CAREER: Corrosion Resistance of Nano-meter Graphene Coatings in Aggressive Microbial Environment

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The annual costs for the direct and indirect effects of metallic corrosion on infrastructure have been reported to reach nearly $1 trillion in United States. Microbial corrosion accounts for nearly 20-40 % of the total corrosion costs. While there are several protective coatings available for metal protection, the commercial coatings tend to fail in the aqueous and microbial environments. The central goal of this project is to investigate a new class of minimally invasive (thickness of few nanometers), pin-hole-free, robust, and protective coatings made from conformal graphene for use against microbial corrosion. This CAREER project enables the rational design of the next generation of minimally invasive, nanometer-scale, microbial-corrosion resistant coatings featuring graphene building blocks. This CAREER proposal seeks to make fundamental contributions in our understanding on why graphene works effectively under microbial conditions. Towards this end, the PI will use Desulfovibrio vulgaris as a model for sulfate-reducing bacteria to investigate the effectiveness of graphene-coatings under varying stimuli related to: i) electrochemical constraints, ii) physiological parameters, iii) the point defects in graphene, iv) wettability of graphene, v) cytotoxicity of graphene, and, vi) graphene-production techniques. In preliminary studies, a detailed electrochemical analysis revealed that the graphene offers ~100-fold improvement in microbial corrosion resistance compared to Parylene coatings, ~41-fold compared to bare graphene, and ~10-fold compared to polyurethane coatings. These findings shows a promise for microbial corrosion-resistant graphene coatings as their average thickness (1-2 nm) is 25-fold smaller than Parylene (40-50 nm), and 4000-fold smaller than polyurethane (20-80 micron). The microscopy and spectroscopy techniques revealed that the microbes observed in this study (e.g. *Strenotrophomonas* species within gammaproteobacteria) can attack polymers and induce micron-length tears leading to non-conformal polymer coatings, while the graphene coating was found to be electrochemically inert, extremely conformal, and resistant to microbial attack. The nano-scale graphene coatings also cause minimal changes to the underlying surface topology.

References (10 point font)

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[2] Krishnamurthy, A.; Gadhamshetty*, V.; Mukherjee, R.; Chen, Z.; Ren, W.; Cheng, H. M.; Koratkar, N. (2013). Passivation of microbial corrosion using a graphene coating. Carbon, 56, 45-49