The effects of impurities and incidence angle on the secondary electron emission of Ni(110)

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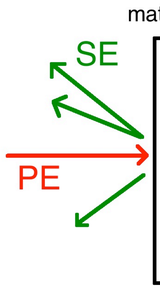
Secondary Electron Emission (SEE)

- SEE is induced when primary incident electrons of sufficient energy strike the surface of a material
- SEE decreases sheath potential in magnetic fusion devices and plasma hall thrusters
- Total secondary electron yield (SEY) could be expressed as a function of primary electron energy

$$f(x) = A \times \sigma_M \times exp[-\frac{[ln\frac{E_{PE}}{E_{PEmax}}]^2}{2\alpha^2}]$$

- Incidence angle, bulk material, surface composition, crystal structure, and temperature also affect total SEY



Experimental Setup

- 10^{-10} Torr base pressure
- Quadrupole mass spectrometer monitors background gases and gases absorbed on single crystal surface
- Utilizes both Auger electron spectroscopy (AES) and low energy electron diffraction (LEED) optics
- Continuously varies incident electron beam energy

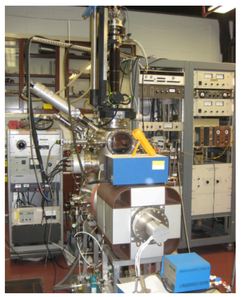


Figure 2: High-resolution electron energy loss spectrometry chamber at the Surface Science and Technology Laboratory at PPPL

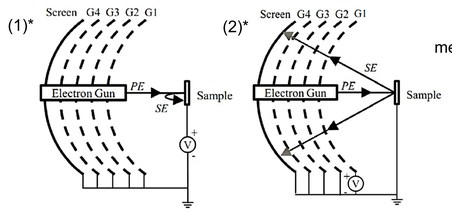


Figure 3: 4-grid LEED/AES optics for measuring (1) primary electron current from the sample current and (2) secondary electron current from the collector

$$I_S = I_{PE} - I_{SEE}$$

$$(i)\quad \sigma = \frac{I_{SEE}}{I_{PE}} = \frac{I_{PE} - I_S}{I_{PE}}$$

$$(ii)\quad \sigma = \frac{I_{SEE}}{I_{PE}} = \frac{I_C}{I_{PE}}$$

Procedure

- SEY measurements of a single crystal of Ni(110) were taken at different incidence angles with impurity levels monitored
- Primary electron current from electron guns was measured on sample
- SE current from sample was measured using sample or collector method
- AES scans and temperature programmed desorption (TPD) curves were used to examine the composition and impurity levels on Ni(110)

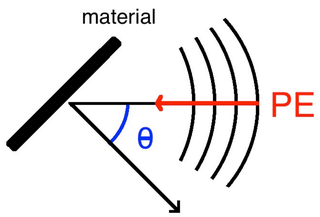


Figure 4: Setup for electron beam incidence

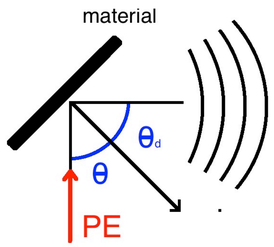
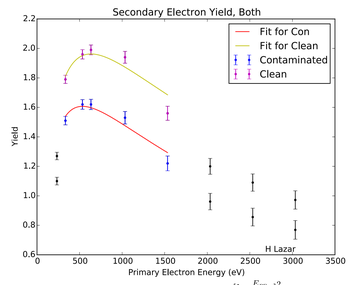


Figure 5: Setup for electron beam incidence used by Mayer and Weiss

SEY as a Function of Time After Cleaning

- Total SEY measurements were taken using sample method 15 times over a period of approximately 120 minutes
- Applied universal curves for total SEY reveal a decrease of total SEY as a function of time



$$f(x) = A \times \sigma_M \times exp[-\frac{[ln\frac{E_{PE}}{E_{PEmax}}]^2}{2\alpha^2}]$$

Figure 6: Universal curves for total SEY applied to two data sets taken 11 and 123 minutes after cleaning, respectively. Irreproducibility and instrumental errors are accounted for

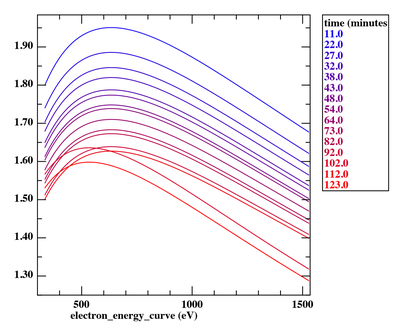
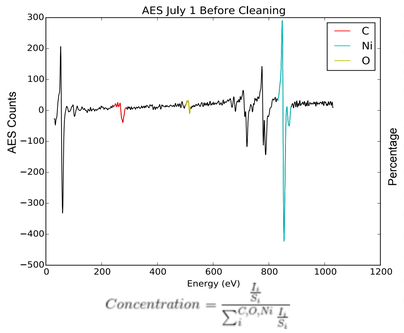


Figure 7: Universal curves for fifteen measurements taken at different times after sample was cleaned. Plot made by Brandon May using ElVis, a visual program developed by Eliot Feibush

- Concentrations of carbon and oxygen on the surface of Ni(110) were determined through AES scans after each of the 15 measurements
- There was an increase in carbon and oxygen and a decrease of nickel on the surface as a function of time after cleaning



$$Concentration = \frac{\frac{I_i}{S_i}}{\sum_i^{C,O,Ni}\frac{I_i}{S_i}}$$

Figure 8: An AES scan taken before the sample was cleaned

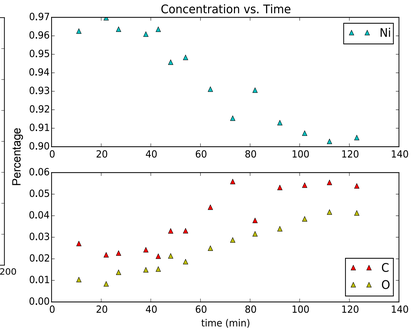


Figure 9: Increase of contamination on the surface of the sample as a function of time

- Temperature was not kept constant after cleaning, which could influence the decrease in SEY
- Total SEY measurements were taken for three electron beam energies for a short period of time to account for irreproducibility error
- Temperature was then increased and kept constant to reduce irreproducibility error

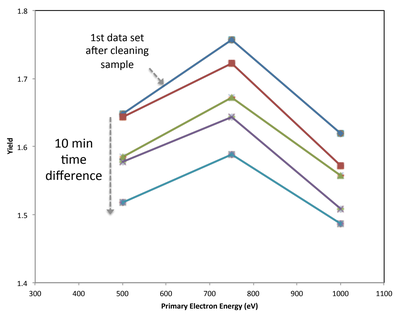
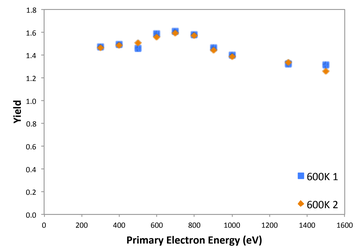


Figure 10: SEY at 500, 750, and 100 eV taken in a 10 minute time span without fixing temperature. AES scans indicated a 39% increase of C, 16% decrease of O, and 2% decrease of Ni at the surface

SEY as a Function of Electron Incidence Angle



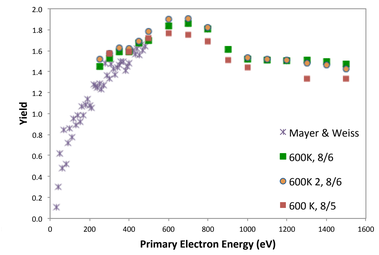
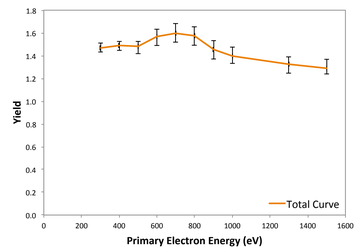


Figure 11 and 12 : Data sets taken at 0 and 50 degree incidence angles, respectively



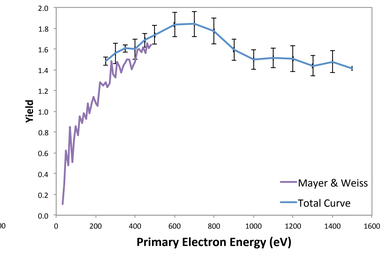


Figure 13 and 14 : Total curves for 0 and 50 degree incidence angles, respectively

- SEY was measured at different incidence angles using collective method
- Sample kept at 600 K to minimize impurity level based on TPD
- Irreproducibility and voltage bias for LEED collector accounted for in error

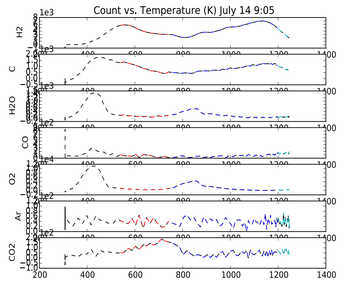


Figure 15: Temperature programmed desorption (TPD) of a contaminated sample

Conclusions

- Higher temperatures and reproducibility are correlated
- Sample temperature affects contamination due to continuous desorption
- Angle of incidence affects SEY by increasing PE path in near sample surface region

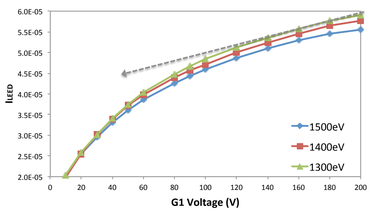


Figure 16: Total SE currents collected at the LEED optics as a function of G1 voltage. Three different primary electron energies are shown at 50 degree incidence

Future Work

- Conduct SEE measurements for lithium, which is utilized in limiters and dividers of magnetic fusion devices
- Characterize change in SEY when using collective method at different temperatures
- Determine the effects of individual contaminants on SEY by dosing the sample

Acknowledgments

Figures (1)* and (2)*: M. I. Patino, Y. Raitses, B. E. Koel, and R. E. Wirz, "Analysis of secondary electron emission for conducting materials using 4-grid LEED/AES optics," J. Phys. D: Appl. Phys., vol 48, pp.19204 Dec. 18, 2015.

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