Nanotech Battery Technology

Overview: Lithium ion batteries (LIBs) are very popular in portable electronics because of their high energy density and small memory effect. They play an important role in the progress of electric vehicles, power tools, military and aerospace applications. However, like any other any storage system, LIBs still suffer from many shortcomings. While normal electronic devices have seen very rapid progress following Moore's law, batteries have advanced only slightly. Our goal at Nanotech Energy is to minimize that gap by developing a new generation of batteries with performance features far exceeding those currently available in the market.

SUPERbattery: Thanks to its outstanding surface area and high electronic conductivity, Nanotech Energy used graphene to improve the electrochemical properties of the lithium ion battery anode and cathode simultaneously. This has enabled a new generation of lithium ion batteries, we call graphene SUPERbattery, with outstanding power density, energy density and cycling life.

Nanotech Battery Plans: In addition to graphene SUPERbattery, Nanotech is working with four other battery chemistries that handle everything from improved electrochemical performance, higher safety and lower cost. Check out Table 1 in the end of this report for a summary of the characteristics of the five upcoming batteries. Also check out figures 1 and 2 for direct comparison with commercially available energy storage devices.

Generation (V) Chemistry and Specifications:

Electrochemical capacitors, also known as supercapacitors, are energy storage devices like batteries, yet they can be recharged a hundred to a thousand times faster. Because of their enabling features, supercapacitors are replacing batteries and capacitors in an increasing number of applications. They also play an important role in the progress of hybrid and electric vehicles. However, the low energy density of carbon electrodes is the main impediment to realizing the full commercial potential of this technology. This has triggered tremendous research efforts in order to develop new hybrid electrode materials that are capable of providing a huge amount of energy in a short period of time. Nanotech Energy has developed groundbreaking energy storage technology that has the high capacity of a battery and the power performance of supercapacitors in one device. This was made possible by carefully addressing the device chemistry and combining active materials with electrolytes that operate at high voltages. Nanotech Generation V Batteries feature aqueous alkaline electrolytes and are assembled in air without the need for expensive 'dry rooms' required for building today's supercapacitors, which promises ten times reduction in production cost. Furthermore, these hybrid batteries can store more charge than a traditional lithium ion battery, yet they can be recharged in just a few seconds compared to hours for conventional batteries. The capacity of the new hybrid batteries is also superior to commercially available supercapacitors, pseudo-capacitors, lithium ion capacitors and asymmetric supercapacitors we tested under the same conditions. In addition, the device combines very low ESR of less than 5 milliohms (18650 form factor) and essentially unlimited charge/discharge cycles. They also demonstrate excellent rate capability as demonstrated by ultrafast charge/discharges rates of up to 200 C, Figure 3 and 4. More importantly, These batteries are non-toxic, non-flammable and contains no silicon, which has raised many issues in modern electronic devices. With their remarkable performance, Generation V batteries will ultimately offer novel opportunities in powering the next generation of portable electronics.

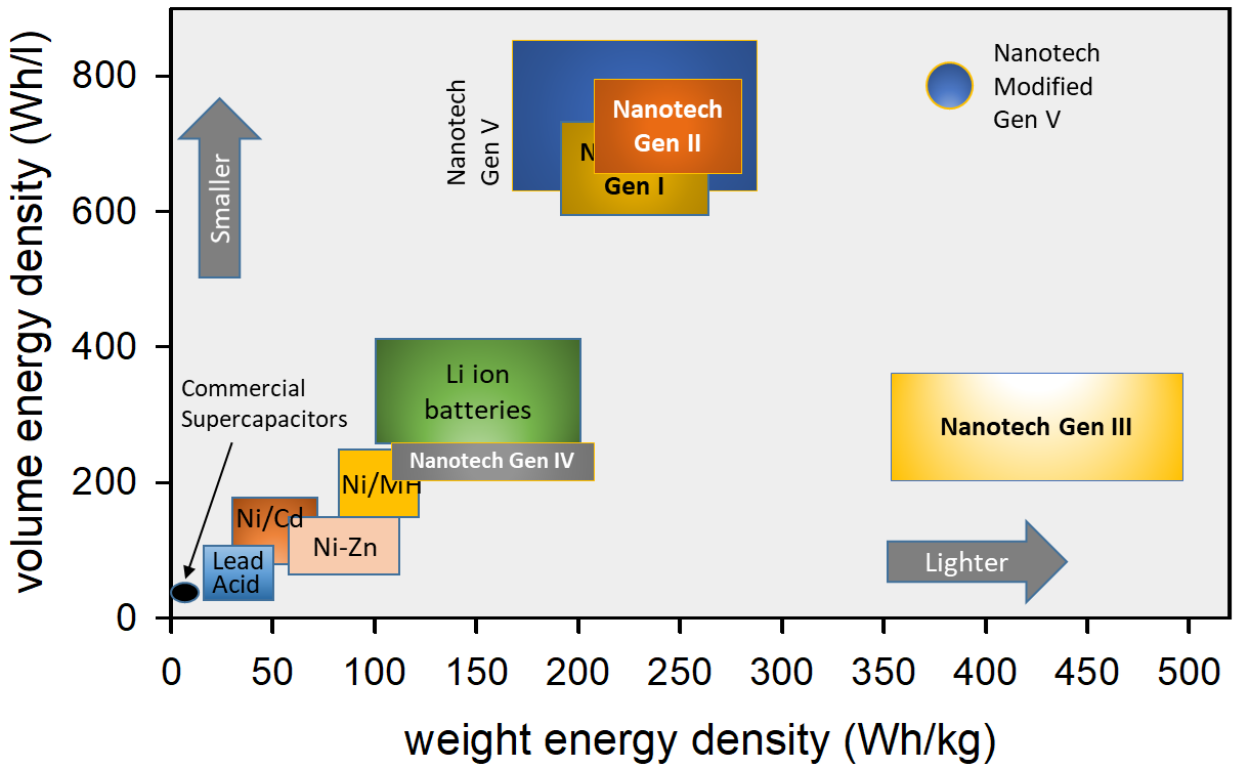


Figure 1: Comparison of the gravimetric and volumetric energy densities of Nanotech batteries (Gen I through V) with those of commercial batteries.

We currently have five generations of energy storage devices whose energy density (gravimetric and volumetric) are superior to those of other energy storage technologies.

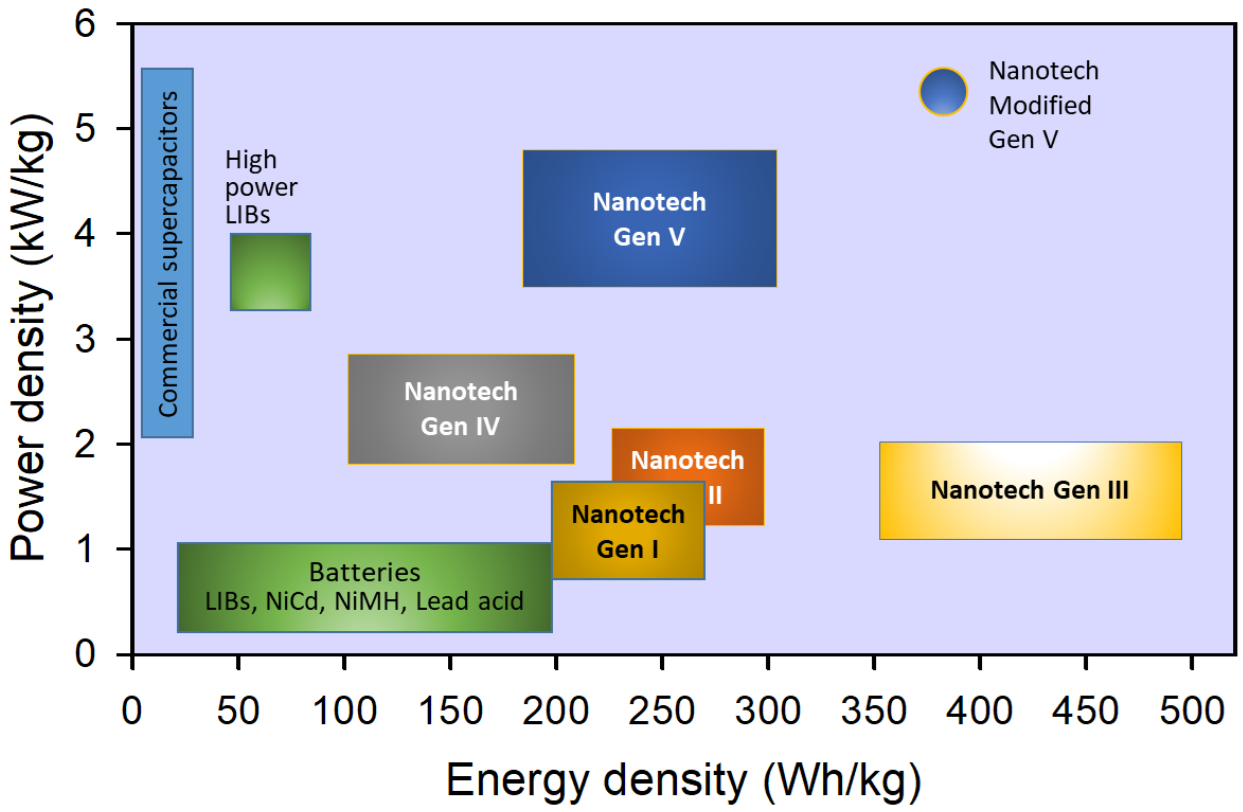


Figure 2: Ragone Plot showing the energy density and power density of Nanotech batteries.

This Ragone plot shows that Nanotech energy storage devices demonstrate high energy density and power density compared with those of commercial batteries and supercapacitors.

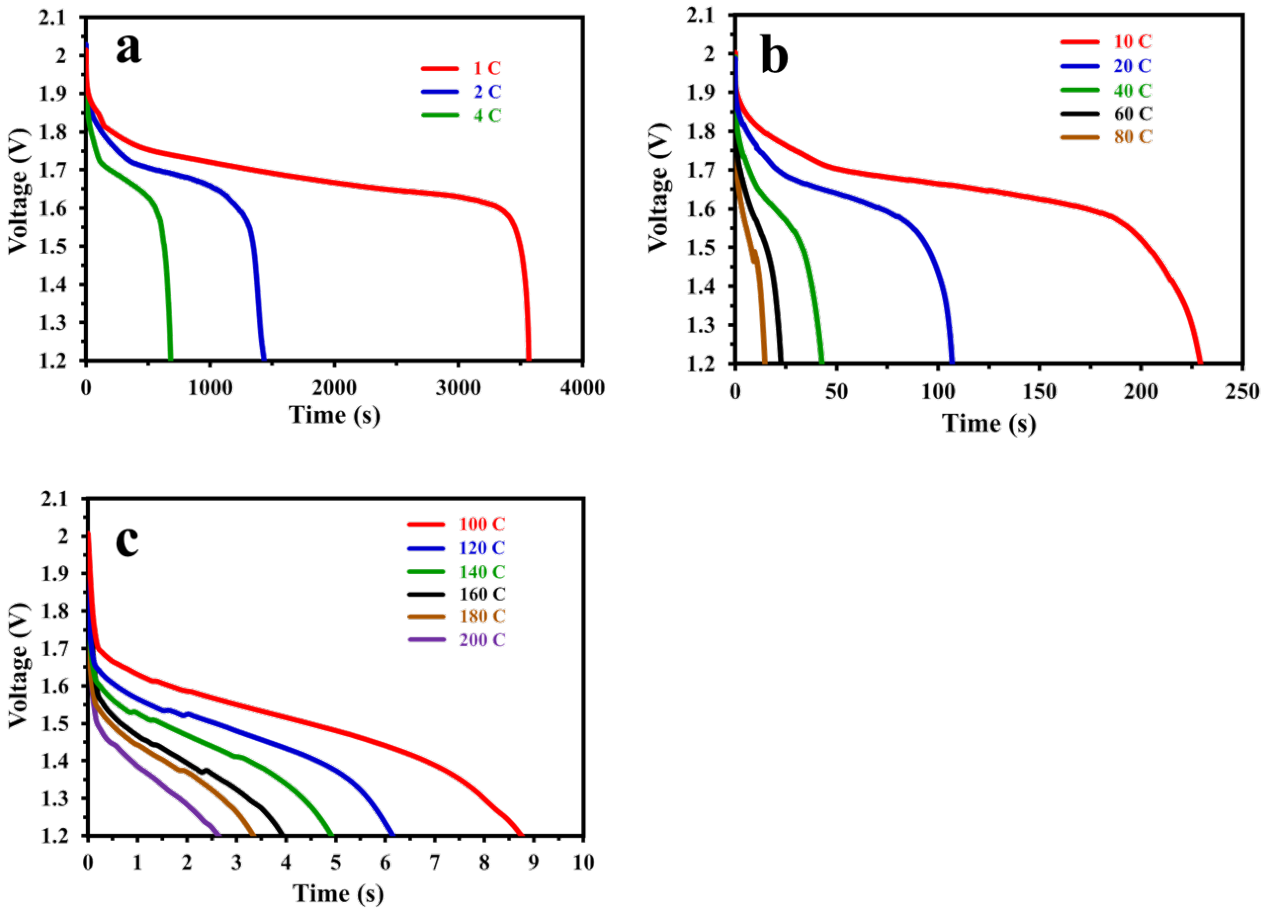


Figure 3: Discharge characteristics of Gen V supercapacitors tested at different rates. Note the discharge time vary from hours to 2.5 seconds if high power current pulses are needed.

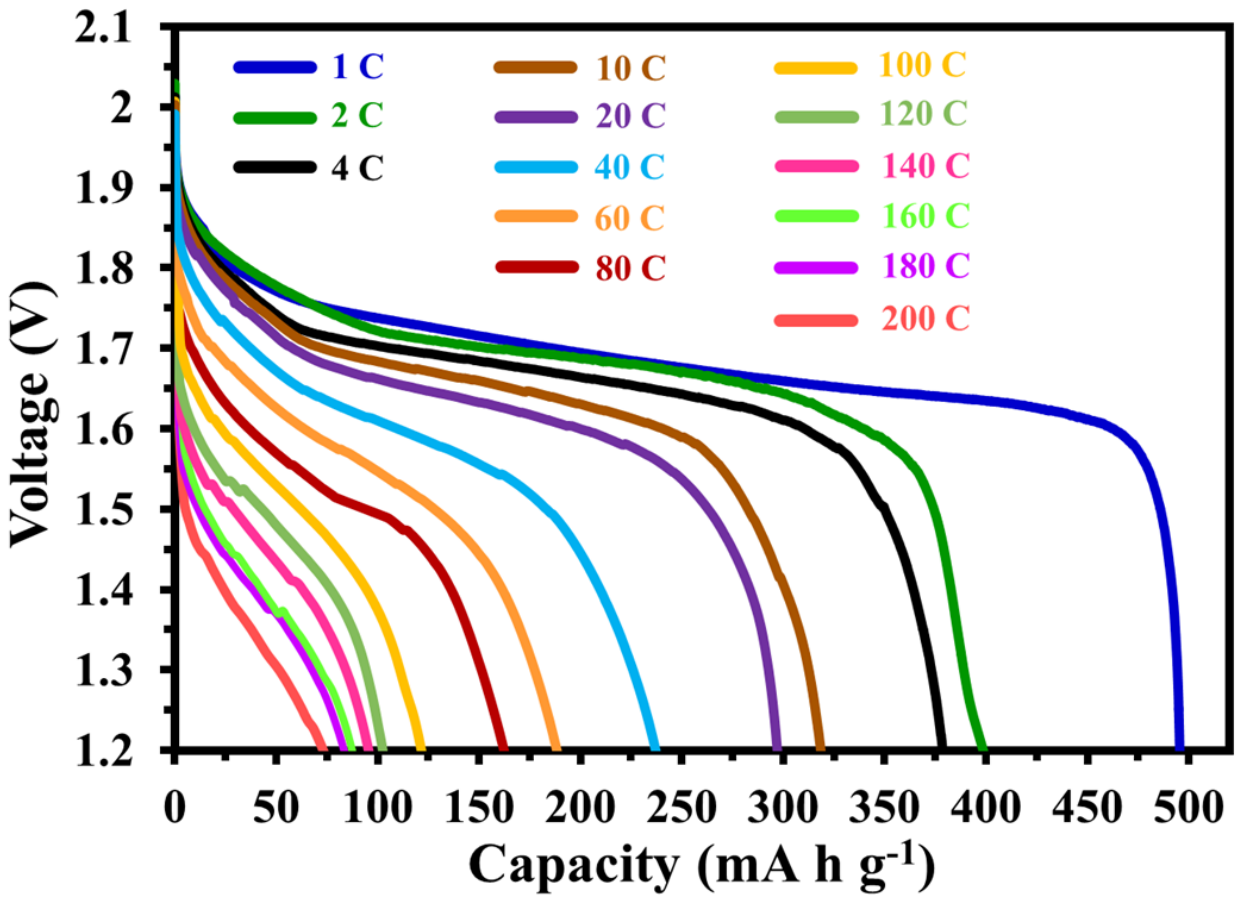


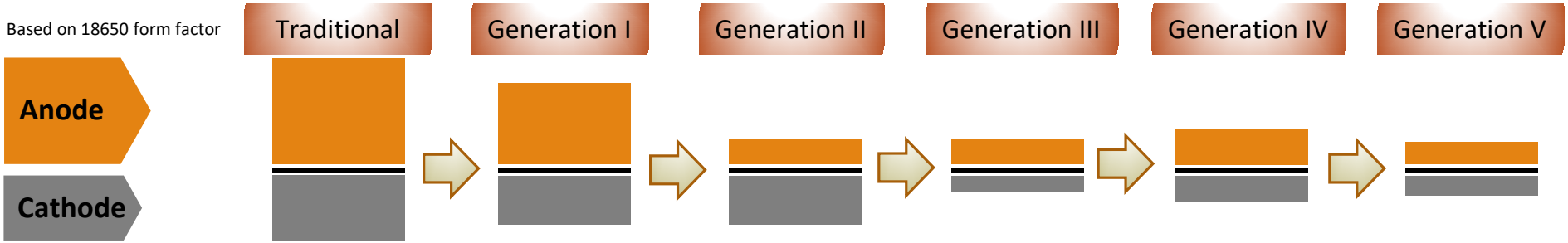
Figure 4: Discharge characteristics of Gen V at different discharge rates. Capacity normalized to the mass of active electrode materials. A maximum capacity of ~ 500 mAh/g can be achieved, which is superior to lithium ion batteries at ~100 mAh/g for lithium ion batteries. These batteries were assembled in air and no expensive dry room operations.

Gen V supercapacitors maintain very high capacity of approximately 500 mAh/g and maintains excellent performance even when tested at higher discharge rates up to 200 C, compare at ~6-10C for high power lithium ion batteries currently available in the market.

NANOTECH ENERGY

Nanotech Battery Roadmap

Based on 18650 form factor



Performance	Traditional	Generation I	Generation II	Generation III	Generation IV	Generation V
Anode	**Graphite** ▪ Capacity: 300 mAh/g ▪ Processing: NMP	**Anode I** ▪ Less binder & more active material	**Anode II** ▪ Processing: water ▪ 600-800 mAh/g	**Anode II** ▪ Processing: water ▪ 600-800 mAh/g	**Anode III** ▪ >2250 mAh/g	**Anode IV** ▪ >600 mAh/g
Cathode	**LiMOx** ▪ Capacity: 100-200 mAh/g	**Cathode I** ▪ Less additives & more active material	**Cathode I** ▪ Using cathode developed in Gen. I	**Cathode II** ▪ Processing: water ▪ >1000 mAh/g	**Cathode III** ▪ >3177 mAh/g	**Cathode IV** ▪ >500 mAh/g
18650 mAh	**1500-2200 mAh**	**2500-3400 mAh**	**>3000 mAh**	**>5000 mAh**	**2500-3000 mAh**	**6450-8600 mAh**
Electrolyte	**Organic**	**Organic**	**Organic**	**Organic**	**Aqueous**	**Aqueous**
Power (ESR)	**~100 mΩ**	**10-30 mΩ**	**30 mΩ**	**20-30 mΩ**	**< 10 mΩ**	**< 5 mΩ**
Cycle life (100% DoD)	**200-300 cycles**	**~1000 cycles**	**~1000 cycles**	**~1000 cycles**	**10,000+ cycles**	**10,000+ cycles**
Status	**Finished**	**Finished**	**In progress**	**Future/Development**		