Proximity effect of two-dimensional van der Waals magnet Fe_3GeTe_2 on nickel films

Qian Chen, [a] Jian Liang ,[b] Bin Fang, [c] Yonghui Zhu, [a,b] Jiachen Wang, [a] Weiming Lv, [a,c] Wenxing Lv,[d] Jialin Cai [a,c], Zhaocong Huang, [b] Ya Zhai, *[b] Baoshun Zhang [a] and Zhongming Zeng*[a]

Corresponding Authors: zmzeng2012@sinano.ac.cn; yazhai@seu.edu.cn

[a] Key Laboratory of Multifunctional Nanomaterials and Smart Systems, Suzhou Institute of Nano-Tech and Nano-Bionics, Chinese Academy of Sciences, Suzhou, Jiangsu, 215123, China

[b] School of Physics, Southeast University, Nanjing, Jiangsu, 211189, China

[c] Nanchang Nano-Devices and Technologies Division, Suzhou Institute of Nano-Tech and Nano-Bionics, Chinese Academy of Sciences, Nanchang, Jiangxi, 330200, China

[d] Physics Laboratory, Industrial Training Center, Shenzhen Polytechnic, Shenzhen, Guangdong, 518055, China

Supplementary material

Contents:

S1. Details of the Au-assisted exfoliation process.

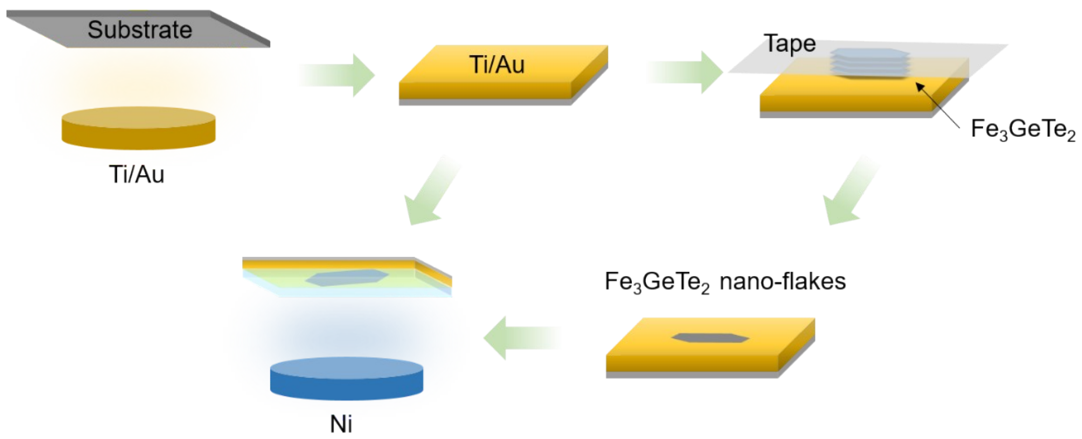
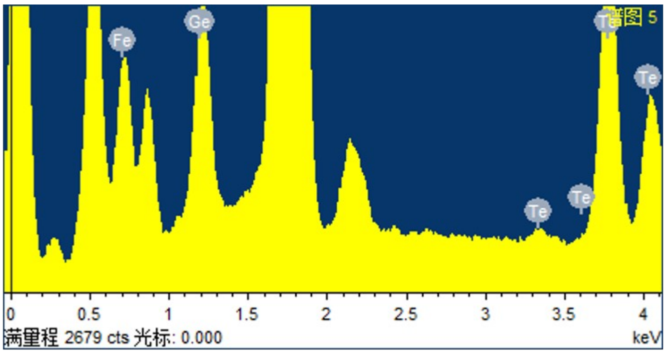


Figure. S1 Schematic of the sample preparation process. First, 2 nm Ti and 4 nm Au are deposited successively onto the Si (001) substrate. To prepare the sample Ti/Au/Ni, 6 nm Ni is deposited immediately on Ti/Au substrate. To prepare the sample Ti/Au/FGT/Ni, a freshly cleaved layered bulk crystal on tape is brought in contact with the Au layer. Adhesive tape is placed on the outward side of the crystal, and gentle pressure is applied to establish a good layered crystal/Au contact. Upon peeling off the tape, 6 nm Ni is deposited on the Ti/Au/FGT substrate in rapid sequence, to avoid excessive interface degradation or oxidation, providing a relatively clean interface with the subsequent deposited Ni by EBE.

S2. Element composition of FGT/Ni determined by energy-dispersive x-ray spectroscopy



Elements	Weight (%)	Atom (%)	Proportion
Fe (K)	33.91	50.21	2.99
Ge (K)	14.20	16.17	0.96
Te (L)	51.89	33.62	2

Figure. S2 Element analysis of FGT/Ni performed using energy-dispersive x-ray spectroscopy (EDX), which gives Fe and Ge with a composition of 3:1. The composition proportion of Fe, Ge and Te is 3:1:2.

S3. Optical images during the device fabrication process

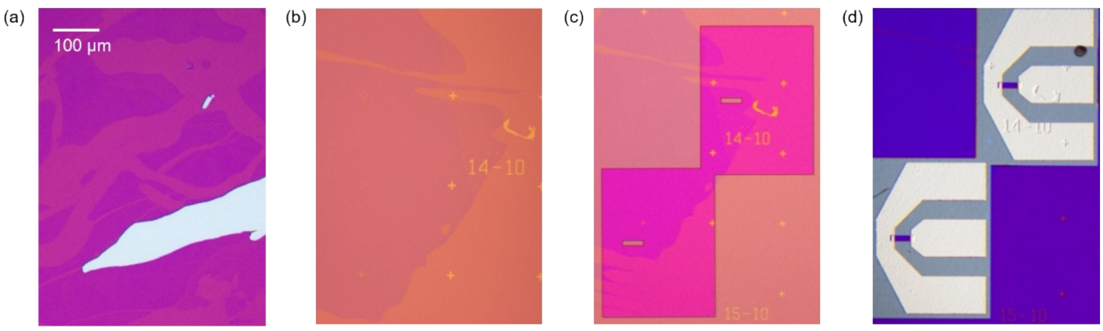


Figure. S3 Optical images during the device fabrication process. (a) (b) Exfoliated FGT capped with Ni thin film. (c) Selections of device areas. (d) Selected areas are patterned into micro-strips by electron-beam lithography and Ar ion milling, and electrical connections are made by Ti/Au contact pads.

S4. Frequency dependences of the resonance field obtained from supplementary devices

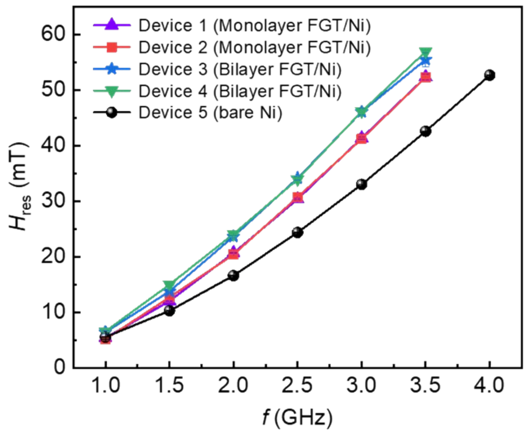


Figure. S4 Frequency dependences of the resonance field obtained from different devices.

S5. Characterizations of CGT and FGT exfoliated on Al_2O_3

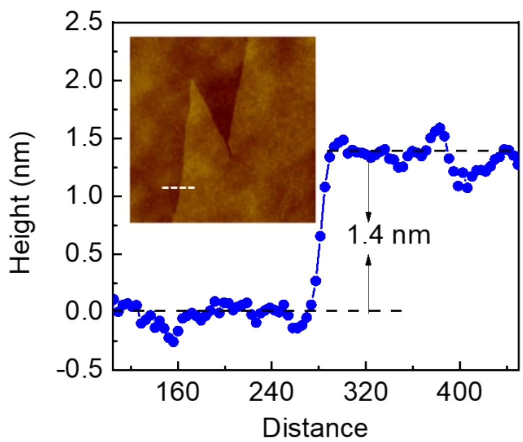


Figure. S5 AFM topography and the height profile of CGT/Ni taken along the dashed line.

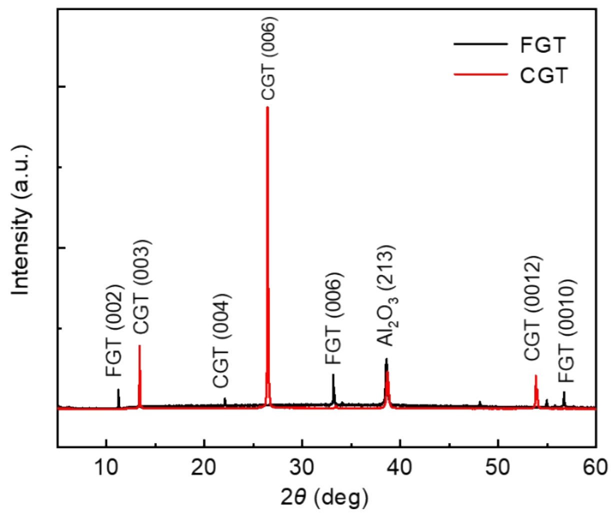


Figure. S6 XRD pattern of FGT and CGT exfoliated on Al_2O_3.

S6. Special method for ST-FMR detection

We choose the bilayer FGT and bilayer CGT exfoliated on Al_2O_3 for comparison in keeping with the above studied. In this case, however, the above used homodyne ST-FMR detection will not work: because of the lack of a structural inversion asymmetry, there is no effective excitation to excite the precession of magnetic moments in Ni. Here, we change the way of probe contact as illustrated in Figure S7 to create a non-uniform radio-frequency excitation current. Previous studies have demonstrated that such a method is effective in detecting the Kittel's mode FMR dynamics of a single ferromagnetic layer[1]. Although the line-shape and the linewidth from the FMR spectrum detected by this method are hard to be analyzed, the value of H_{res} is exactly consistent with the uniform FMR mode (Kittel's mode), which reflects the intrinsic magnetic properties of the device.

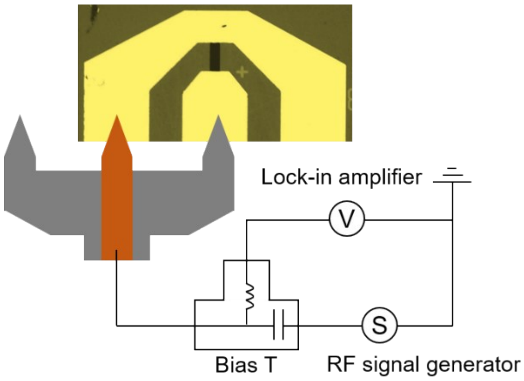


Figure. S7 Special probe contact used for detecting the Kittel's mode FMR dynamics of Al_2O_3/Ni, Al_2O_3/bilayer FGT/Ni and Al_2O_3/bilayer CGT/Ni.

Reference

(1). T. Ikebuchi, T. Moriyama, Y. Shiota, T. Ono, *Appl. Pyhs. Express*, 2018, **11**, 053008.