Tuning Thz Dirac Plasmons in Topological Insulator Micro-Ribbons With Magnetic Field

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Introduction

Dirac Plasmons, the collective quantum oscillations of Dirac fermions in graphene or topological insulators (TIs), have recently attracted a great deal of attention. It has been theoretically suggested that graphene and TIs may be able to replace noble metals in future plasmonic devices, as it can host surface plasmons with longer lifetime and higher degree of optical-field confinement, owing to its extraordinary material properties. Moreover, recent advances in graphene and TIs synthesis and fabrication have made it possible to pattern large-scale micrometer-sized structures with increasing carrier mobility and tunable carrier density. These advances enable broadband "Dirac" plasmonics operating at terahertz (THz) frequencies and make graphene and TIs promising candidate materials for next generation optoelectronics.

Experimental

We fabricated large-area arrays of TI micro-ribbons from MBE-grown Bi_2Se_3 thin films using large writing field e-beam lithography and reactive-ion etching. Two ribbon samples were prepared with a width/period ratio of 0.87μm/2μm and 2.75μm/6μm, respectively. Using the 18 T superconducting magnet in SCM-3 and Fourier transform infrared (IR) spectrometer, we studied the interactions between the plasmon mode and the magnetic field in a Faraday configuration using polarized IR light either perpendicular or parallel to the ribbon direction.

Results and Discussion

We studied the plasmon-type collective excitations in TI micro-ribbons exposed to a perpendicular magnetic field. Plasmons confined in both samples exhibit a blue shift behavior as increasing magnetic field (as shown in Fig.1a), due to the formation of upper hybrid mode (UHM) coupling the plasmon resonance with the cyclotron resonance (CR) [1,2]. Both the 1st- and 2nd-order plasmon modes are evidenced in Fig.1b, signifying the high quality of our samples. We compare the effective mass extracted from the UHM with the CR measurements (Fig.1c) of as-grown Bi_2Se_3 thin films.

Conclusions

In conclusion, we fabricated large-scale TI ribbon arrays with two different configurations and studied their plasmonic properties in a perpendicular magnetic field. The TI ribbons exhibit a strong plasmon mode, which is tunable via external magnetic field through the formation of UHM.

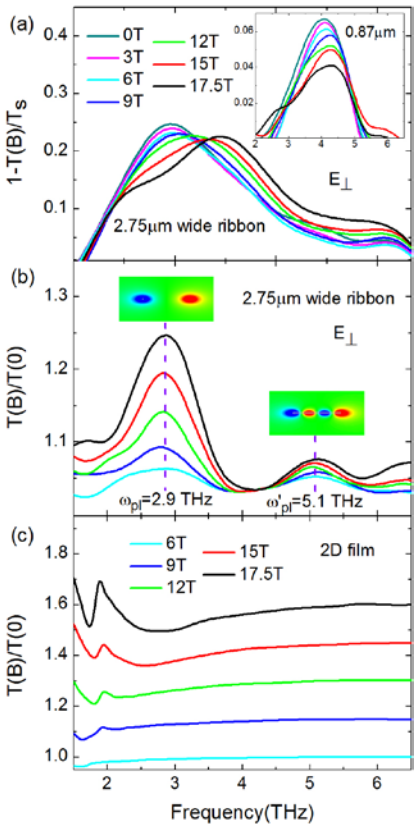

Fig.1 (a) Extinction spectra of 2.75 μm and 0.87 μm (inset) wide TI ribbon arrays in perpendicular magnetic fields. Clear blue shifts are observed in both samples with increasing magnetic field. (b) Normalized transmission spectra of the 2.75 μm wide ribbon sample, demonstrating the 1st and 2nd order plasmon modes. (c) Normalized transmission spectra of a 2D, unpatterned Bi_2Se_3 thin film. The data are shifted vertically for clarity.

Acknowledgements

The IR measurement of this work was supported by the DOE (DE-FG02-07ER46451), and the TI ribbon array fabrication was supported by the DOE BES through a contract with SNL. The TI materials synthesis at Rutgers was supported by the NSF (DMR-0845464) and the ONR (N000141210456). The NHMFL is supported by NSF Cooperative Agreement No. DMR-1157490, the State of Florida, and the U.S. Department of Energy. The SNL is a multiprogram laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the United States Department of Energy's National Nuclear Security Administration under Contract No. DE-AC04-94AL85000.

References

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