Conclusion

5. Conclusions

The present study had come out three remarkable conclusions; i) The optimum simple method for the isolation and the separation of the bacterial nanowires, ii) Examination of the electrochemical conductive properties of the separated bacterial nanowires and iii) The enhanced conductivity of the bacterial nanowires by layering of metal oxide nanoparticles (CuO, NiO and ZnO) over the nanowires. These three conclusions would lead to further investigations and studying nanowires of aerobic bacteria like *P. aeruginosa* is first model of its kind.

The present investigation suggested that the sonicator shearing with log phase culture method is the best for the isolation and separation of the extracellular bacterial nanowires. In addition, sonicator shearing culture showed a qualitative intact image of separated bacterial nanowires. From this, it is observed that chemostat cultures and controlled electron acceptor limited growth conditions were not necessary to get the intact and separated bacterial nanowires structures. Further, it is proved that the separation and isolation of the nanowires from bacterial cells is simple and cost effective and easily reproducible at any laboratory with the commonly available instrument of sonicator.

Electrochemical methods (CV, LSV and EIS) were employed to examine the electrochemical conductive behavior of the bacterial nanowires to understand the EET phenomena. By choosing the suitable techniques and situation, these techniques can be used as non-destructive methods, and permit the determination of electron transfer from the bacterial nanowires. The measurements reported here motivate the further investigations on how to increase the bacterial nanowires conductivity. The results of this study would pave the way for a green chemistry approach using bacterial nanowires for the efficient electron transfer and can be used as an electron source for various potential (bio) electronic applications such as microbial fuel cells, biosensors and organic solar cells.

The metal oxide nanoparticles coated with bacterial nanoparticles, resulting the improved electrochemical impedance properties. The polarization resistance(R_p) values were found to be 2618, 2270 and 4042 Ω for CuO, NiO and ZnO coated bacterial nanowires respectively and the CPE–T values were found to be 8.15, 9.32 and 7.75 $\mu F\ cm^{-2}$ for the CuO, NiO and ZnO coated bacterial nanowire nanocomposite thin films. The NiO nanoparticles coated bacterial nanowires exhibited a low polarization resistance when compared to those three metal oxide nanoparticles coated bacterial nanowires, explaining the electronic and conductive properties of the Ni. It is understood that the polarization resistance of the bacterial nanowires sample is inversely proportional to the interfacial conductive properties of the electrodes. Hence, NiO nanoparticles coated bacterial nanowires exhibited a high interfacial conductivity in comparison to other electrodes studied in the investigation.

The measurements reported in this study motivate further investigations into the molecular structure and physical transport mechanism of bacterial nanowires, both to understand and realize the broad implications for natural microbial systems and biotechnological applications such as bio-electronic devices. This study will inspire further investigations into the molecular and electronic structures of nanowires from a variety of microbes, both to reveal their role(s) in diverse natural environments and for accelerating a wealth of potential applications. On the other hand, organic semiconducting bacterial nanowires might potentially be a new class of functional, one-dimensional bionanomaterials for applications such as nanoelectronics and nanosensors, which deserve further investigations.