بسم الله الرحمن الرحيم

بالرسالة صفحات
لم ترد بالاصل

A

THESIS

Entitled

STUDIES ON AUGER ELECTRON OPTICS

By

Hany Talaat Ahmed Ali Mohsen

B.Sc. in Physics, Helwan University (1992)

In Partial Fulfillment
For the Requirements of
the Degree of Master of Science
(Physics)

Department of Physics
Faculty of science
Suez Canal University
Ismailia, Egypt
1998

STUDIES ON AUGER ELECTRON OPTICS

Thesis Referees

Prof. Dr. M. E. ABDEL AZIZ

Prof. Emeritus, Ex. Chairman of
Atomic Energy Authority

Prof. Dr. A. H. GERGES

Prof. of Experimental Physics
Faculty of Science
Ain Shams University

Prof. Dr. FOUAD M. SHARAF

Head of Physics Department
Prof. of Experimental Optics
Faculty of Science
Suez Canal University

Prof. Dr. M. H. S. Bakr

Ex. Vice Head of the Division of Basic Nuclear Science
Prof. of Nuclear Physics
Accelerators & Ion Sources Department
Nuclear Research Center
Atomic Energy Authority

STUDIES ON AUGER ELECTRON OPTICS

Supervisors **Approved**

Prof.Dr. FOUAD M. SHARAF

F. Sharaf

Head of Physics Department
Professor of Experimental Optics
Faculty of Science
Suez Canal University

Prof.Dr. M. H. S. Bakr M. H. S. Bakr

Ex. Vice Head of the Division of Basic Nuclear Sciences
Professor of Nuclear Physics
Accelerator & Ion Sources Department
Nuclear Research Center
Atomic Energy Authority

Dr. M. S. Ragheb

M. S. Ragheb

Head of Electron Acceleration & its Applications Unit
Accelerator & Ion Sources Department
Nuclear Research Center
Atomic Energy Authority

To My

Parents

ACKNOWLEDGMENT

The author wishes to express his deep thanks and great appreciation to *Prof. Dr. FOUAD M. SHARAF* Prof. Of Experimental Optics, Head of Physics Department, Faculty of Science, Suez Canal University especially for his continuous encouragement and guidance, constructive comments, support and supervision.

The author wishes to express his sincere appreciation and deepest gratitude to *Prof. Dr. M. H. S. BAKR* Prof. Of Nuclear Physics, Ex. Vice Head of the Division of Basic Nuclear Sciences, Accelerators & Ion Sources Department, Nuclear Research Center, Atomic Energy Authority for his kind help, direct supervision, continuous encouragement and guidance throughout executing this work.

The author wish also to express his deep thanks, sincere appreciation and deepest gratitude to *Dr. M. S. RAGHEB*, Head of Electron Acceleration & its Applications Unit, Accelerators & Ion Sources Department, Nuclear Research Center, Atomic Energy Authority, for suggesting the point of research, continuous advise, his direct supervision, valuable discussions, continuous encouragement, support and guidance through the whole period of this work.

He wishes to acknowledge *W. GHALY* Demonstrator in Accelerators & Ion Sources Department, Nuclear Research Center, Atomic Energy Authority for his help in mechanical design of the system.

The author wishes to record his appreciation to *M. TAHA, F. E. El SHENAWY, A. G. ALI* and *A. MARAAE* members of the Electron Acceleration & Its Applications Unit, Accelerators & Ion Sources Department, Nuclear Research Center, Atomic Energy Authority.

Thanks to all the technicians in the workshop of Nuclear Physics Department, Nuclear Research Center, Atomic Energy Authority, for their great help in constructing the mechanical parts of the experiment.

Finally, the author would like to acknowledge *M.A. GALAB* technician in Engineering Department, Nuclear Research Center, Atomic Energy Authority.

Contents

Chapter 3: Experimental Setup

Chapter 4: Results & Discussion

Abstract

An electron gun of a pentode type has been used to produce Auger electrons for a surface elemental analysis. The optical parameters affecting the primary electron beam have been studied. The results have been used to optimize electron beam current and beam focus position. The technological aspects and the operation of the electron gun have been experimentally illustrated. The experimental study has been made for electron beam diagnostic as a primary beam for Auger electron spectroscopy in a field free region. The trajectory and the electron beam profile are experimentally studied and illustrated at different positions from the gun anode. A security device for cooling systems is designed and constructed against hazardous failure of water cooling and/or electrical mains supply in order to prevent damages of the high vacuum pumps and to provide better operating condition.

A retarding field analyzer has been used for surface elemental analysis. A remote controlled multi-sample holder has been designed and constructed to give the analyzing system the ability to investigate more than one sample at same operating conditions. The multi-sample holder has secured the gun cathode from poisoning by residuals during sample change. First and second derivatives have been experimentally obtained for Auger spectra by means of an audio frequency modulation technique using a lock-in amplifier for the detection of Auger spectra. Four samples have been investigated in order to check up the multi-sample operation and to examine the existence of the copper, brass, nickel, and iron in the chosen samples. A computer program has been used for the calculation of the derivatives of the spectra obtained and for comparison with that of the spectra obtained experimentally.

Introduction

Electron optics, in recent years has been greatly developed and now is often regarded as an independent science involving a wide scope of problems associated with the motion of charged particles in an electron optical medium, (i.e. in electric and magnetic fields) under vacuum conditions. Electron beams behaviour is analogous to that of the propagation of light and rules of optics (light) can be used to solve the problems of electron optics. Electrons in many cases behave like waves. The light also is considered as an electromagnetic radiation of very small wavelength. The propagation of this light wave in a homogenous medium may be regarded as rectilinear if the linear dimensions of the wave front of a light wave appreciably exceed the wavelength. In the framework of geometrical optics, the propagation of a light beam in any inhomogeneous medium can be described by making use of the law of light refraction. Inspired from the optical rules there is a general approach to above electron optical problems to find the form of the paths. This approach comes from the deep analogy between the motion of a charged particle in an electrostatic field and the propagation of a light beam in a transparent refracting medium.

An important application of electron beams is the spectroscopy of solid surfaces where a primary electron beam hits a target in order to produce Auger electrons. These electrons are organized in a spectrum according to their energies to give a full elemental analysis of the surface target. The importance of surface science results from the fact that solids interact with their surroundings through their surfaces. Many important physical and chemical processes in solids such as optical reflection, adhesion, corrosion, thermoionic and photoelectric emission, etc. depend critically on the nature and condition of the surface. The necessity of preparing solid surfaces of known chemical purity in material science and communication engineering cannot be overemphasized. This fact calls for sensitive techniques for the detection of impurities. The use of Auger electrons for surface chemical analysis was first suggested by lander(1953). Recent developments in auger electron spectroscopy (AES) have led to its emergence as one of the most effective techniques in this kind of work. Now Auger spectra are being increasingly used as a tool in the investigation of solid surfaces. The availability of solid state detectors and high-resolution electron spectrometers with high transmission has helped the measurement of fluorescence and Auger yields. This is an example of the interaction between pure science and technology. The usefulness of Auger spectra in the analysis of surface impurities has, in recent years, necessitated the study of environmental effects on these spectra. Auger transitions are also important to the understanding of nucleur internal conversion and orbital capture of electrons.

There are general requirements for any surface elemental analysis method. The method must be of high sensitivity to the properties of the surface rather than the bulk, also it must be non-destructive for the surface and widely used for many elements. In addition, the low power consumption and radiation-less hazards are required too. The importance of Auger electron spectroscopy (AES) lies in the fact that it nearly satisfies all the above conditions. The penetration of the primary beam into the solid is limited by the inelastic events, so AES is a surface probe as the emitted electrons come from the most top atomic layers depending upon the material and ionization energy. In addition, it is easy to obtain monochromatic electron beam by using stable electron optics. The electron beam can be focused, deflected and collimated by electrostatic lenses. The energy required for AES is about three KeV so that the power consumption and the radiation hazards are very low comparing with that of the X-rays spectroscopy.

In 1923, Pierre Auger discovered the Auger electron process while irradiating samples with X-rays. The energy of the Auger electron is characteristic of the element from which it is emitted thus it can be used to identify the element. The short inelastic mean free path (IMFP) of Auger electrons in solids ensures the surface sensitivity of AES.

The idea of using electron-stimulated Auger signals for surface analysis was first suggested in 1953 by J. J. Lander. However, it was not until 1967 that Larry Harris demonstrated the use of differentiation for enhancing the Auger signals. This development provided the necessary sensitivity for useful measurements. Early differentiating instruments used analog circuits and lock-in amplifiers to provide differentiated spectra directly, but more the modern instruments acquire electron intensities directly and use computer Display Algorithms to provide differentiated spectra.

AES is a popular technique for determining the composition of the top few layers of a surface. It cannot detect hydrogen or helium, but is sensitive to all other elements, being most sensitive to the low atomic number elements. AES may be carried out in UHV conditions for better analysis. A popular method of looking at buried layers with AES is to use the technique in combination with sputter cleaning. Normally, when a sample is brought into the UHV environment from air, it will be coated with carbon and oxygen, These have to be removed before the investigation of the surface.

Electron energy analyzers measure the number of ejected electrons as a function of the electron energy. The analyzers must be located in a high vacuum chamber and isolated from stray magnetic fields that deflect electrons. Auger spectrometry uses several types of electron energy analyzers, including spherical sector and cylindrical mirror analyzers.

Primary Electron Sources are very important in AES, the excited beam for Auger electron production must have some specifications. The primary electron beam is a monochromatic beam of energy in the range of three KeV