# Electrochemical Synthesis of Polymer Nanostructures for Thermal Management

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Polythiophene (Pth) nanotube arrays were electropolymerized in boron trifluoride ethyl ether electrolyte using porous anodic alumina (PAA) templates diffusion bonded to metal substrates. Two-dimensional deposition produced tubes with a moderate degree of polymer chain alignment and significantly enhanced thermal conductivity. We have scaled the fabrication process to produce arrays on large-area heat spreaders for power electronics and energy conversion applications. The Pth arrays are chemically stable over 200 °C and provide excellent adhesion, low shear modulus, and contact thermal resistances that are substantially lower than any other pure polymer material. These attractive properties and the facile electrochemical processing can be exploited for advanced and reliable thermal management.

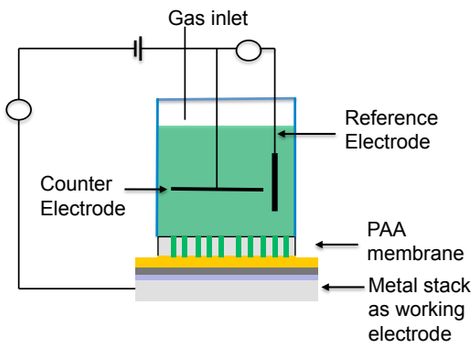


**Figure 1.** Illustration of the 3-electrode cell used to electropolymerize thiophene in the nanotemplate to produce vertically aligned arrays of polythiophene nanotubes.

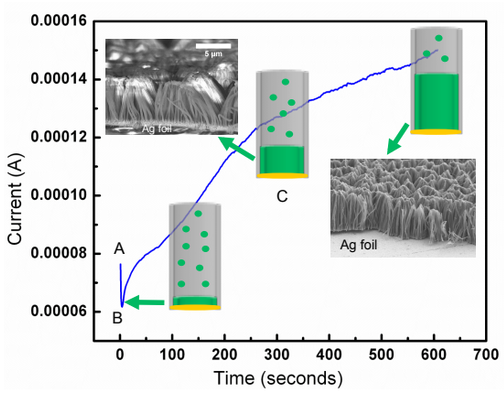


**Figure 2.** Current vs time during electropolymerization of thiophene. The plot shows characteristics of nucleation and 2-D growth. The insets show scanning electron microscope images of the vertical Pth arrays.

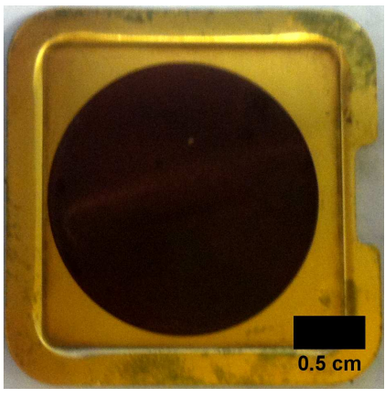


**Figure 3.** Vertically aligned Pth nanotube array grown on the underside of a copper heat spreader used in the packaging of microelectronics.

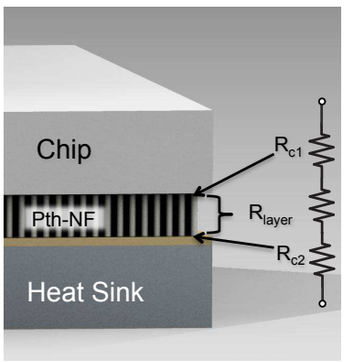


**Figure 4.** Schematic of a typical interface configuration showing that the total resistance is comprised of an intrinsic layer resistance (thickness/thermal conductivity) and the resistance of 2 contacts.

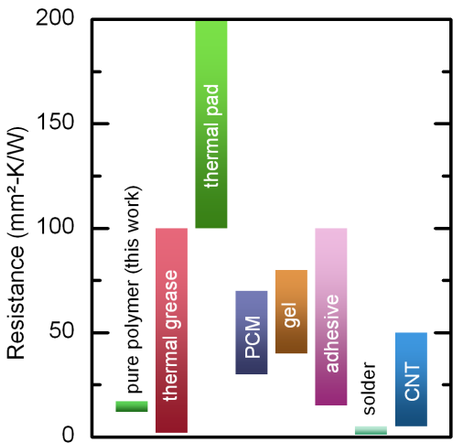


**Figure 5.** Resistances of state of the art thermal interface materials (TIMs) compared to pure polymer nanostructure TIMs.

## ACKNOWLEDGMENTS

We are grateful for the financial support of National Science Foundation Award No. CBET 1133071 and the Georgia Institute of Technology Center for Organic Electronics and Photonics through a seed grant.