South Korea at the Forefront of Electrical Vehicle Commercialization

High Performance Ultracapacitors Based on Nitrogen-doped Graphene

Professor Jang Wook CHOI (Graduate School of EEWS)

It is difficult to imagine a world without electricity. From computers and car dashboards to household appliances, practically everything that we utilize in our daily lives uses electricity. Behind this modern 'electricity civilization' lies the hidden role of capacitors. Capacitors play a critical role of storing electricity and supplying it to various devices whenever and wherever required. They are particularly important in automobiles. Capacitors are the components that initiate the engine when a driver starts the car, and they are essential in electrical vehicles, which are being developed worldwide. In the case of electrical vehicles, limited storage capacities have presented many difficulties in the development process. For the item to be commercialized, it is critical to ensure sufficient travel distance after charging. The high performance ultracapacitors based on nitrogen-doped graphene developed by Professor Jang Wook Choi and his research team have resolved the insufficient capacitance issue and will likely expedite the commercialization of electrical vehicles.

Conventional capacitors are commonly used in small household appliances. This is because their capacity is not large enough to supply electricity to larger devices. With growing interest for the development of a new energy storage device to replace fossil fuel, there has been growing demand for supercapacitors. Active research in the development of ultracapacitors, which have greater capacitance than their original counterparts, has opened new possibilities to replace auxiliary power supplies for power plants and electrical vehicles. Ultra high performance capacitors developed to this day are considerably advanced in terms of energy storage capacity and efficiency; however, their applicability does not exceed 50%. Furthermore, few cases have effectively resolved the life cycle problem, which is arguably the most important factor in power supplies.

Two important determinants of a device's life cycle are electrode durability and the capacity to store large amounts of energy. Graphene is a so-called 'dream material' that satisfies both of these properties. The energy storage property of graphene, a nanomaterial composed of carbon produced by a single sheet exfoliated from the surface of graphite, can be enhanced by applying a simple procedure. This improvement will enable the production of capacitors with increased storage capacity and life cycle.

Nitrogen-doped Graphene Serves Dual Purpose

Supercapacitors must meet two conditions prior to commercialization: storage capacity and life cycle. These two properties, however, often offset each other. Increasing storage capacity reduces the life cycle and vice versa. Attempting to fulfill both properties is analogous to chasing two rabbits at the same time. In the case of graphene, repeated use does not deteriorate its performance, and thus long life cycle is guaranteed. On the other hand, its storage capacity is not sufficient for commercialization.

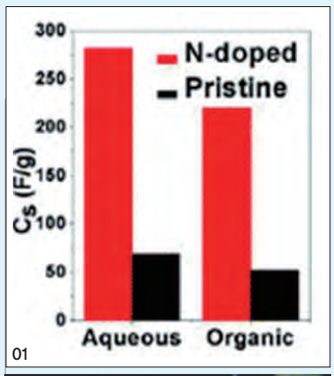
By doping nitrogen – which has one more electron than does a carbon atom – to graphene, it is possible to create a capacitor with significantly enhanced energy storage capacity. The force attracting electrical charges is much greater for nitrogen-doped graphene than in the case of ordinary graphene. As a result, the capacitor's storage capacity can be increased by storing larger amounts of electrical charges. Moreover, the addition of nitrogen does not alter the original graphene's durability or mechanical

properties, and consequently the favorable life cycle property is preserved. The capacitor developed by Professor Choi and his research team exhibits capacitance of 280 F/g, roughly six times greater than that of capacitors based on ordinary graphene, and robust cycling of 230,000 times, well above the commercialization standard of 100,000. This constitutes the most outstanding performance in the world with respect to storage capacity and life cycle.

Wearable Capacitor

Graphene is a nanomaterial composed of carbon produced by a single sheet exfoliated from the surface of graphite. Since graphene retains its key properties even when it is bent or folded, it can be used to produce components with modifiable shape, such as 'flexible displays' and 'folded memory'. The IT industry, in particular, is keeping a close eye on graphene development, because the ability to change shape can increase the device' s portability. The same flexible property applies to graphene capacitors, allowing them to be designed to be worn as part of clothing. Professor Choi developed a capacitor based on nitrogen – doped graphene that could be wrapped around the arms. Flexible capacitors will improve portability and electrical efficiency, and play a critical role in the next generation IT devices.

Professor Choi's results overthrow some previously established theories in academia. There have been many investigations combining graphene with other atoms such as nitrogen, due to graphene's favorable properties as material. While previous studies have shown that nitrogen does not mix with graphene on the basal plane and is only attached to the edge, the plasma process employed by Professor Choi allowed nitrogen to dope with graphene not only at the edges but on the basal plane as well. The results have been verified by a component analysis using ion accelerators. This breakthrough is expected to have a large impact on academia as it overthrows many ideas that were generally accepted in the academia. Professor Choi not only succeeded in developing ultracapacitors based on nitrogen – doped graphene, but also achieved a remarkable academic accomplishment.



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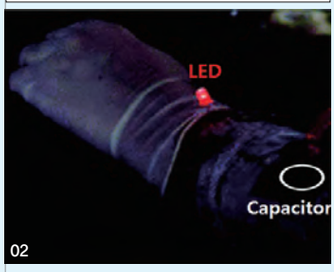

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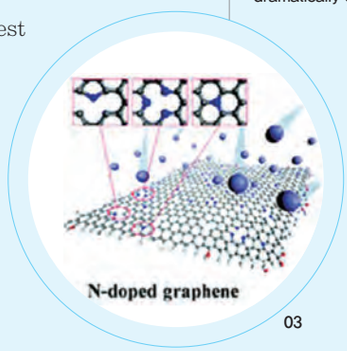
01 Comparison of nitrogen – doped graphene and ordinary graphene. Capacitors based on nitrogen – doped graphene exhibit storage capacity six times greater than that based on ordinary graphene.

02 Graphene – based capacitors can be applied in various settings as they can change shape freely. Wearable capacitors are expected to be commercialized soon.

03 In nitrogen – doped graphene, nitrogen atoms are forced into the graphene structure. The nitrogen atoms attached to the graphene surface dramatically enhance electrical efficiency.

Implications and Future Prospects

The performance of Professor Choi's ultracapacitors is arguably the best in the world. They are immediately applicable to areas that require high storage capacities such as electrical vehicles. The newly developed capacitor is also expected to contribute to environmentally friendly industry as it will help replace fossil fuels. The technology can be readily commercialized because the nitrogen – doping process is very simple and does not require new infrastructure for industrial production. Above all, the extraordinary finding that nitrogen doping enhances the energy storage property is expected to have a major impact in academia.



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- **Patent** | In the process of domestic patent procurement
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