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# DEVELOPING TITANIUM DIOXIDE-GRAPHENE METAMATERIALS FOR NEXT GENERATION THERMOELECTRICS

**Abstract**

Thermoelectric devices have enabled the exploration of space for nearly 60 years. However, these devices face significant limitations in their future usage due to the current standards for material design. Such limitations include extremely low efficiencies (<7%) and fabrication from hazardous and expensive materials, to name a few. For astronautical purposes, the next generation of thermoelectric devices require fabrication from materials that are lighter, Earth-friendly, and free of tellurides. As such, graphene has been recently proposed as a thermoelectric filler to polymer based ceramic composites. Pristine graphene possesses a thermoelectric figure-of-merit (ZT) of around 0.01, while graphene with defects and functional groups lead to increased ZT values up to 3 times that of the pristine graphene. Incorporation of such altered graphene sheets into a polymer-based ceramic composite was expected to yield thermoelectric behavior in a highly Earth-abundant material system. However, lackluster thermoelectric properties were observed most likely due to a non-synergistic interface between the modified graphene sheets (i.e. reduced graphene oxide) and the polymer matrix of the composite. In order to modify this interface and to understand the influence of the interface on resulting thermoelectric properties of composite systems, this research looks into creating a titanium dioxide-reduced graphene oxide (TiO2-rGO) metamaterial that will be embedded into the ceramic matrix. Here, we have composited TiO2 onto graphene oxide thin films via atomic layer deposition (ALD) in order to create a highly coherent interface between the two components. The creation of such an interface should lead to enhanced thermoelectric properties in the metamaterial when compared to either material by themselves. To investigate this behavior, ALD processing conditions (i.e. precursor, cycle time, number of cycles, and quality of graphene oxide) is systematically varied and relations to the resulting interface structure and chemical composition, electronic, and thermoelectric properties are presented. Multiple types of electron microscopy and spectroscopy were conducted to gain information on the thin film structures and interactions between the TiO2 and graphene oxide. Four-point probe resistivity, Hall measurement, and Seebeck coefficient were the key techniques used to correlate the structural and chemical information to the electrical and thermoelectric properties of the fabricated thin films.