Energy Conversion and Storage

Graphite has been traditionally used as electrodes for Li ion battery and is a highly important energy storage application. However, after the discovery of graphene and reduced graphene oxide, it has been shown these novel 2D materials could be used as electrodes for supercapacitor applications. Similarly, other 2D materials such as transition metal dichalcogenides (TMDs; MoS$_2$, TiS$_2$, SnS$_2$, etc.) and layered oxides (V$_2$O$_5$) have been recently used as excellent electrodes for battery and supercapacitors (Fig. 1). However, there are other layered materials that can have important uses in energy conversion (fuel cell catalysts, piezoelectric conversion devices etc.). This topical area investigates how the atomic thinness of the basic building units of these materials allows one to explore new avenues for design energy storage and conversion devices.

Industrial Relevance
New materials and structures used as building blocks of energy storage devices – batteries and supercapacitors – are emerging from atomically thin layers as these materials have naturally very high surface area and excellent electrochemical behavior. Similarly, some of these structures also show high catalytic activity, making them useful for energy conversion reactions such as the oxygen reduction and hydrogen evolution reactions. Realizing the advantages of these materials on macroscopic and/or industrial scale necessitates studying not only the properties of the individual materials, but also their interaction to surrounding environment. Although specific properties of these 2D nanomaterials were studied in recent years, their behavior in complex, energy conversion/storage devices needs to be investigated. Parameters of the material and device preparation methods need to be optimized. There also needs to be a screening of various 2D materials to identify the appropriate compositions for the right applications. Moreover, the atomically thin dimensions also allow us to explore new applications of these based on thin film constructs for energy storage and conversion applications. Industrial applications of thin films and coatings in the broad area of energy will arise from the knowledge gathered in this project. Specific successes in identifying 2D materials for applications in energy conversion and storage could be further taken up as focused projects that our industrial partners are keen to pursue.

Objectives
The main objective will be to develop various approaches to allow integration of 2D materials into energy conversion and storage devices.

Determined Industry Need
Energy storage (thin film supercapacitors, thin film batteries), energy conversion (electrocatalysts), and self-powered films with multifunctional properties.