위상절연체 표면의 전자특성 제어 쉬워진다

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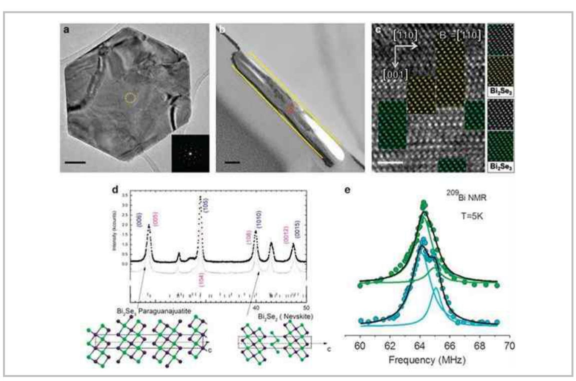
연구내용

최근 이세돌 9단과 구글의 인공지능 알파고간의 바둑 대결, 애플과 미국 연방수사국간에 아이폰 암호 해독 문제 등의 사례를 통해 양자컴퓨터로 대표되는 미래형 컴퓨터 개발에 대한 관심이 고조되고 있음.

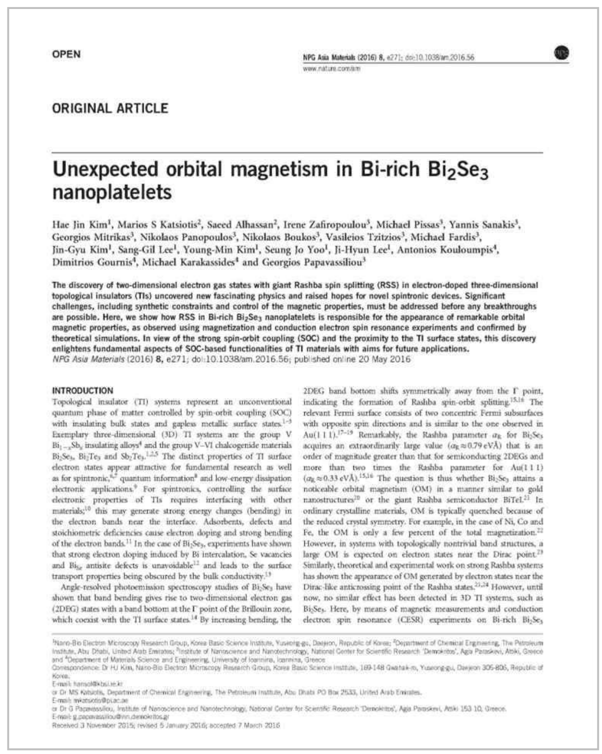
양자컴퓨터는 노벨물리학상(1965년) 수상자인 리처드 파인만 교수에 의해 1982년에 그 개념이 제안됐으며, 반도체가 아닌 스핀을 기 억소자로 활용하는 것으로 알려져 있음. 이 양자컴퓨터의 소재로 주목 받고 있는 위상절연체 표면의 전자특성을 제어할 수 있는 새로운 방법이 발견됨에 따라, 위상절연체를 활용한 스핀트로닉스 소자 개발 및 양자컴퓨터 실용화에 한 걸음 더 다가서게 될 전망임.
본 연구팀은 2차원 전자가스 상태인 위상절연체 표면에서 라쉬바 효과용어 설명6에 의해 놀랄만한 표면 궤도자성이 나타남을 발견함. 또한 3차원 위상절연체 물질로 주목받고 있는 비스무스셀레나이드(Bi_2Se_3)에 비스무스층을 삽입하는 방법을 통해 표면의 반데르발스 갭 (Van der Waals Gap)을 확장시킴으로써 전자 도핑효과를 만들어내고 이로 인한 궤도자성의 특성을 갖게 할 수 있음을 밝혀냄.



[그림1] a)나노 구조의 비스무스 셀레나이드 전자현미경 사진 b)나노 구조의 비스무스 셀레나이드 단면 전자현미경 사진 c)비스무스 층이 삽입된 비스무스 셀레나이드의 고배율 전자현미경 사진 및 원자 분포 이미지. d)비스무스 층이 삽입된 비스무스 셀레나이드의 XRD 실험결과 및 이론적 계산 결과 e)비스무스 층이 삽입된 비스무스 셀레나이드의 비스무스 핵자기 공명 실험결과

기대효과

이번 연구는 위상절연체의 전자스핀 상태를 물질의 삽입이라는 물리적 작용을 통해 에 너지를 거의 사용하지 않으면서도 손쉽게 제어할 수 있다는 새로운 발견이 핵심"이라 며 "향후 다양한 나노구조 물질과 위상절연 체의 물리 화학적 특성 연구를 통하여, 스 핀트로닉스 소자 개발 및 양자컴퓨터 실용 화 등 다양한 응용방법을 제시해 나갈 계획 임.



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ORIGINAL ARTICLE

Unexpected orbital magnetism in Bi-rich Bi_2Se_3 nanoplatelets

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The discovery of two-dimensional electron gas states with giant Rashba spin splitting (RSS) in electron-doped three-dimensional topological insulators (TIs) uncovered new fascinating physics and raised hopes for novel spintronic devices. Significant challenges, including synthetic constraints and control of the magnetic properties, must be addressed before any breakthroughs are possible. Here, we show how RSS in Bi-rich Bi_2Se_3 nanoplatelets is responsible for the appearance of remarkable orbital magnetic properties, as observed using magnetization and conduction electron spin resonance experiments and confirmed by theoretical simulations. In view of the strong spin-orbit coupling (SOC) and the proximity to the TI surface states, this discovery enlightens fundamental aspects of SOC-based functionalities of TI materials with aims for future applications.
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INTRODUCTION

Topological insulator (TI) systems represent an unconventional quantum phase of matter controlled by spin-orbit coupling (SOC) with insulating bulk states and gapless metallic surface states.[1–3] Exemplary three-dimensional (3D) TI systems are the group V $Bi_{1-x}Sb_x$ insulating alloys[4] and the group V–VI chalcogenide materials Bi_2Se_3, Bi_2Te_3 and Sb_2Te_3.[1,2,5] The distinct properties of TI surface electron states appear attractive for fundamental research as well as for spintronic,[6,7] quantum information[8] and low-energy dissipation electronic applications.[9] For spintronics, controlling the surface electronic properties of TIs requires interfacing with other materials;[10] this may generate strong energy changes (bending) in the electron bands near the interface. Adsorbents, defects and stoichiometric deficiencies cause electron doping and strong bending of the electron bands.[11] In the case of Bi_2Se_3, experiments have shown that strong electron doping induced by Bi intercalation, Se vacancies and Bi_{Se} antisite defects is unavoidable[12] and leads to the surface transport properties being obscured by the bulk conductivity.[13]

Angle-resolved photoemission spectroscopy studies of Bi_2Se_3 have shown that band bending gives rise to two-dimensional electron gas (2DEG) states with a band bottom at the Γ point of the Brillouin zone, which coexist with the TI surface states.[14] By increasing bending, the 2DEG band bottom shifts symmetrically away from the Γ point, indicating the formation of Rashba spin-orbit splitting.[15,16] The relevant Fermi surface consists of two concentric Fermi subsurfaces with opposite spin directions and is similar to the one observed in Au(1 1 1).[17–19] Remarkably, the Rashba parameter α_R for Bi_2Se_3 acquires an extraordinarily large value ($\alpha_R \approx 0.79$ eVÅ) that is an order of magnitude greater than that for semiconducting 2DEGs and more than two times the Rashba parameter for Au(1 1 1) ($\alpha_R \approx 0.33$ eVÅ).[15,16] The question is thus whether Bi_2Se_3 attains a noticeable orbital magnetism (OM) in a manner similar to gold nanostructures[20] or the giant Rashba semiconductor BiTeI.[21] In ordinary crystalline materials, OM is typically quenched because of the reduced crystal symmetry. For example, in the case of Ni, Co and Fe, the OM is only a few percent of the total magnetization.[22] However, in systems with topologically nontrivial band structures, a large OM is expected on electron states near the Dirac point.[23] Similarly, theoretical and experimental work on strong Rashba systems has shown the appearance of OM generated by electron states near the Dirac-like anticrossing point of the Rashba states.[21,24] However, until now, no similar effect has been detected in 3D TI systems, such as Bi_2Se_3. Here, by means of magnetic measurements and conduction electron spin resonance (CESR) experiments on Bi-rich Bi_2Se_3

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