Development support tools for nano/advanced electronic materials, Semiconductor process monitoring and inspection technology

Terahertz emission spectroscopy for advanced electronic materials and devices ~from phenomenology to quantitative analysis~

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Abstract

Photocarriers excited with an femtosecond laser generates terahertz radiation. The terahertz emission spectroscopy has been attracting much attention to unveil the intrinsic ultrafast carrier dynamics. Now we are extending the method from the phenomenological discussion tool of the space-time photocarrier dynamics to a quantitative analysis tool that can extract specific physical properties of semiconductors in a non-destructive, non-contact manner. Here, we introduce two examples of our work.

Background & Results

Breakthroughs in the development of advanced materials and devices are always waiting novel analytical methods. The terahertz wave emission spectroscopic imaging technique is characterized by its ability to visualize the spatio-temporal transfer of photo-excited high-speed carriers. Extension of this technique to various fields will lead to breakthroughs in the developments of the advanced materials, devices, and semiconductor industries. In the future, it is expected not only to bring important innovations in the development of advanced electronic materials and devices, but also to expand into a large market by ensuring its use in semiconductor R & D.

Significance of the research and Future perspective

Terahertz radiation spectroscopy has been used mainly for semiconductor characterization since the 1990s, and we have been playing a leading role in its application to other novel materials. Recently, it has also been used for the evaluation of spin materials. However, its application as a spectroscopic method has been mainly limited to supporting phenomenological discussions, and we have been working on extracting various case studies in order to apply it to more practical fields. Here, we introduce two examples.

One is an example in which we have clarified the dynamics of excitons and post-dissociated free-carriers in carbon nanotubes with the theoretical model in the phenomenological discussion. In particular, by comparing an array of nanotubes with a random system, the former shows ballistic conduction within the same tube, while the latter reveals a picture in which the contacts between the tubes act as defects and drift like conventional free electrons. This approach is a new spectroscopic technique that will greatly contribute to the development of advanced materials and devices.

Another example is the application to the evaluation of surface treatment of silicon wafers. Surface treatment is an important part of the semiconductor process. As an example, a surface is covered with oxides, fluorine, and hydrogen before, during, and after treatment with a buffered hydrogen fluoride (BHF) solution. The surface potentials during these changes can be easily analyzed non-destructively, non-contact, quantitatively, and over a large area. We are proud of the fact that we have completed this method to the point where it can be used in semiconductor R&D, together with our previous work on MOS structures, through-silicon vias, and solar cell evaluations.

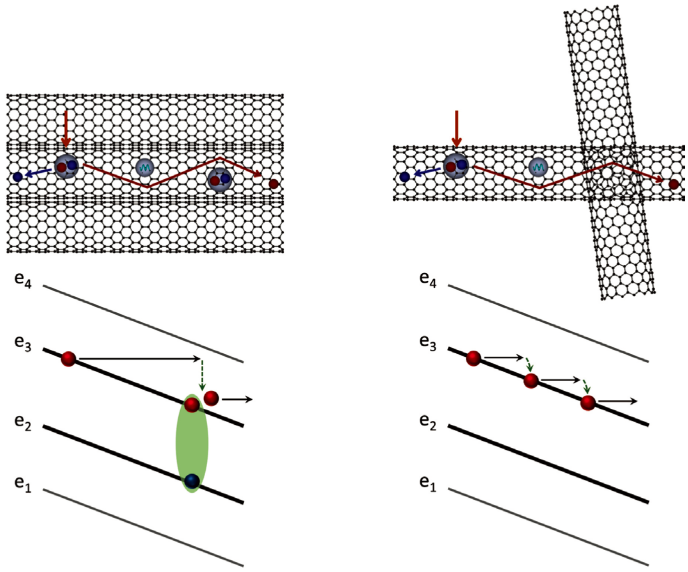

Fig. 1 One-dimensional confinement of quasiparticles within aligned and randomly oriented carbon nanotubes (CNTs) leads to highly anisotropic electronic and optical properties. In macroscopic aggregates, hot carriers move in ballistic and relaxed manners, respectively.

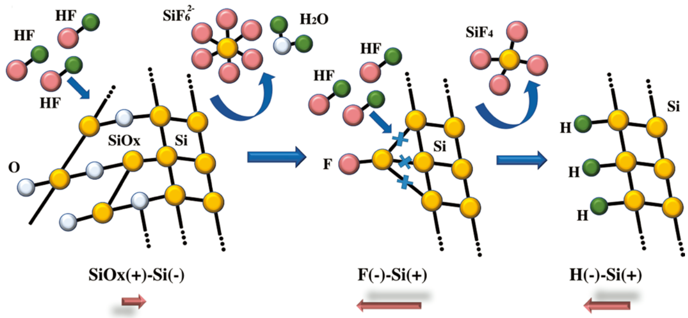

Fig.2 Si surface chemistry during BHF etching and the surface dipole moment resulting from the different electronegativity of the surface atoms. The native oxide film is removed, F-terminated Si is formed as an intermediate step, and finally H-terminated surface is formed as the stable state.

Nanotechnologies / Materials

Patent

Treatise
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