The Equivalent Circuits of Molecular Tunnel Junctions

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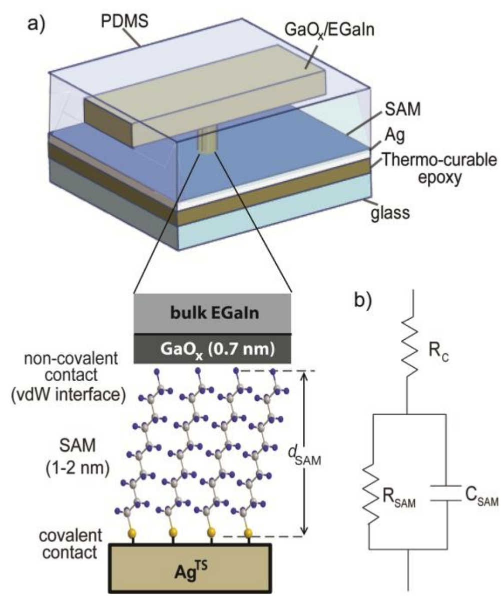
Molecular junctions of the form of electrode–SAM–electrode (SAM = self-assembled monolayer) are appealing because of their potential of inducing, and controlling, electronic function at the nanometer length scales.[1,2] Understanding the nature of the molecule-electrode contacts in these two-terminal junctions is crucial but it is mostly poorly understood.[3] The reason is the electrical properties of electrode–SAM–electrode junctions are usually studied by two-terminal DC measurements which only determine the total current (impeded by all components of the junction) as a function of applied bias. Hence, these methods do not distinguish the contributions of each component (the SAM, the electrodes, and the two SAM–electrode interfaces) to the measured current and are not suitable to measure the dielectric response.

Recently we showed that impedance spectroscopy makes it possible to isolate the contribution of each component in the junctions to the total impedance of EGaIn based junctions (Figure 1).[4,5] Here I will present that temperature dependent and potentiodynamic impedance spectroscopy make it possible to elucidate the bias and temperature dependency of each circuit component (contact resistance, SAM resistance, and the capacitance of the SAM) of two-terminal SAM-based junctions, unlike DC measurements, independently from each other. We found that the metal–electrode contact resistance is independent of the temperature or applied bias and more than 4 orders of magnitude smaller than the thinnest SAM measured, the thin conductive oxide layer plays an insignificant role. We also find that by introducing large polarizable atoms the dielectric response can be engineered at the molecular level.



We believe that impedance spectroscopy as a function of temperature and applied bias is a useful and complementary tool to DC measurements to elucidate how each component of two-terminal SAM-based junctions impedes charge transfer and it opens the door to investigate dielectric response in 2-terminal junctions at the molecular scale.

References

1) Nerngchanmnong, N.; Yuan, L.; Qi, D. C.; Jiang, L.; Thompson, D.; Nijhuis, C. A. *Nature Nanotechnol.* **2013**, *8*, 113.
2) Tan, S. F., Wu, L., Yang, K. L. W., Bai, P., Bosman, M., Nijhuis, C. A. *Science*, **2014**, *343*, 1496.
3) Yuan, L.; Nerngchamnong, N.; Li, J.; Qi, D.-C.; Hamoudi, H.; del Barco, E.; Roemer, M.; Sriramula, R. K.; Thompson, D.; Damien Thompson; Nijhuis, C. A *Nat. Commun.* **2015**, *6*, 6324.
4) Wan, A.; Jiang, L.; Suchand Sangeeth, C. S.; Nijhuis, C. A. *Adv. Funct. Mater.* **2014** *24*, 4442.
5) Suchand, S.S.C.; Wang, A.; Nijhuis, C.A. *J. Am. Chem. Soc. 2014*, *136*, 11134–11144.
6) Heitzer, H. M.; Marks, T. J.; Ratner, M. A. *ACS Nano*, **2014**, 8, 12587.