The nonlinear electron scattering spectroscopy of the surface plasmon resonance for Au nano-structures on graphite surface

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Synopsis The electron energy loss spectra of Au nanostructures on graphite surface have been measured at different tip voltage and tip-sample distance by a home-made scanning probe electron energy spectrometer. The nonlinear electron scattering is observed during the excitation process of Au surface plasmon polariton, indicating that the nonlinear electron scattering could be a common process for the surface plasma excitation of noble metal nanostructures.

Spectroscopic techniques are the basic tools for us to study the chemical properties and processes at the microscopic level. In order to fully understand the properties of the matter at the nanoscale, it is highly desirable to develop spectroscopic techniques with high spatial resolution. In this context, the electron energy loss spectroscopy in combination with scanning tunneling microscopy can be regarded as the perfect candidates to meet such demands [1-3]. However, the inelastic electron scattering probability is known to be very small and it thus possesses a huge technical challenge for high resolution measurements. This problem may be solved by recent discovery of a new physical process, named nonlinear electron scattering (NES), in which the intensity of the inelastic scattering electron signal can be nonlinearly enhanced by the external electric field [4]. Since the previous experiment of NES is carried out only for one sample, which is silver nanostructures on graphite, more experiments on different samples are required to further confirm this discovery and figure out its principle.

In this work, we carried out the NES experiments on gold nanostructures on graphite surface by a home-made scanning probe electron energy spectrometer [2]. Electron energy loss spectra (EELS) have been acquired at different tip voltage under two different tip-sample distance, 166 μm and 80 μm, respectively. The relative intensity, which is defined as the area ration of the energy loss peak due to Au surface plasmon polariton (SPP) excitation to the elastic scattering peak in the EELS, is shown as a dependence of tip voltage in figure 2. It is revealed that the intensity of the Au SPP excitation increases nonlinearly with respect to the external electric field, similar to the previous work on Ag nanostructures [4]. However, the relative intensity is weaker compared to that of Ag nanostructures.

This result provides evidence that the NES process could be a common phenomenon during the SPP excitation process of noble metal nanostructures. Furthermore, the different behavior of NES for Ag and Au samples may due to the different properties of the excited surface plasma oscillation of Ag and Au nanostructures, such as localized electric field, dipole moment, polarizability, etc. This may in the future provide a way to study these properties of the SPP, which is very important but hardly to be investigated due to the ultra-short damping time of surface plasma.

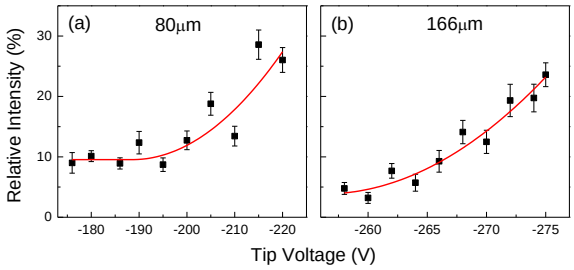

Figure 1. The relative intensity of the Au SPP excitation with dependence of the tip voltage at tip sample distance 80 μm (a) and 166 μm (b) respectively.

References

[1] Festy F. & Palmer R. E. 2004 *App. Phys. Lett.* 85 5034-5036.
[2] Xu C. K. et al. 2009 *Rev. Sci. Instrum.* 80, 103705.
[3] Murphy S. et al. 2015 *Appl. Phys. Express* 8, 126601.
[4] Xu C. K. et al. 2014 *Nature Phys.* 10, 753-757.

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