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（博士課程）
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論 文 要 旨

THESIS SUMMARY

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学生氏名： Student's Name	工藤 泰彦	指導教員（主）： Academic Advisor(main)	木口 学
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words）

Graphene has attracted tremendous attentions owing to its unconventional electronic properties originating from the linear band dispersion described by the massless Dirac equation. In addition, nano-sized graphene increasingly attracts interests because of its possession of edges. A localized electronic state at zigzag-shaped edges, called the edge state, has been examined in terms of its exotic electronic and magnetic properties. Furthermore, the edge state can be sensitively affected by functional groups bound to the edge carbon atoms. Studies on the magnetic properties of the edge state have been usually employed nanographite samples having a large amount of edges. However, such samples show apparently different electronic behavior compared with graphene. It is indispensable to examine the emergence and the modification of the edge state in a single graphene sheet for elucidation of the fundamentals as well as potential applications, although experimental information is lacking. Thus, in this thesis, it has been examined how electronic phenomena originating from edges can be observed in graphene having artificial edges and whether the edge state actually emerges at the edges. Moreover, the method of chemically controlling the edge state has been explored. Firstly, in order to verify what kind of nanostructure of graphene can have a large contribution of edges, nano-fabricated antidot graphene and Ar^+-irradiated graphene having atomic vacancies were prepared and examined in terms of scattering mechanisms of electrons using Raman spectroscopy and magnetotransport measurements. The Raman D band due to the defect-induced intervalley scattering significantly appeared for Ar^+-irradiated samples, whereas it was weak for antidot samples. Following these results, the backgate-dependent conductivities for antidot and Ar^+-irradiated samples were fitted by the charged-impurity scattering and the vacancy-edge scattering regimes, respectively, leading to nice agreements. In high magnetic fields, magnetic oscillations were observed only for antidot sample. This fact supports the weak scattering by charged impurities in antidot sample and the strong defect scattering in Ar^+-irradiated sample. In addition, characteristic scattering lengths were derived via theoretical fits for weak localization effect observed in low magnetic fields. The inter-valley scatterings due to vacancies were effective for Ar^+-irradiated sample, whereas the intra-valley scatterings by charged impurities were significant in antidot sample. Then, dominant scattering sources in antidot and Ar^+-irradiated samples have been concluded as charged impurities and edges of vacancies, respectively, so that the contribution of the edge state can be expected in graphene with atomic vacancies. Next, the emergence of the edge state over a macroscopic area of a sample upon the creation of atomic vacancies has been verified using near-edge X-ray absorption fine structure. The edge state peak has been obviously observed upon 100-eV Ar^+ irradiation. As the kinetic energy of Ar^+ ions were stepwisely increased to 3 keV, drastic changes in the π^* and the σ^* peaks were observed. The broadening of these peaks indicates the mixing of π and σ states as a consequence of structural transformation into amorphous-like state. Given that the increase of sp^3 carbons decreases the concentration of conducting electrons, the observed blue shift of the π^* peak has been explained on the basis of the reduction of the core-hole screening. Interestingly, the contribution of the edge state remained even in the severely damaged amorphous-like state, which indicates the survival of substantial extent of the π-conjugation network. Finally, in order to establish a way of tuning the electronic and magnetic properties of the edge state by an artificial control of functional groups at vacancies, hydrogenation of vacancies has been investigated. Hydrogenation process was performed *in-situ* by exposing Ar^+-irradiated graphene samples to H or H_2 flows. Here, the spontaneous dissociative adsorption of H_2 at vacancies can occur because of high reactivity of edges. In the H case, a quite large amount of electron donation, as much as 0.6*e* per a vacancy, was observed, whereas H_2 exposure did not show such a significant feature. According to a theoretical calculation, the charge transfer effect, as much as 0.5*e*, can occur in the C−H bond at a vacancy, although the transferred electrons are unlikely to be conducting. Thus, it has appeared that the case of H_2 exposure agrees with the theoretical results. It has been considered that hydrogenation of vacancies in graphene is performed by exposing to H_2. This simple method can be applied to other gas species for arbitrary functionalization of vacancies in graphene. To be summarized, it has been verified that the carrier scattering sources in artificial nanostructured graphene and graphene having randomly distributed atomic vacancies are inevitably involved charged impurities and edges of vacancies, respectively. Furthermore, it has been confirmed that the edge state emerges over a wide area upon creation of vacancies. Then, it has been suggested that the creation of atomic vacancies in graphene immediately followed by molecular exposure can be a method of decorating edges with arbitrary functional groups.

備考 ： 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。
Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1copy of 800 Words (English).