The Future of Graphene Nanoparticles in Industrial Automation Applications

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Graphene is touted for several applications due to its beneficial properties and the synergistic benefits brought about by utilizing its different properties. There are already many applications where graphene is having a real-world, commercial impact and there are several emerging applications. It is also thought that graphene will play a role in industrial automation in the near future.

Almost all manufacturing and industrial processes will be automated in some way in the near future in the era of the so-called Industry 4.0. The ability for many processes to become automated offers the following benefits:

- Cost-efficient
- Enables system monitoring
- Provides warnings to operators
- They can be optimized with minimal (or zero) human input

There has been a drive to implement industry 4.0 on a wide scale, combining physical monitoring approaches, big data, and artificial intelligence algorithms, as well as the Internet of Things (IoT). While many industrial automation processes focus on software (as these provide the analyses and optimization protocols), the importance of the physical infrastructure that underpins the data/software cannot be understated.

In terms of industrial automation's physical infrastructure, there is much potential for graphene to be used. These promising areas will be discussed below.

Sensors in Industrial Automation

Sensors are one of the most important devices in any automation, monitoring, or IoT approach. While the software and data algorithms get a lot of credit, they would not be able to make predictions or optimize processes without data. This data comes from an array of sensors strategically placed around the process/manufacturing line and are in place to detect and monitor a range of factors. These can include but are not limited to, detecting different gases, temperature, humidity, strain, the optical properties of product, and the presence of harmful chemicals in the working area.

Out of all the electronic devices where people talk about graphene, sensors have the most potential and there are already a range of graphene-based sensors on the market which are designed to detect different parameters. The infrastructure is already being created using graphene, it just needs to be implemented into the automation systems.

Why Use Graphene in Sensors?

The inherent thinness of graphene can create very small sensors. Graphene sensors are very interactive with their local environment and minute changes can trigger a detectable response thanks to graphene’s high electrical conductivity and charge carrier mobility which changes in response to an external stimulus. Graphene sensors are highly sensitive and can be integrated into locations where other (bulkier) sensors may struggle.

With IoT and artificial intelligence algorithms, the more accurate the data being recorded is, the more accurate the predictions and optimizations will be. Therefore, there is a need to obtain the most accurate data possible to complement the automation algorithms, and it is likely that we will see graphene sensors being used to provide this accurate data in the future as graphene sensor commercialization and automation integration gain more traction.

Energy Devices

he creation of graphene-based energy storage devices has seen a lot of recent commercial involvement. Energy storage devices are not applicable for all automation processes as many sensors and components are connected to the mains. However, energy storage devices can be key for monitoring processes that are more remote/in harsh processing conditions, reliable and long-lasting.

Many components and devices require batteries or supercapacitors, and both graphene-based batteries and supercapacitors are now starting to become a commercial reality.

Graphene's high electrical conductivity enables large amounts of charge to be stored and released, enabling devices to be powered for longer.

Another area, which is only applicable to more remote monitoring and data acquisition methods, is energy harvesting devices. There has been a drive to create nanogenerators that convert energy from the local surroundings (be it mechanical energy, heat/thermal energy, or otherwise) and convert it into electrical energy. While the energy produced is small, it is often enough to power the sensor it is attached to.

While energy storage and harvesting devices are not applicable for all industrial industries, those that require some levels of remote or environmental monitoring could benefit from graphene-enhanced devices to power the remote sensors. There is a lot of work going into these devices—especially energy storage devices—and the use of graphene energy storage devices is likely to extend into many industrial applications in the future (not just in terms of automation/monitoring).

Wireless Communications

One of the key things about automation systems is their ability to collect and analyze data from many locations, pick out trends, and implement an appropriate response to the data being provided. Sometimes there is no response, however, in others, it can be a warning to a human operator. An internal optimization by the software itself may also be needed. For all of this to occur, the different components need to interact and communicate with each other. In some cases, this can be through wired communications. However, for many devices to be connected around large sites (and in large monitoring systems) they need to be connected wirelessly. This tends to be via microwaves or radio frequency (RF) waves.

There have been several devices created using graphene that can act as either transmitters or receivers for both RF waves and microwaves—with RF waves being the more common approach. A lot of these have been based around creating graphene-based transistors, which can then primarily be used to build antennas (for either a receiver or transmitter) that can communicate using different electromagnetic waves.

Graphene transistors are also being used in other receiver/transmitter components, including amplifiers, mixers, switches, oscillators, and modulators that enable various forms of signal modulations.

While graphene’s electrical properties are crucial in creating transistors that are highly efficient (and small), the small size, its mechanical properties, as well as the properties that graphene induces into the transistors are also vitally important. For example, many graphene transistors have been made to date already, and there has been much interest in creating RF communication systems with graphene. A lot of the devices to date have a high performance, but also exhibit a high gain and a high cut-off frequency—which can be high into the Gigahertz (GHz) and the Terahertz (THz) range.

There is much interest in developing graphene-based wireless communication systems, but they have not reached the commercial level/market adoption phase that other graphene-based systems are at. Nevertheless, there is the potential (if research and development efforts continue) for graphene to be used within these communications systems in the near future, as there are several different components within receiver/transmitter systems where graphene can be integrated.

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