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# Attempts to Improve the Sensitivity and the Energy Resolution of an Analyzer for Auger Photoelectron Coincidence Spectroscopy and Electron Ion Coincidence Spectroscopy

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## 1 Introduction

Auger photoelectron coincidence spectroscopy (APECS) is a powerful technique to elucidate the correlation between a specific photoemission and the resultant Auger processes. Recently we constructed a coincidence analyzer that can be used for APECS and electron ion coincidence spectroscopy [1]. The coincidence analyzer consists of a coaxially symmetric mirror electron energy analyzer (ASMA), a double-pass cylindrical mirror electron energy analyzer (DP-CMA), a time-of-flight ion mass spectrometer (TOF-MS), a magnetic shield, and a positioning mechanism. A sample surface is irradiated by synchrotron radiation, and emitted electrons are energy-analyzed and detected by the ASMA and the DP-CMA, while desorbed ions are detected by the TOF-MS.

The electron-energy resolution ($E/\Delta E$) of the previous coincidence analyzer is about 55 and the APECS count rate is about 4.5 cps at the best for Si-$L_{23}VV$ Auger electron Si-2$p$ photoelectron coincidence spectra of clean Si(100)-2×1. For detailed study of valence electronic states, however, a higher electron-energy resolution is desirable. To investigate minor Auger processes, on the other hand, a higher sensitivity is required. To address these subjects we constructed two types of coincidence analyzers. The first one is designed for high resolution measurements, and the second one is dedicated for high sensitivity measurements. In this paper we report the performance of the two coincidence analyzers.

## 2 Attempt to improve the electron energy resolution of a coincidence analyzer

We constructed a coincidence analyzer which involves a double-pass ASMA (DP-ASMA) with a 1-mm-diameter pinhole, DP-CMA with a 1-mm-diameter pinhole, and TOF-MS, and a positioning mechanism, as shown in Fig. 1. The electron acceptance angle from the surface normal is 55˚–69˚ for DP-ASMA and 33.7˚–40.7˚ for DP-CMA. The inner and outer electrodes of the DP-CMA are isolated from the ground. Based on Si 2$p$ photoelectron spectra of Si(111)-7×7 we estimated the energy resolution of DP-ASMA and DP-CMA ($E/\Delta E$) to be about 36. Typical APECS count rate was 1.54 cps in the case of Si-$L_{23}VV$-Si-2$p$ APECS spectrum at the adatom site measured with Si 2$p$ photoelectron and Si $L_{23}VV$ Auger electron energies of 25.92 and 87.5 eV.

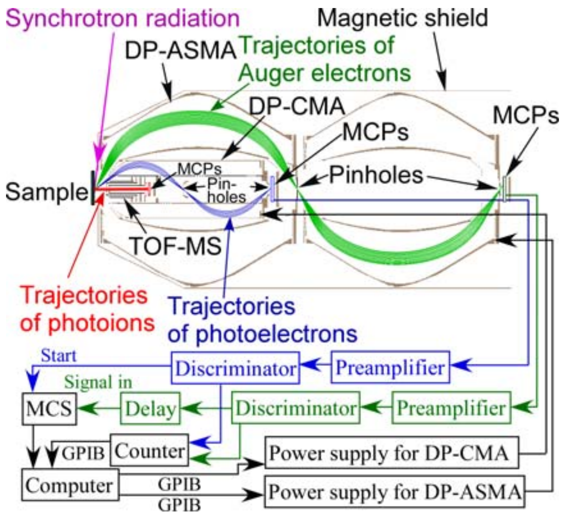


Fig. 1: Schematic of the coincidence analyzer for high resolution measurements.

## 3 Attempt to improve the sensitivity of a coincidence analyzer

To improve sensitivity we constructed another coincidence analyzer. The analyzer contains a single-pass ASMA (SP-ASMA) with a 6-mm-diameter pinhole, DP-CMA with a 6-mm-diameter pinhole, and TOF-MS. $E/\Delta E$ of the ASMA and the DP-CMA was estimated to be about 13. Using this coincidence analyzer we measured a Si-$L_{23}VV$-Si-2$p$ APECS spectrum of a clean Si(111) at the photon energy of 130 eV, as shown in Fig. 2. Si 2$p$ photoelectron, Si $L_{23}VV$ Auger electron, and APECS count rates were 12 kcps, 21 kcps, and 5.0 cps at the Auger electron kinetic energy of 87 eV.

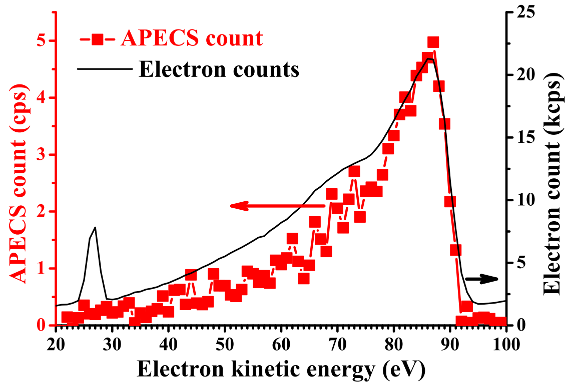


Fig. 2: Si-$L_{23}VV$ Auger electron spectra of a clean Si(111)-7×7 obtained with the coincidence analyzer for high sensitivity measurements at the photon energy of 130 eV. Energy-selected Si-2*p* photoelectron with a kinetic energy of 27 eV is taken as the trigger.

4 Conclusions

The energy resolution of the DP-ASMA and the DP-CMA of the coincidence analyzer for high electron energy resolution measurements ($E/\Delta E$ = ~36) is smaller than that of the previous one ($E/\Delta E$ = ~55) [1]. This result is disappointing because the $E/\Delta E$ of DP-ASMA is usually better than that of SP-ASMA [2]. Positioning accuracy does not seem to be responsible for the reduced $E/\Delta E$ because we spent sufficient effort in positioning the analyzer. One probable reason for the reduced $E/\Delta E$ is thought to be the bending of the coincidence analyzer axis due to the weight of the first ASMA. The misalignment of the first and the second ASMAs is thought to be another reason. Subjects in future are to develop the DP-ASMA with a more solid structure and to reduce the errors due to the assembly processes.

The APECS count rate of the coincidence analyzer for high sensitivity measurements (5.0 cps) is better than that of the previous one (3.3 cps) [3]. This improvement is unsatisfactory because the sensitivity of the ASMA and DP-CMA is improved on the sacrifice of the energy resolution ($E/\Delta E$ = ~13). The insufficient sensitivity seems to be derived from the mismatch between $\Delta E$ of the DP-CMA ($\Delta E$ = ~2 eV at E = 26 eV) and the width of the Si 2*p* peak of the adatom (330 meV [4]). The APECS count rate is expected to be the maximum when $\Delta E$ of the DP-CMA is adjusted to 330 meV. Since best $\Delta E$ depends on the sample and the aim of the measurements a subject in future is to develop the DP-CMA with retarding grids that can vary $\Delta E$ by changing the pass energy.

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