) (b) Thermal camera image at 5 5V

6. Conclusions and Future Work

- **Design of experiment** results showed that optimal homogenous silver nanoparticles were synthesised by lime peel extract in an alkaline environment above room temperature.
- Initial electrothermal results suggest that an **excess of iron** has caused the joule heating of 58°C at 6V. Other samples demonstrate resistance of >115 kΩ and no joule heating.
- Further work is underway to optimise the synthesis of polypyrrole capped silver nanoparticles *in situ* on linen to **improve thermal and electrical conductivity**, and to analyse **the temperature dependent resistance and mechanical properties** of the developed e-textile.

References

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Acknowledgements

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