# The Analysis and Application of the Emergent Electronic Properties of Self-Assembling Nucleopeptide Systems

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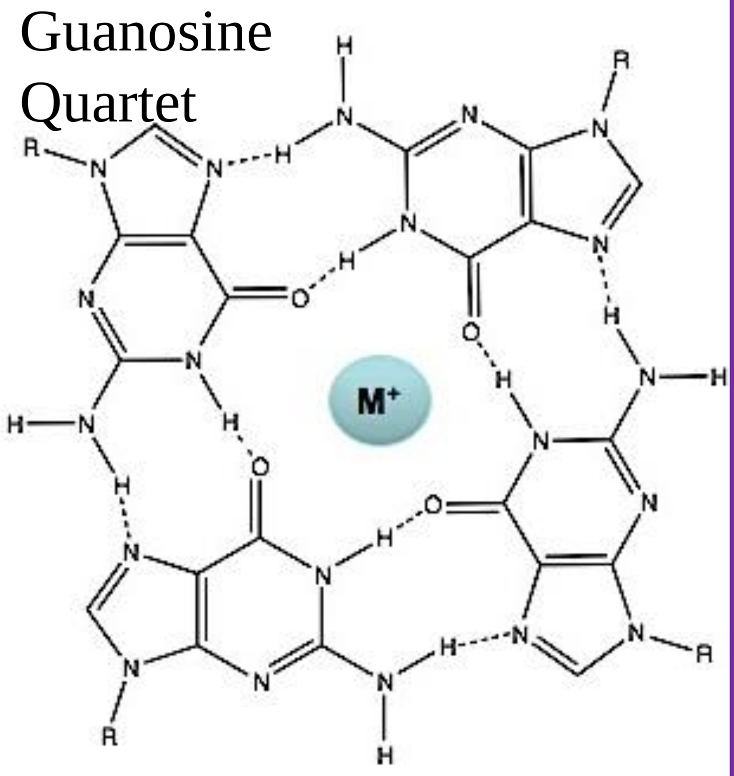
## Abstract

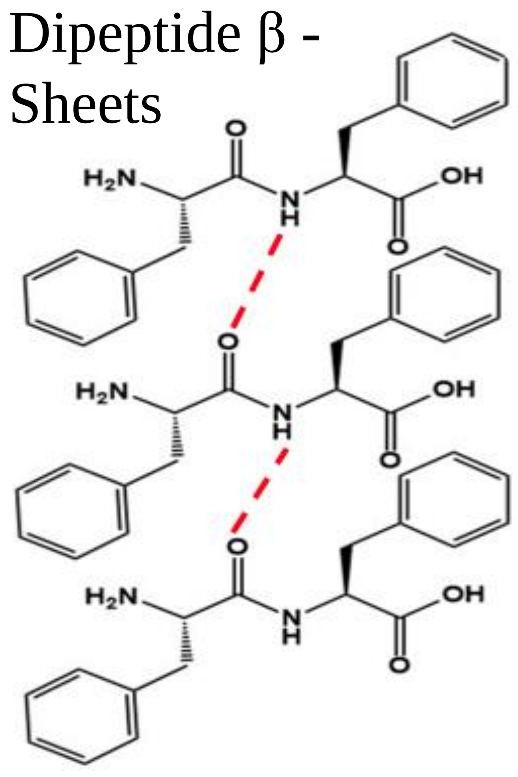
Biomolecular structures are held together by a complex network of molecular interactions that direct assembly and stabilize structures. In order to translate the fundamental molecular interactions of biomolecules into the design of functional biomaterials, we have developed a model system that integrates nucleic acids and self-assembling peptides (shown below). These nucleopeptides serve as a small-model system for the study of the non-covalent molecular interactions involved in biomolecule self-assembly measured through impedance. The peptides are in this case our system of electronic circuit. The emergent electronic properties found in most of our 21 samples, which were measured by Electrical Impedance Spectroscopy (EIS) and analyzed by ZMAN software shows promise. This is because one of the most frequent application to show up was Battery and Supercapacitor which can be used in Biosensors.

## Supramolecular Secondary Structures

Guanosine Quartet

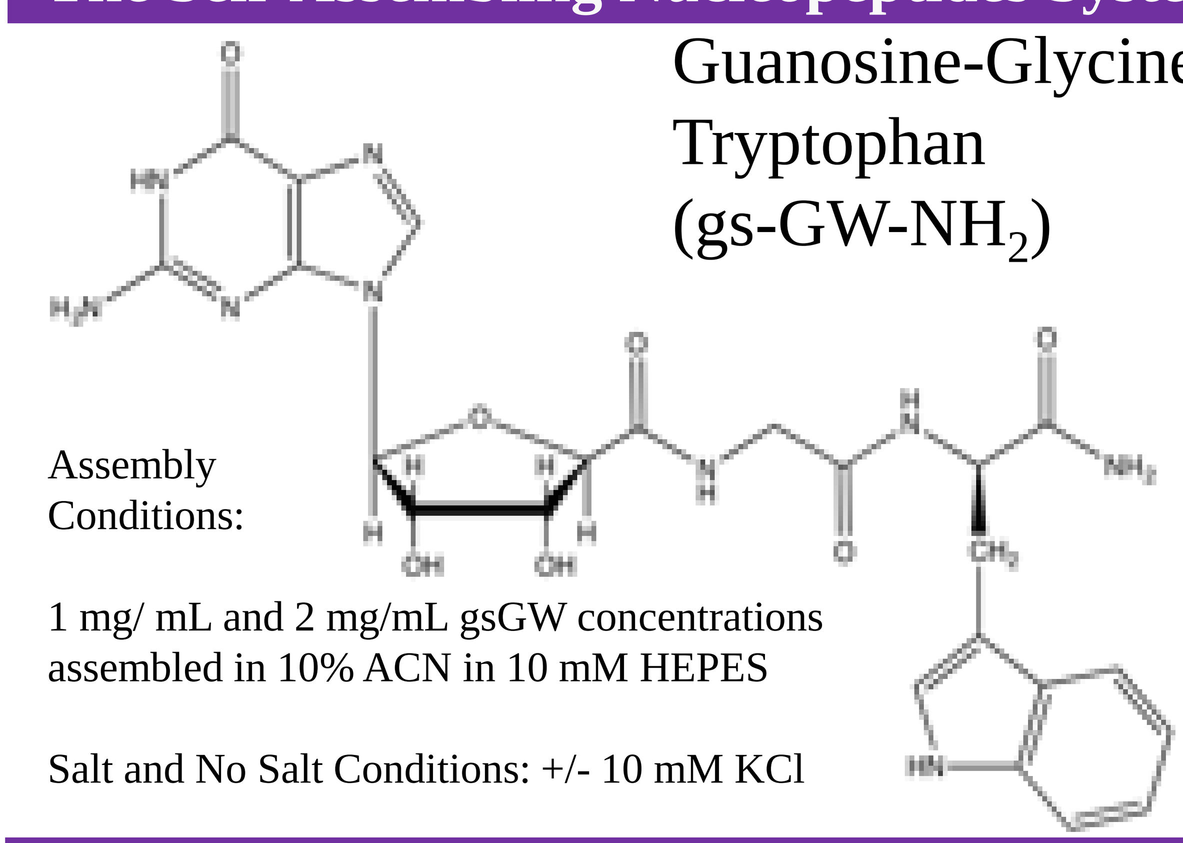



Dipeptide β - Sheets



## The Self-Assembling Nucleopeptides System

Guanosine-Glycine-Tryptophan ($gs\text{-}GW\text{-}NH_2$)

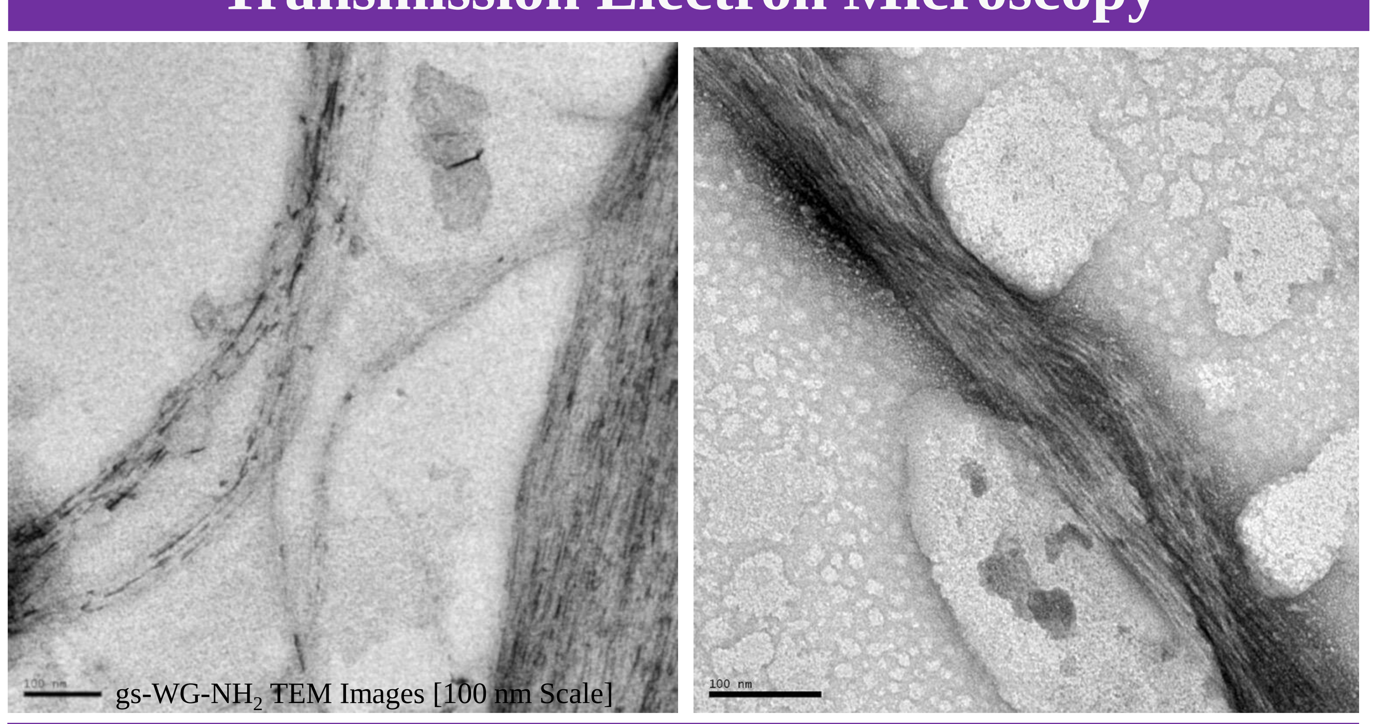


Assembly Conditions:

1 mg/ mL and 2 mg/mL gsGW concentrations assembled in 10% ACN in 10 mM HEPES

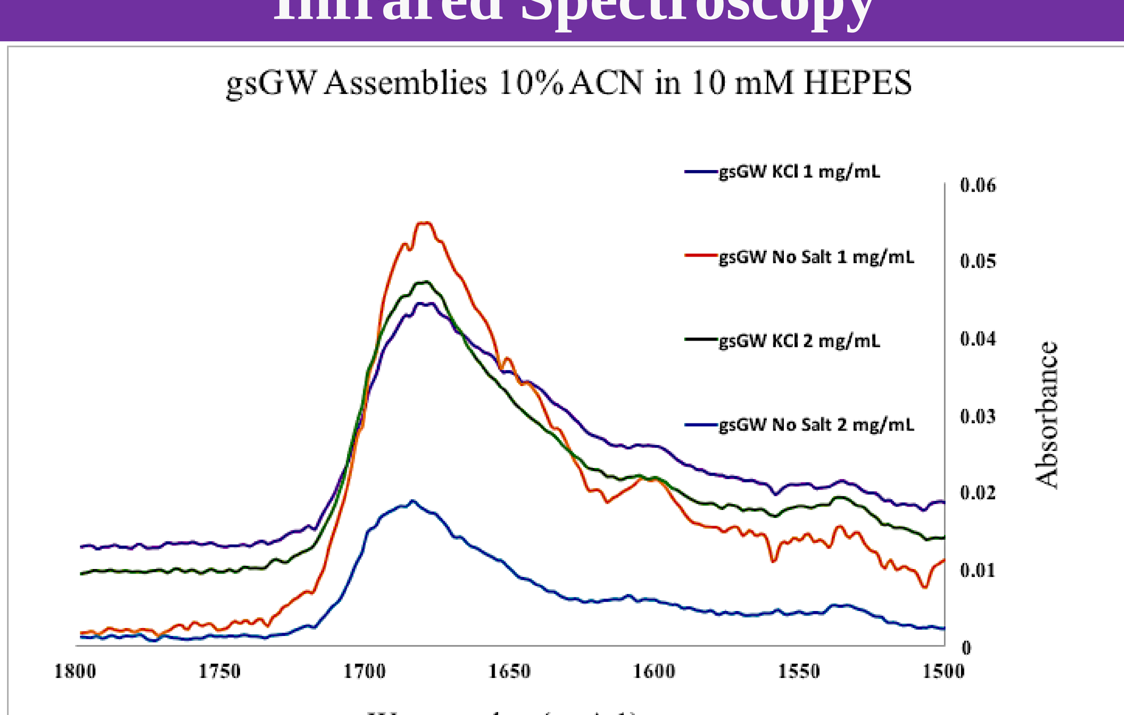
Salt and No Salt Conditions: +/- 10 mM KCl

## Transmission Electron Microscopy

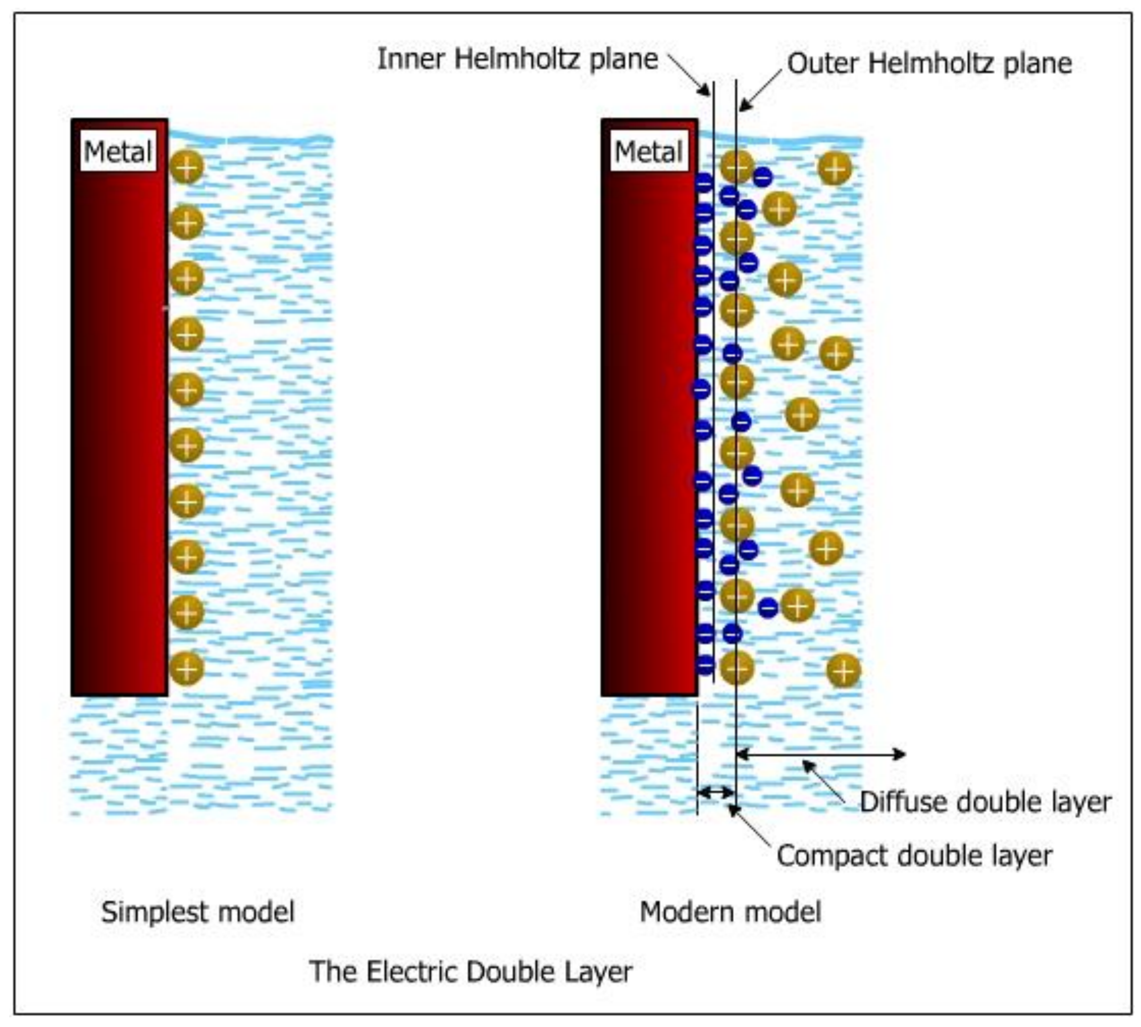


$gs\text{-}WG\text{-}NH_2$ TEM Images [100 nm Scale]

## Infrared Spectroscopy

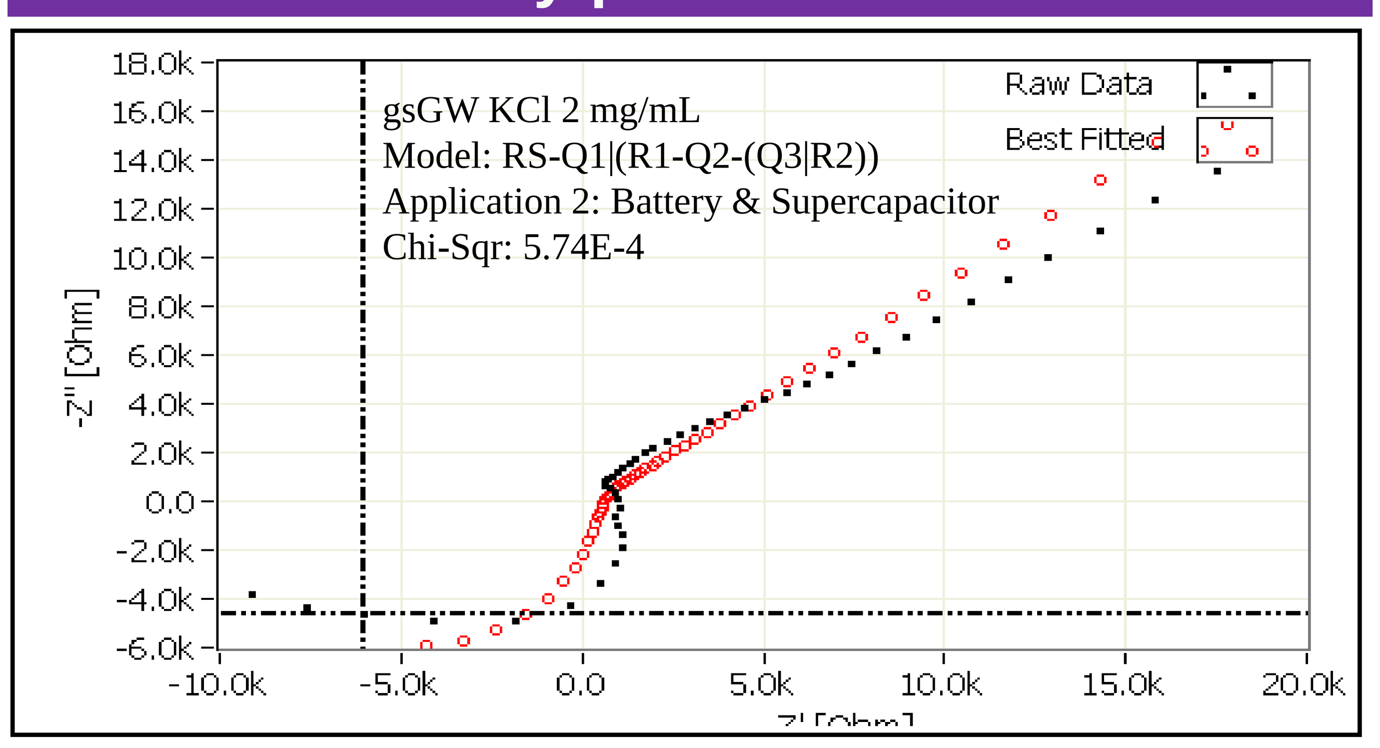


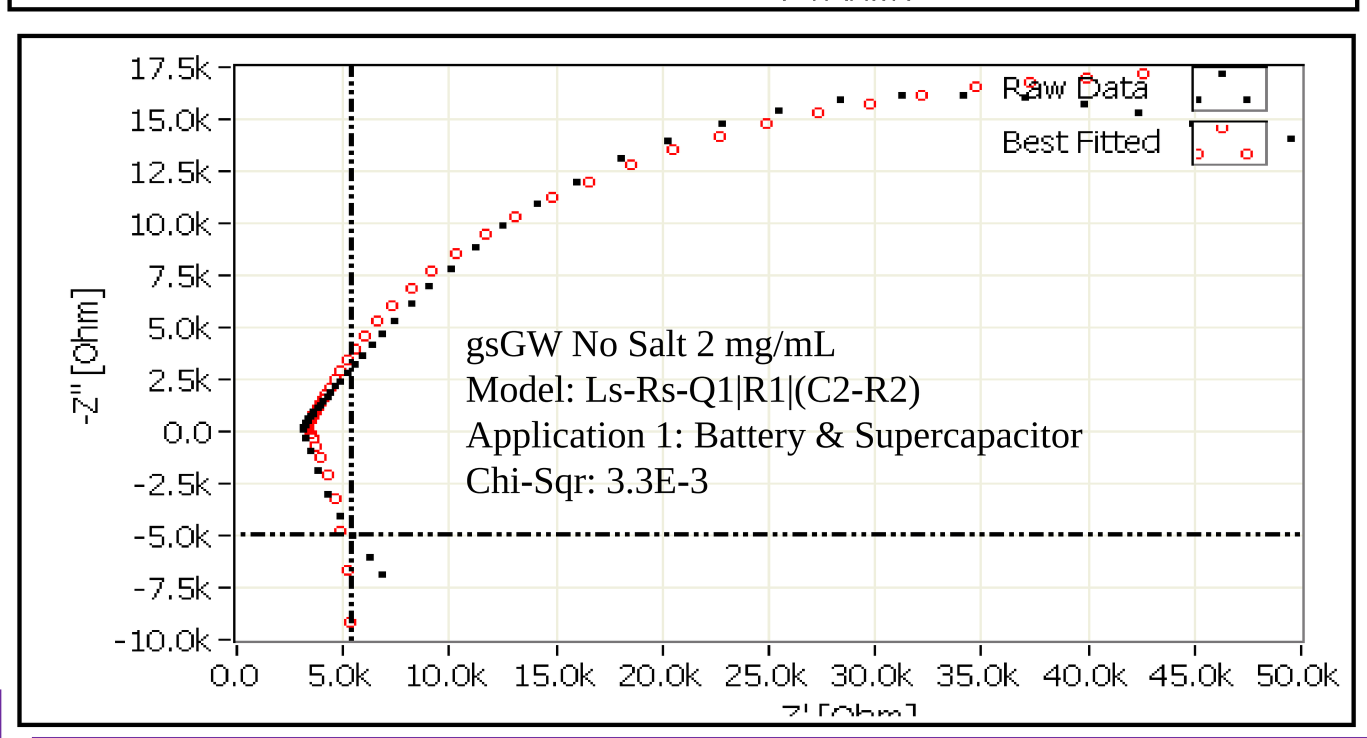

## Electrochemical Impedance Spectroscopy (EIS)




EIS is used to measure the impedance or total resistance in an AC electrical circuit. For a electric circuit to function it has 3 basic components a resistor, conductor, and inductor. Each component has its own impedance presented by the symbol Z. Through the LCR Reactance Phasor Diagram one can eventually find Z total. The first step to analyzing the peptides is by applying a small voltage perturbation and measuring the current response. This is done by taking the bulk solution or peptides and introducing a electrode or cable. In the diagram above the cable is shown as a metal that attracts the anions and makes a Electric Double Layer. This creates a region in the vicinity of the charged surface upto a distance until the bulk solution called debye length, with the inner and outer Helmholz regions forming the first few layers of the ions in the vicinity of the charged surface. Once the data from the sample is collected, it is then plotted by two ways; Bode plots and the Nyquist plots. The Nyquist plot is read right to left and the variables are Z real and Z imaginary. From the 21 samples that we tested, a representative Nyquist plot is shown on the left including the sample name, model, application and chi squared value. The first 3 applications that were shown by the software were chosen and analyzed. The model shows the different components of the system where as the lower the Chi-Sqr the more reliable the equation.

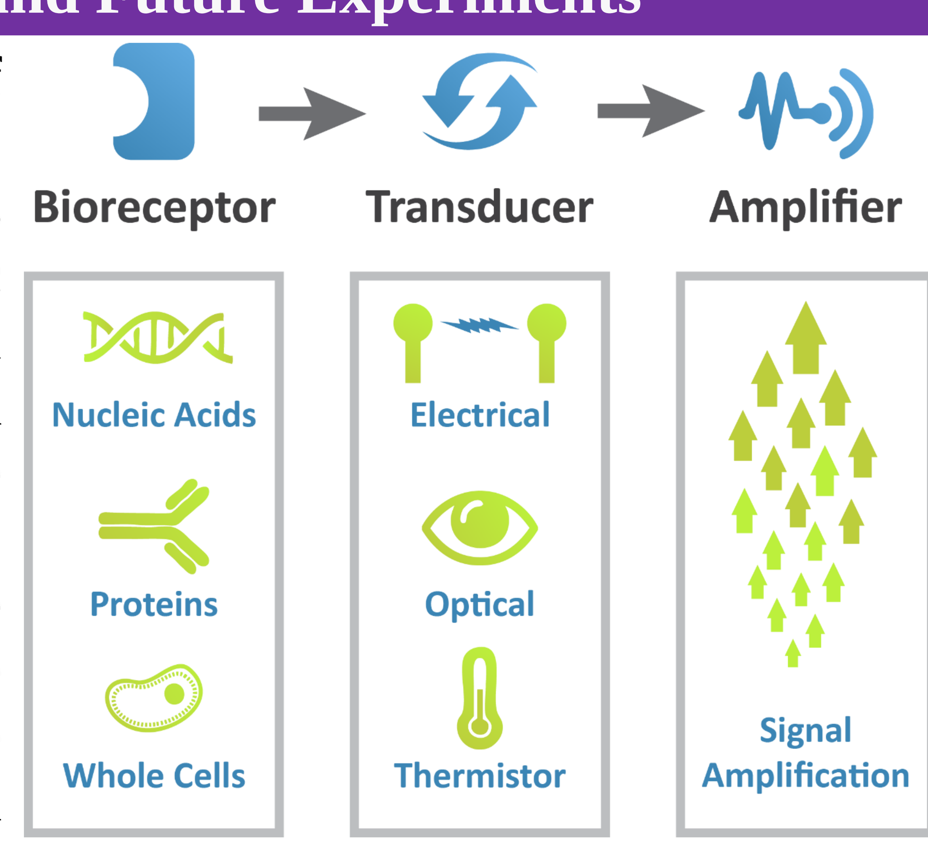
## Nyquist Plots




## Preliminary Successes and Future Experiments

- Successful synthesis and purification of guanosine modified nucleopeptides.
- Characterization of nucleopeptides supramolecular structures by Atomic Force Microscopy, Transmission Electron Microscopy, Infrared Spectroscopy, and Electrical Impedance Spectroscopy.
- In future, further analysis on more samples with different variables will be done. The samples above show promise to be used as Batteries and Supercapacitors in biosensors. More trials will be needed in order to perfect the solutions.

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## References

1. www.Zivelab.com/ 2011 “Zman Software.” Zman EIS analysis software, Zive Lab
2. Orazem, Mark E., and Bernard Tribollet. 2017 Electrochemical impedance spectroscopy.

3. Lisdat, F. & Schäfer, D. Anal (2008) Bioanalytical Chemistry
4. Lasia A. (2002) Electrochemical Impedance Spectroscopy and its Applications.
5. White R.E. (eds) (2010) Modern Aspects of Electrochemistry. Modern Aspects of Electrochemistry, vol 32.