Positronium Formation at Metal, Semiconductor and Graphene Surfaces

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Positrons implanted into the subsurface region of a material diffuse back to the surface and are emitted as positronium by picking up surface electrons when the positronium work function is negative. When positronium is formed, positrons select electrons at the vacuum side of the surface, where the screening effect of the Coulomb potential is adequately reduced. Because of the energy conservation law, the electrons occupied below the Fermi level to the positronium work function contribute to the positronium formation. The angular distribution of emitted positronium reflects the electron momenta, i. e., the band dispersions. Using the spin polarized positrons, electron spins can also be detected. For these reasons, ‘Positronium spectroscopy’ may be a potential tool to investigate the electronic structure of solid surface. In the photoemission measurement, electrons in ~nm depth are detected on average and hence it is not easy to specify which layers the electrons come from. One advantage of positronium spectroscopy is its top-surface sensitivity. To establish the positronium spectroscopy, positronium formation process needs to be revealed in detail.

So far, the positronium formation process has been studied mainly for metal surfaces. However, the theoretical understanding is still not sufficient. The investigation of semiconductor surfaces and furthermore single-layer materials such as graphene is remained nearly untouched. Application of spin-polarized positronium spectroscopy is not extensively progressing. In this paper, we will report (i) theoretical interpretation of positronium energy spectrum of metal surface [1], (ii) positronium formation at Si, SiC and graphene/SiC surfaces [2] and (iii) spin-polarized positronium annihilation at ferromagnetic surfaces [3].

For (i), we attempted to reproduce the positronium energy spectra at Al(111), Ni(111), Pt(111) and W(100) surfaces based on the Ishii’s theory and first principles calculation. We found that the dissociation of once generated positronium due to the interaction with remaining hole needs to be considered to reproduce the experimental spectra. For (ii), we found that there are two types of positronium distinguished from their kinetic energies at Si and SiC surfaces. For (iii), we found the spin-polarized electrons in graphene grown on Co(0001), Ni(111), Fe(110) and Co_2FeGaGe(001) surfaces .

References

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