

Synthesis of Graphene Hybrid-based Nitrate Salt Mixture For Potential Thermal Energy Storage Applications

Mahesh Vaka¹, Rashmi Walvekar² and Mohammad Khalid³

¹School of Computer Science and Engineering, Faculty of Innovation and Technology Taylor's University, Malaysia.

²Department of Chemical Engineering, School of New Energy and Chemical Engineering, Xiamen University, Malaysia

³Graphene & Advanced 2D Materials Research Group, School of Engineering Technology, Sunway University, Malaysia

Introduction

The global thermal energy storage market is evaluated at **US\$4.204 billion** for the **year 2019** growing at a compound annual growth rate (CAGR) of 12.38% reaching the market size of **US\$8.466 billion** by the **year 2025**.

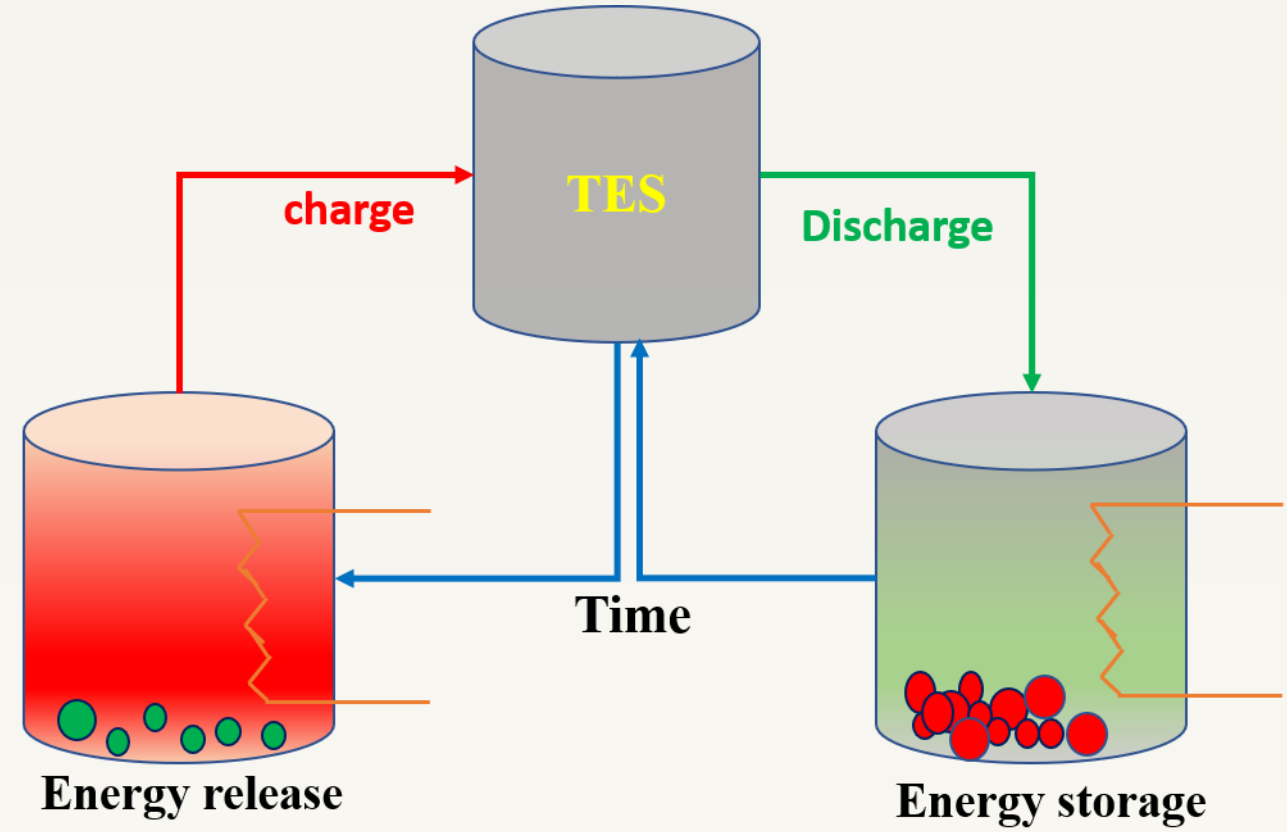
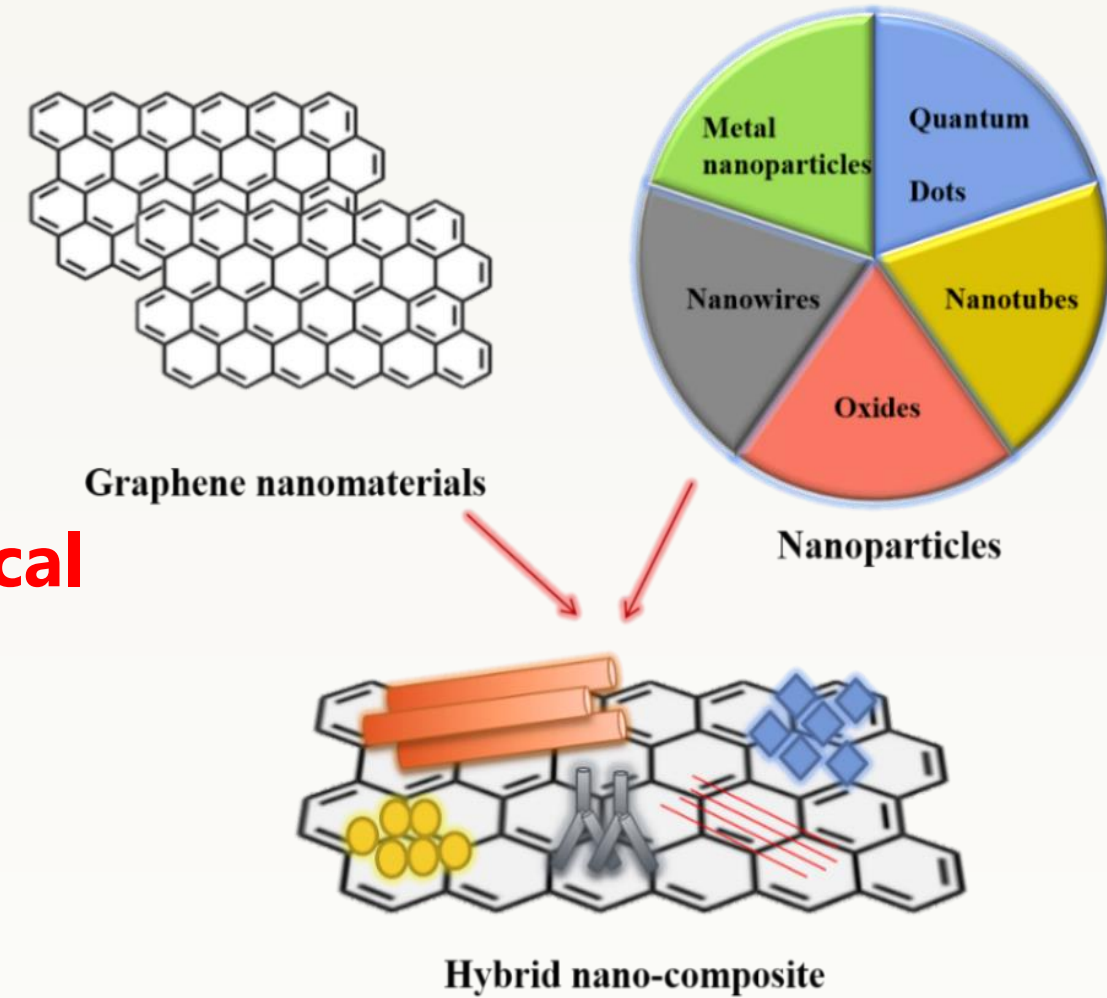


Fig 1. The process of TES system

The **main challenges** with phase change materials are:

- Low specific heat capacity
- Highly viscous in nature
- Easy to decompose
- Highly Corrosive

The most effective way to **improve the thermophysical properties** of PCMs is by **doping of nanomaterials**.



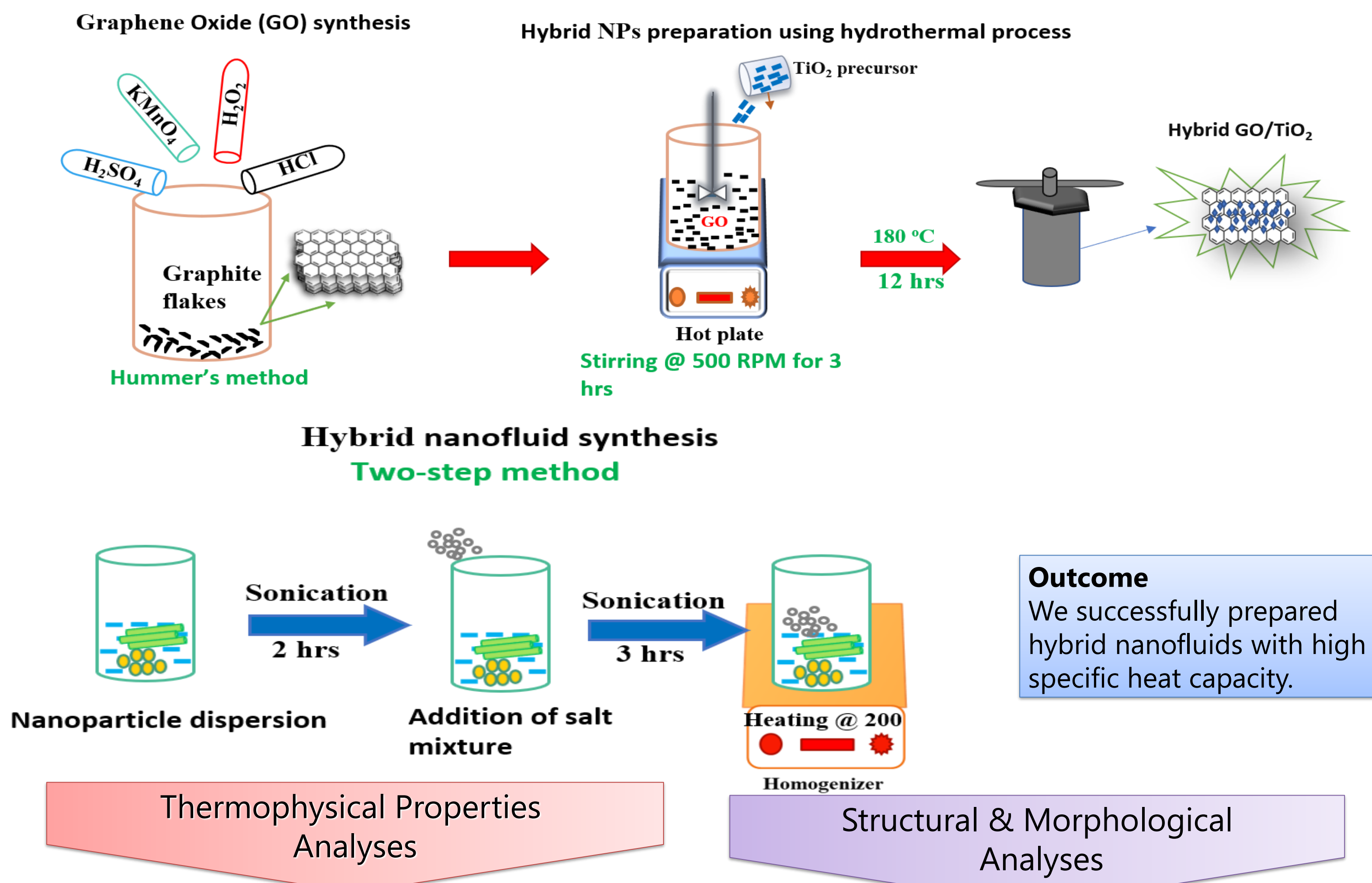
Aim

The **Main aim** of this research is

To develop nitrate eutectic salt mixture with wide operating temperature, low-cost, thermal stability, non-toxic, eco-friendly, and doping graphene hybrid nanoparticles in the eutectic salt mixture to improve the thermophysical properties such as enhanced specific heat capacity, thermal degradation for thermal energy storage applications.

Methods

In our research, we develop a non-toxic, environmental friendly, wide temperature range and high thermal degradation of nano-PCM materials for thermal energy storage applications.



	DSC	TGA
Temp range: 30-400 °C,	Temp range: 50-900 °C,	
Ramping rate 10 °C/min, purified air 20 ml/min	Ramping rate 10 °C/min, purified air 20 ml/min	

TEM, SEM

FTIR, Raman

Results and discussion

Table 1: Specific heat capacity of hybrid nanoparticles with different wt% (0.01, 0.05 and 0.1)

Sample	Base Salt (BS)	BS+0.01%GO/TiO ₂	BS+0.05%GO/TiO ₂	BS+0.1%GO/TiO ₂
Average (after 3 runs)	1.342	1.474	1.606	1.599
Enhancement (%)	-	9.8	19.6	19.1
Standard deviation	0.08	0.21	0.24	0.14
Standard error	0.02	0.07	0.08	0.04

The highest specific heat capacity of **19.6%** was reported with 0.5 wt% of hybrid nanoparticles in the nitrate salt mixture.

Table 2: Percentage weight loss of different samples

Sample	Weight loss (%)
Base salt	60-190 °C (3%) 520-740 °C (80%)
GO/TiO ₂ - 0.01	60-190 °C (2%) 540-760 °C (80%)
GO/TiO ₂ - 0.05	60-190 °C (2%) 540-760 °C (78%)
GO/TiO ₂ - 0.1	60-190 °C (2%) 540-760 °C (75%)

The weight loss% from 60-190 °C is due to **moisture loss**

DTGA table shows an increase in thermal degradation from **520 to 540 °C** after the addition of hybrid nanoparticles.

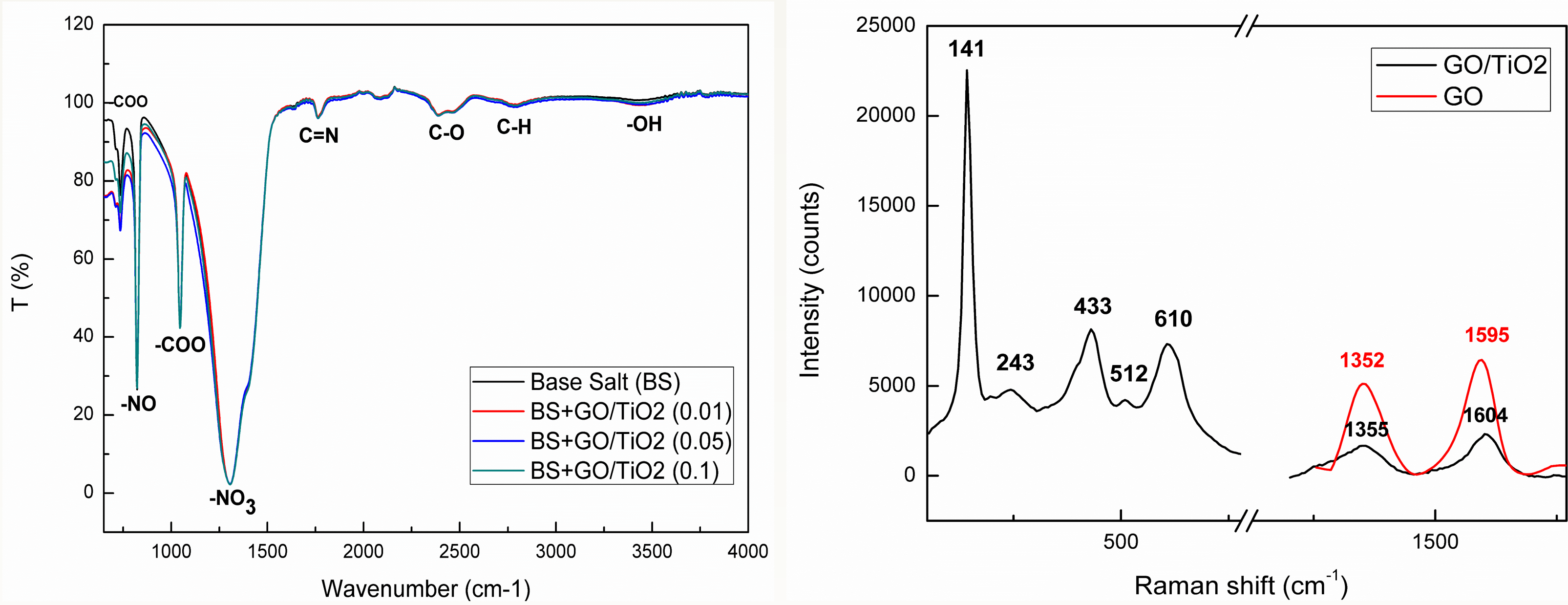


Fig 2. a) FTIR spectrum of nitrate salt mixture and hybrid nps in the nitrate salt mixture b) Raman spectra of GO (Red) and GO/TiO₂ (black)

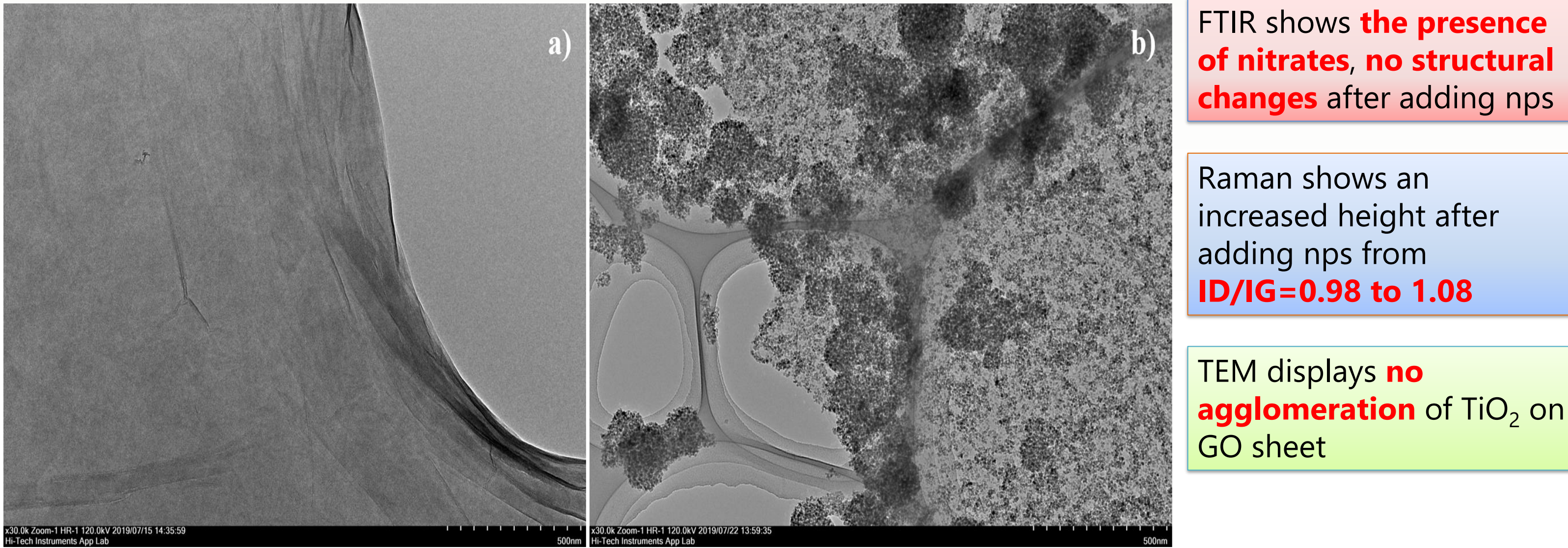


Figure 3. HRTEM images of a) Graphene Oxide (GO) and b) hybrid GO/TiO₂

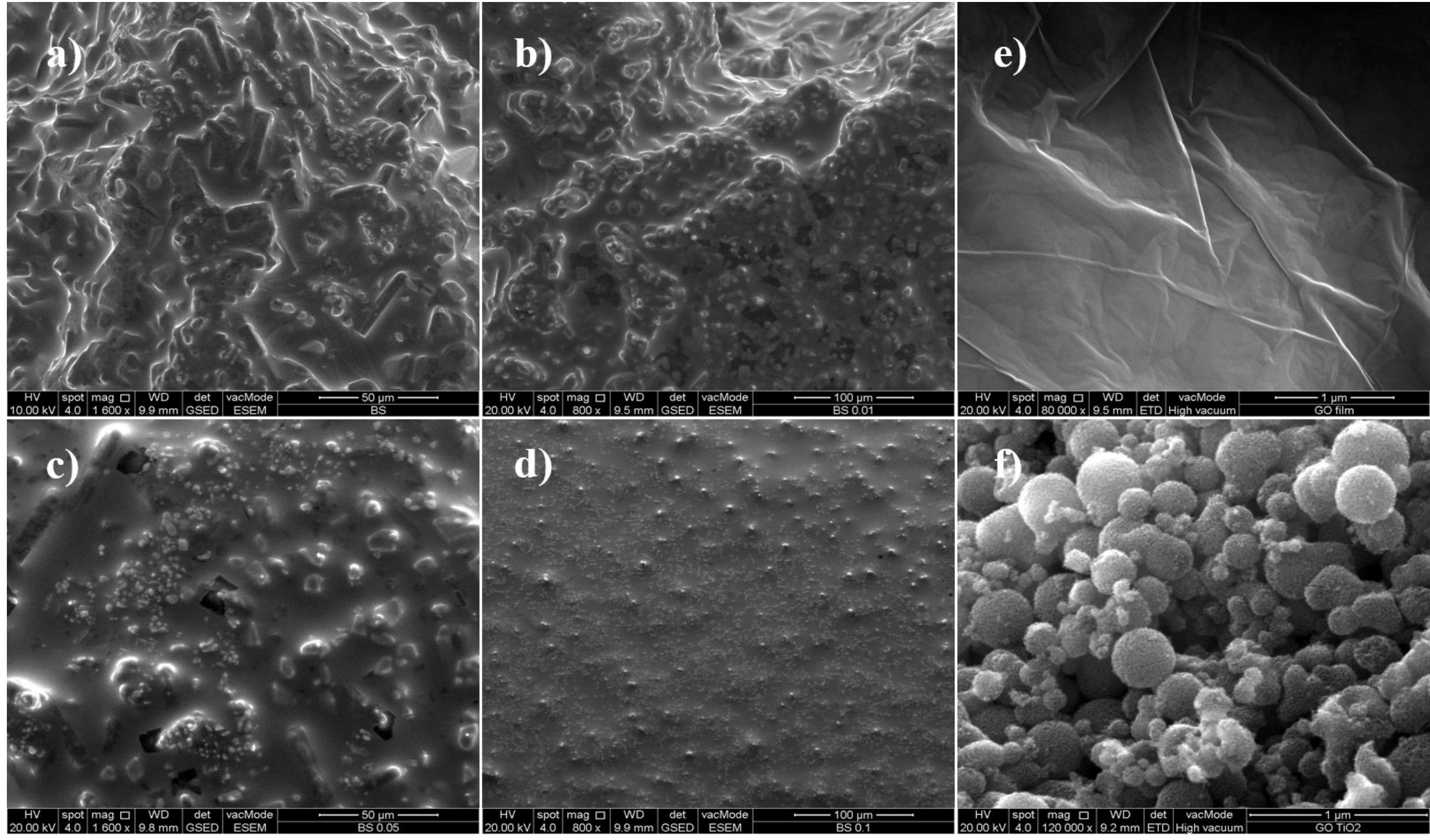


Figure 4. SEM images of base salt and base salt with different concentrations of hybrid nanoparticles: a) Base salt, b) Base salt + 0.01 wt% of GO/TiO₂, c) Base salt + 0.05 wt% of GO/TiO₂, d) Base salt + 0.1 wt % of GO/TiO₂, e) Structural morphology of graphene and f) Hybrid GO/TiO₂ nanoparticle.

Conclusion

1. The effect of hybrid nanoparticles showed improved specific heat up to 19.6% enhancement at 0.05wt% nanoparticle concentration and can withstand temperatures up to 540 °C.

2. The characterisation techniques demonstrated good dispersion of GO/TiO₂ into base salt and also binding of GO with TiO₂ produced via a hydrothermal process. Thus makes this nanofluid as a suitable candidate for thermal energy storage applications.

References

- Y. Li et al., *Solar Energy*, vol. 183, pp. 776-781, 2019; Y. Hu, Y. He, Z. Zhang, and D. Wen, *Solar Energy Materials and Solar Cells*, vol. 192, pp. 94-102, 2019; W. Vallejo, A. Rueda, C. Díaz-Urbe, C. Grande, and P. J. R. S. o. s. Quintana, vol. 6, no. 3, p. 181824, 2019; C. J. J. o. C. Basheer, vol. 2013, 2012; M. Lasfargues, A. Bell, and Y. J. J. o. N. R. Ding, vol. 18, no. 6, p. 150, 2016; P. D. Myers Jr, T. E. Alam, R. Kamal, D. Goswami, and E. J. A. e. Stefanakos, vol. 165, pp. 225-233, 2016; B. Jo and D. Banerjee, in *ASME/JSME 2011 8th Thermal Engineering Joint Conference*, 2011, pp. T30084-T30084-7; American Society of Mechanical Engineers. <https://www.globenewswire.com/news-release/2021/01/28/2165704/0/en/Global-Thermal-Energy-Storage-Market-2020-to-2025-Molten-Salt-Storage-is-Expected-to-Have-a-Significant-Share.html>

Acknowledgements

The authors are grateful to **Taylor's University** through its **Taylor's PhD Scholarship Programme** for their opportunity and would like to thank **Sunway University** for their support and laboratory facilities.