Development of Radio Frequency STM for ESR Spin Detection

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Purpose

Expansion of the detection bandwidth of scanning tunneling microscopy (STM) up to several gigahertz was studied. Such a radio-frequency STM (RF-STM) has been previously investigated to develop electron spin resonance STM (ESR-STM), which detects a single spin precession under a week magnetic field enabling single spin detection in an atomic scale spatial resolution[1], or nanoscale electric/optoelectric devices that works in microwave frequency ranges. In such applications, the system should have ultrahigh sensitivity to detect very low energy signals from a single unpaired electron or microscale/nanoscale electric devices. In general, however, ultralow noise and ultrawide bandwidth are conflicting requirements and are difficult to realize. We report our recent achievement in this area.

System setup

The schematic of our measurement system is shown in Fig. 1. A conventional STM working in the air sits on a vibration insulator. RF and DC signals on the tunnel current are separated by high pass filter and low pass filter, and the latter is used for the conventional STM measurement. The cutoff frequency of the conventional STM current-voltage converter is limited below 100 kHz. The RF signal is then processed by a preamplifier with a low noise figure (n/f 2.5 dB), the nominal gain of which is 45 dB. The amplified signal is introduced into a spectrum analyzer for ESR-STM measurement or a vector network analyzer for RF device analysis. In order to conduct a transfer function measurement, a reference oscillator with stability of 10^{-9} can be used to dictate the carrier signal generation part, which consists of the excitation oscillator and pulse oscillator, and the analyzer part, which consists of spectrum analyzer and vector network analyzer, to stabilize the system frequency.

Specification

The performance of the measurement system was examined by a model experiment. A very weak

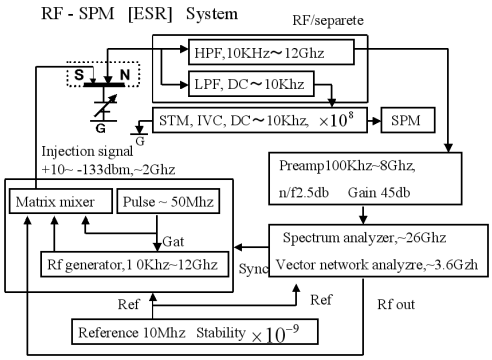
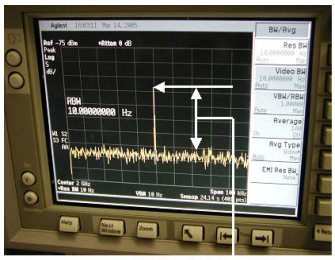


Figure 1 Block diagram of the RF-STM



C/N 、 P-P , 22dbm
RBW 10hz ,VBW 10hz ,Span 100khz
Injection level -130dbm , 2Ghz

Figure 2 Obtained signal to noise ratio

(-130 dBm) RF signal at 2 GHz was fed into the HOPG specimen under tunneling condition and the signal to noise ratio was observed by the spectrum analyzer. The result is shown in Fig. 2. In this condition, the effective amplification of the RF preamplifier was about 15 dB and the final signal to noise ratio of 22 dBm was achieved.

Conclusion

The signal level for single spin ESR detection is expected in the range of -120 dBm. Thus, the system seems to have sufficient sensitivity. Now, the sample preparation and the stable magnetic field control are under development.

References

[1] Y. Manassen et al., PRB 61 (2000) 16223.