Effects of Incident Ions Energy on the Asymmetry of Spin Polarized Auger Electrons

A. Mudhafer and T. A. Selman
Physics Department, College of Science, University of Basrah
Basrah, Iraq

Abstract

The theoretical aspects of the spin polarization of Auger electrons have been formulated in a simple model. The model allow us to explain in quantitative terms the measured spin polarization of the yield in the interaction of spin polarized He^+ ions with metal surfaces.

The spin polarized emitted Auger electrons can be simply related to the character of the hole state on the He^+ ion.

The effects of the energy of incident of the He^+ ion on the emitted spin polarized electron are calculate and discussed,

Our calculations to the spin polarized emitted electrons from Ni(110) , Al(100) surfaces are compared with experimental data show a good agreement.

Keyword: Spin polarizations, Ni(110) surface , Auger neutralizations ,spin polarized He^+ ion , emitted Auger electrons

1- Introduction

In the last few decades, the importance of surface has begun to be recognized, and there has been a resulting explosion in the field of surface science(F. J. Kontur ,2005 ; F.Amuryr et al ,2010). The study of the neutralization (de-excitation) of spin-polarized He^+ ions (He^* metastable atoms) interacting with magnetic metal surfaces constitutes an active field of research. Low velocity He^+ ions (He^* metastable atoms) are among the most used projectiles due to the absence of resonant electron capture processes from the metal valance band to the 1s bound state of the incident particles. In the case of paramagnetic surfaces special attention has been paid to the spin-polarization of electrons emitted during the neutralization (de- excitation) of the projectile that takes place via Auger process.

Analysis of emitted electrons provides information on the electronic properties of the metal surface, as well as on the characteristics of the charge- exchange processes that take place. A large amount of experiments based on this technique has been devoted to investigate magnetic properties or, in more general sense, spin related effects on the interaction of the particles and surfaces(L. Lavagnino et al , 2011 ; Pratt A et al, 2010 ; M . Alducin and M . Rosler , 2007 ; M .Onellion et al ,1984; M . Salvietti et al , 1996 ; D.L. Bixler et al ,1999; R . Moroni et al , 2003; J.C. Lancater et al , 2003; M . Kurahashi et al , 2003) .

In the last years, a variety of theoretical models have been proposed to study different aspects of Auger process(M . Alducin and M . Rosler , 2007 ; N . Lorente et al , 1994 ; M . Alducin ,1996 ; M .A. Cazalilla et al , 1998 ; N.P.Wang et al , 2001 ; N.P.Wang et al , 2003) but little about spin polarization , some papers analyzed spin effects (M. Alducin and M . Rosler , 2007; D.R. Penn and S.P.Apell , 1990; L.A.Salmi ,1992; M . Alducin et al , 2004; M . Alducin et al , 2004(*); M . Alducin et al ,2005; J.I.Juaristi et al , 2005; R.Vincent et al ,2007)

In this paper, we try to calculate the asymmetry of the emitted Auger electrons following the neutralization of He^+ ions scattered off the Ni(110) and Al(100) surfaces . The present study was motivated by experiments by Onellion et al and Lancaster et al on spin resolved Auger transition that involves two valance band electrons of Ni(110) and Al(100) surfaces.

2- Theoretical consideration

Following the work of David R. Penn and Peter Apell(D.R. Penn and S.P.Apell , 1990), the theoretical framework is described in details in this section. As a first step, we derive a coupled- channel formulation of ion-surface Auger neutralization. In Auger neutralization, an electron (e_1) with spin σ, decays from an occupied state in the metal surface $|\varphi_k^\sigma\rangle$, with energy E_k^σ, to the empty bound state of the He^+ ion $|\varphi_a^\sigma\rangle$ with energy E_a^σ. Another electron (e_2) with spin $\sigma(\sigma')$ from the band in a state $|\varphi_j^{\sigma(\sigma')}\rangle$ with energy $E_j^{\sigma(\sigma')}$, excited to the state $|\varphi_f^{\sigma(\sigma')}\rangle$ with energy $E_f^{\sigma(\sigma')}$, (where σ' is opposite to σ). The process is schematically shown in Fig.1.

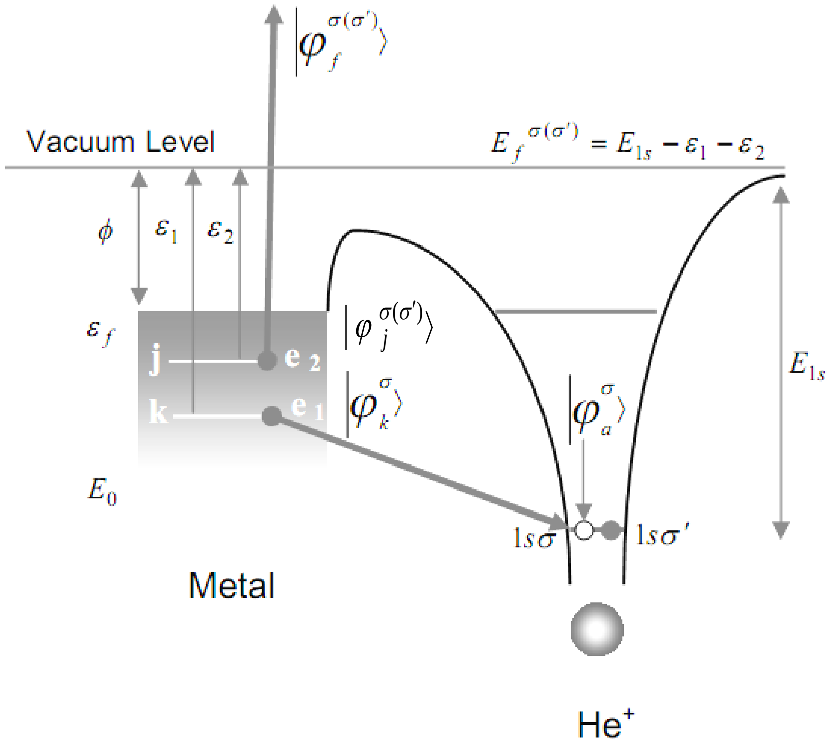

Fig.1. Schematic drawing of the Auger Neutralization Process.

The one- electron wave function corresponding to the metal $|\varphi_{k(j)}^{\sigma,\sigma(\sigma')}\rangle$, ion $|\varphi_a^{\sigma}\rangle$ and excited electron $|\varphi_f^{\sigma(\sigma')}\rangle$ states are as follows:

1- The metal state wave function is described by (R .Zimung , et al 1991)

$$\varphi_{k(j)}^{\sigma,\sigma(\sigma')}(r) = \frac{1}{\sqrt{L^2}} \sum_g B_g^{k(j)} e^{i(\vec{k}_{11}+\vec{g})\cdot\vec{r}_{11}} R_{\vec{k}_{11}+\vec{g}}(z) \tag{1}$$

where $R_{\vec{k}_{11}+\vec{g}}(z) = e^{-\theta_{k(j)}z}$ (2)

is the solution of the following one- dimensional Schrödinger equation,

$$\left\{\frac{\hbar^2}{2m}\frac{d^2}{dz^2} + [E_{k(j)}^{\sigma,\sigma(\sigma')} - \frac{\hbar^2}{2m}(\vec{k}_{11}+\vec{g})^2]\right\}\vec{R}_{11+\vec{g}}(z) = 0 \tag{3}$$

with $\vec{k}_{11} = \vec{k}_x + \vec{k}_y$; $\vec{r}_{11} = \vec{x} + \vec{y}$ and $\theta_{k(j)} = \sqrt{\frac{2m}{\hbar^2}\left|E_{k(j)}^{\sigma,\sigma(\sigma')}\right| + (\vec{k}_{11}+\vec{g})^2}$ (4)

here, $\vec{g}$ is the reciprocal lattice vector, L^2 is the surface area introduced for the normalization purpose and $B_g^{k(j)}$ are coefficient (to be determined) related to the partial density of the electronic states(for g=0) $\rho_0(E,\vec{k}_{11})$ as follows (S.I.Easa ,1986) .

$$\rho_0(E,\vec{k}_{11}) = \sum_{k,k'_{11}} \left|B_0^{k(j)}\right|^2 \delta k_{11}k'_{11}\delta(E - E_{k(j)}^{\sigma,\sigma(\sigma')}) \tag{5}$$

2- The wave function of the incident ion orbital is approximated by hydrogen like 1s state wave function as,

$$\varphi_a^{\sigma}(r) = \sqrt{\frac{\beta_a^3}{\pi}} e^{-\beta_a r} \quad (6)$$

Where β_a is the effective core charge

3- The wave function of the Auger electron (emitted above the vacuum level) can be well approximated by a plane wave for all energies $E_f^{\sigma(\sigma')}$ as,

$$\varphi_f^{\sigma(\sigma')}(\vec{r}) = L^{-\frac{3}{2}} e^{i\vec{q}\cdot\vec{r}} \quad (7)$$

With the Auger electron wave vector magnitude,

$$q = \sqrt{\frac{2m}{\hbar^2}(E_f^{\sigma(\sigma')} - E_0)} \quad (8)$$

With E_0 is the bottom of the valance band

4- The two electron Hamiltonian is given by:

$H(e_1,e_2,;t)=H(e_1;t)+H(e_2;t)+V_p(r,t)+V(e_1,e_2)$ (9)

Where H(i;t) is the one- electron Hamiltonian (with i refer to1 or 2 electron). $V_p(r,t)$ is the interaction energy of the electron at *z*(t) from the metal surface with it's own image, any other electron image and atomic core image inside the metal. The interaction term V (e_1,e_2) between the two electrons can be used for Auger neutralization process as screened coulomb potential when the energy transfer is small (less than plasmon frequency)(T.A. Selman ,2000)

$V(e_1,e_2) = \frac{\exp(-\lambda|\vec{r}_1 - \vec{r}_2|)}{|\vec{r}_1 - \vec{r}_2|}$ with λ is the screening parameters ($\frac{1}{\lambda}$ is the screening distance).

The eigenstate expansion method is used for obtaining a coupled channel formulation of two-electron state amplitudes, relevant for Auger neutralization ,where the time-dependent wave function for the ion-surface system is given by (J.C. Tully, 1977),

$$| e_1,e_2;t\rangle = C_{fa}(t)\left|\varphi_f^{\sigma(\sigma')},\varphi_a^{\sigma};t\right\rangle \exp[-i\int_{t_0}^{t}(E_f^{\sigma(\sigma')} + E_a^{\sigma})d\tau] + \sum_{j,k} C_{jk}(t)\left|\varphi_j^{\sigma(\sigma')},\varphi_k^{\sigma};t\right\rangle \exp[-i\int_{t_0}^{t}(E_j^{\sigma(\sigma')} + E_k^{\sigma})d\tau] \quad (10)$$

Where $C_{jk}(t)$ represent the initial state amplitude coefficient which is decay to the final state amplitude $C_{fa}(t)$. Substituting equation (10) into time- dependent Schrödinger equation and using (9) leads to the following coupled equations for the state amplitudes of Auger neutralization process:

$$i\dot{C}_{fa}(t) = \sum_{jk} A^{j\sigma(\sigma'),k\sigma}_{f\sigma(\sigma'),a\sigma}(t)\,\mathrm{C}_{\mathrm{jk}}(t)\exp[i\int_{t_0}^{t}(E^{\sigma}_{a} + E^{\sigma(\sigma')}_{f} - E^{\sigma(\sigma')}_{j} - E^{\sigma}_{k})d\tau] \qquad (11_a)$$

$$i\dot{C}_{jk}(t) = A^{f\sigma(\sigma'),a\sigma}_{j\sigma(\sigma'),k\sigma}(t)\,C_{fa}(t)\exp[-i\int_{t_0}^{t}(E^{\sigma}_{a} + E^{\sigma(\sigma')}_{f} - E^{\sigma(\sigma')}_{j} - E^{\sigma}_{k})d\tau] \qquad (11_b)$$

Where $A^{f\sigma'(\sigma),a\sigma}_{j\sigma(\sigma'),k\sigma}(t) = \langle\varphi^{\sigma(\sigma')}_{j}\varphi^{\sigma}_{k};t|V(e_1,e_2)|\varphi^{\sigma(\sigma')}_{f}\varphi^{\sigma}_{a};t\rangle$ is the Auger neutralization matrix element.

The coupled equations (11_a) and (11_b) have to be solved with initial conditions in time t_0 far before the interaction ($t_0=-\infty$):

$$C_{fa}(t_0) = 0 \qquad (12_a)$$

$$\langle \overset{*}{C}_{j'k'}(t_0)\,C_{jk}(t_0)\rangle = f(E_j)\,f(E_k)\delta_{kk'}\delta_{jj'} \qquad (12_b)$$

Where $\langle\ \ \rangle$ means averaging over the ground state of the metal surface and $f(E)$ is the Fermi-Dirac distribution:

$$f(E) = \{1 + \exp[(E+\phi)/KT]\}^{-1} \qquad (13)$$

With ϕ being work function , T the solid surface temperature. Integrating (11_b) we obtain,

$$C_{jk}(t) = C_{jk}(t_0) - i\int_{t_0}^{t}dt' A^{f\sigma(\sigma'),a\sigma}_{j\sigma(\sigma'),k\sigma}(t)C_{fa}(t')\exp[-i\int_{t_0}^{t'}(E^{\sigma}_{a} + E^{\sigma(\sigma')}_{f} - E^{\sigma(\sigma')}_{j} - E^{\sigma}_{k})d\tau] \qquad (14)$$

Substituting (14) into (11_a) to obtain the integro- differential equation for $C_{fa}(t)$.

$$\begin{aligned} i\dot{C}_{fa}(t) = {} & \sum_{jk} A^{j\sigma(\sigma'),k\sigma}_{f\sigma'(\sigma),a\sigma}(t)\,C_{jk}(t_0)\exp[i\int_{t_0}^{t}(E^{\sigma}_{a} + E^{\sigma(\sigma')}_{f} - E^{\sigma(\sigma')}_{j} - E^{\sigma}_{k})d\tau] - \\ & \mathrm{i}\sum_{\mathrm{jk}} A^{j\sigma(\sigma'),k\sigma}_{f\sigma'(\sigma),a\sigma}(t)\int_{\mathrm{t_0}}^{t}dt'\,A^{a\sigma,f\sigma'(\sigma)}_{k\sigma,j\sigma(\sigma')}(t)\,C_{fa}(t)\exp[i\int_{t_0}^{t'}(E^{\sigma}_{a} + E^{\sigma(\sigma')}_{f} - E^{\sigma(\sigma')}_{j} - E^{\sigma}_{k})d\tau] \end{aligned} \qquad (15)$$

As a second step , we use the separation between the time - and quantum - number - dependence of the matrix elements(Z.L. Miskovic and R.K.Janev, 1986)

$$A^{f\sigma(\sigma'),a\sigma}_{j\sigma(\sigma'),k\sigma}(t) = A^{f\sigma(\sigma'),a\sigma}_{j\sigma(\sigma'),k\sigma}\,u(t) \qquad (16)$$

and introducing the Auger neutralization rates $\Gamma^{\sigma(\sigma')}_{\sigma}(E_A,z)$,

$$\Gamma^{\sigma(\sigma')}_{\sigma}(E_A,z) \propto |C_{fa}(t)|^2 \cong \frac{2\pi}{\hbar}\sum_{jk,fa}|A^{j\sigma(\sigma'),k\sigma}_{f\sigma(\sigma'),a\sigma}|^2\delta(E^{\sigma}_{k} + E^{\sigma(\sigma')}_{j} - E^{\sigma}_{a} - E^{\sigma(\sigma')}_{f})\delta(E_A - E^{\sigma(\sigma')}_{f}) \qquad (17)$$

We obtain the average number of electron $N_{\sigma}(E_A)$ excited during the Auger neutralization process as,

$$N_\sigma(E_A)=\int_0^\infty dz\,\frac{\Gamma_\sigma^{\sigma(\sigma')}(E_A,z)}{v(z)}\exp[-\int_z^\infty dz'\left(\frac{\int_{-\infty}^{\infty} dE_A \Gamma_\sigma^{\sigma(\sigma')}(E_A,z)}{v(z)}\right)] \tag{18}$$

The velocity of the He^+ ion , $v(z)$, normal to the surface is related to the function $u(t)$ in equation (16), where $u(t)=\exp(-az(t))=\exp(-av(z)|t|)$, $z(t)$ is the classical trajectory of the ion , and $v(z)$ is given by,

$v(z)=\sqrt{\frac{2}{M}(E_{inc}+\frac{e^2}{4z})}$, where M is the mass of the He atom , E_{inc} is the energy of the incident ion.

The rate that spin $\uparrow$ electrons are produced at energy E_A by a spin $\downarrow$ empty hole of the He^+ ion is:

$$\Gamma_\downarrow^{(\uparrow)}(E_A,z)=\frac{2\pi}{\hbar}\int d\varepsilon\sum_{l,l'}\rho_{l\downarrow}(\varepsilon)\rho_{l'\uparrow}(E_A+E_{1s}-\varepsilon)\left|A^{ll'}(\varepsilon,E_A+E_{1s}-\varepsilon)\right|^2 f(\varepsilon)f(E_A+E_{1s}-\varepsilon) \tag{19}$$

The modification from (17) to (19) is simplified by (E.O.Kane , 1967). Where $\rho_{l\sigma}(\varepsilon)$, $\rho_{l'\sigma'}(\varepsilon')$ is the surface density of the electronic states. E_{1s} is the energy of the He 1s state.

The rate that spin $\downarrow$ electrons are produced at energy E_A by spin $\downarrow$ empty hole of the He^+ ion is:

$$\Gamma_\downarrow^{(\downarrow)}(E_A,z)=\frac{2\pi}{\hbar}\int d\varepsilon\sum_{l,l'}\rho_{l\downarrow}(\varepsilon)\rho_{l'\downarrow}(E_A+E_{1s}-\varepsilon)$$
$$\times\frac{1}{2}\left|A^{ll'}(\varepsilon,E_A+E_{1s}-\varepsilon)-A^{l'l}(E_A+E_{1s}-\varepsilon,\varepsilon)\right|^2 f(\varepsilon)f(E_A+E_{1s}-\varepsilon) \tag{20}$$

The rate that spin $\uparrow$ electrons are produced at energy E_A by a spin $\uparrow$ empty hole of the He^+ ion is:

$$\Gamma_\uparrow^{(\uparrow)}(E_A,z)=\frac{2\pi}{\hbar}\int d\varepsilon\sum_{l,l'}\rho_{l\uparrow}(\varepsilon)\rho_{l',\uparrow}(E_A+E_{1s}-\varepsilon)$$
$$\times\frac{1}{2}\left|A^{ll'}(\varepsilon,E_A+E_{1s}-\varepsilon)-A^{l'l}(E_A+E_{1s}-\varepsilon,\varepsilon)\right|^2 f(\varepsilon)f(E_A+E_{1s}-\varepsilon) \tag{21}$$

The rate that spin $\downarrow$ electrons are produced at energy E_A by a spin $\uparrow$ empty hole of the ion He^+ ion is:

$$\Gamma_\uparrow^{(\downarrow)}(E_A,z)=\frac{2\pi}{\hbar}\int d\varepsilon\sum_{l,l'}\rho_{l\uparrow}(\varepsilon)\rho_{l'\downarrow}(E_A+E_{1s}-\varepsilon)\left|A^{ll'}(\varepsilon,E_A+E_{1s}-\varepsilon)\right|^2 f(\varepsilon)f(E_A+E_{1s}-\varepsilon) \tag{22}$$

The difference in the rates at which He^+ ion of different spin produce Auger electrons can be calculate as $\Delta\Gamma(E_A,z)=\Gamma_\uparrow(E_A,z)-\Gamma_\downarrow(E_A,z)$ with, $\Gamma_\uparrow(E_A,z)=\Gamma_\uparrow^{(\uparrow)}(E_A,z)+\Gamma_\uparrow^{(\downarrow)}(E_A,z)$ and $\Gamma_\downarrow(E_A,z)=\Gamma_\downarrow^{(\uparrow)}(E_A,z)+\Gamma_\downarrow^{(\downarrow)}(E_A,z)$

$$\Delta\Gamma(E_A,z)=\frac{2\pi}{\hbar}\int d\varepsilon\sum_{l,l'}\{[(\rho_{l\uparrow}(\varepsilon)\rho_{l'\uparrow}(E_A+E_{1s}-\varepsilon)-\rho_{l\downarrow}(\varepsilon)\rho_{l'\downarrow}(E_A+E_{1s}-\varepsilon))$$
$$\times\frac{1}{2}\left|A^{ll'}(\varepsilon,E_A+E_{1s}-\varepsilon)-A^{l'l}(E_A+E_{1s}-\varepsilon,\varepsilon)\right|^2+(\rho_{l\uparrow}(\varepsilon)\rho_{l'\downarrow}(E_A+E_{1s}-\varepsilon)- \tag{23}$$
$$\rho_{1\downarrow}(\varepsilon)\rho_{l'\uparrow}(E_A+E_{1s}-\varepsilon))\left|A^{ll'}(\varepsilon,E_A+E_{1s}-\varepsilon)\right|^2]f(\varepsilon)f(E_A+E_{1s}-\varepsilon)\ \}$$

Also , the total rate $\Gamma_0(E_A,z)$ is given by:

$$\Gamma_0(E_A,z)=\Gamma_\uparrow(E_A,z)+\Gamma_\downarrow(E_A,z)$$
$$=\frac{2\pi}{\hbar}\int d\varepsilon\sum_{l,l'}\{[(\rho_{l\uparrow}(\varepsilon)\rho_{l'\uparrow}(E_A+E_{1s}-\varepsilon)+\rho_{l\downarrow}(\varepsilon)\rho_{l'\downarrow}(E_A+E_{1s}-\varepsilon))$$
$$\times\frac{1}{2}\left|A^{ll'}(\varepsilon,E_A+E_{1s}-\varepsilon)-A^{l'l}(E_A+E_{1s}-\varepsilon,\varepsilon)\right|^2+(\rho_{l\uparrow}(\varepsilon)\rho_{l'\downarrow}(E_A+E_{1s}-\varepsilon)+ \tag{24}$$
$$\rho_{1\downarrow}(\varepsilon)\rho_{l'\uparrow}(E_A+E_{1s}-\varepsilon))\left|A^{ll'}(\varepsilon,E_A+E_{1s}-\varepsilon)\right|^2]f(\varepsilon)f(E_A+E_{1s}-\varepsilon)\ \}$$

Define $\eta(E_A,z)$ and $\Delta\eta(E_A,z)$ as the ratio between the total and the difference in the rates and the ion velocity $v(z)$ as $\eta(E_A,z)=\frac{\Gamma_0(E_A,z)}{v(z)}$, $\Delta\eta(E_A,z)=\frac{\Delta\Gamma(E_A,z)}{v(z)}$, then using equation(18) we get the average number of electrons emitted with different spin during the Auger neutralization process at energy E_A ,

$$N_\uparrow(E_A)=\int_0^\infty dz(\eta(E_A,z)+\Delta\eta(E_A,z))\exp[-\int_z^\infty dz'\int_{-\infty}^\infty dE_A(\Delta\eta(E_A,z')+\eta(E_A,z')] \tag{25}$$

And for the spin-down emitted electrons is,

$$N_\downarrow(E_A)=\int_0^\infty dz(\eta(E_A,z)-\Delta\eta(E_A,z))\exp[\int_z^\infty dz'\int_{-\infty}^\infty dE_A(\Delta\eta(E_A,z')-\eta(E_A,z')] \tag{26}$$

Additionally, the neutralization rate per unit distance $D(z)$ is given by:

$$D(z)=\frac{\int_{-\infty}^\infty dE_A\Gamma_0(E_A,z)}{v(z)} \tag{27}$$

If we consider $n_\sigma(z)$ be the probability that initially empty hole of He^+ ion $(\sigma=\uparrow,\downarrow)$ is still empty after the ion(at $z=\infty$), has reached a distance z from the surface. Far from the surface $n_\sigma(z)\to 1$ and decreases monotonically with decreasing *z*. Thus,

$$n_\uparrow(z)=n_0(z)[1-\int_z^\infty dz'\int_{-\infty}^\infty dE_A\Delta\eta(E_A,z')] \tag{28}$$

$$n_\downarrow(z)=n_0(z)[1+\int_z^\infty dz'\int_{-\infty}^\infty dE_A\Delta\eta(E_A,z')] \tag{29}$$

$n_0(z)$ is the number of He^+ ions and is given by:

$$n_0(z) = \exp[-\int_z^{\infty} dz' D(z')] \quad (30)$$

and $S(z) = n_0(z) D(z')$ is the filling probability(neutralization probability).

With the help of equations (28) and (29) , we can rewrite equations (25) and (26) as,

$$N_{\uparrow}(E_A) = \int_z^{\infty} dz'[\eta(E_A, z') + \Delta\eta(E_A, z')] n_{\uparrow}(z') \quad (31)$$

$$N_{\downarrow}(E_A) = \int_z^{\infty} dz'[\eta(E_A, z') - \Delta\eta(E_A, z')] n_{\downarrow}(z') \quad (32)$$

The number of emitted electrons with energy greater than E_A is given by:

$$N_{\sigma}^{\rangle}(E_A) = \int_{E_A}^{\infty} N_{\sigma}(E'_A) dE'_A \quad (33)$$

The spin polarization $P(E_A)$ of electrons emitted in the neutralization of He^+ ion in a metal surface is defined as the relative difference between the number of spin-down $N_{\downarrow}^{\rangle}(E_A)$ and spin-up $N_{\uparrow}^{\rangle}(E_A)$ electrons, i.e.

$$P(E_A) = \frac{N_{\downarrow}^{\rangle}(E_A) - N_{\uparrow}^{\rangle}(E_A)}{N_{\downarrow}^{\rangle}(E_A) + N_{\uparrow}^{\rangle}(E_A)} \quad (34)$$

Calculation and discussion

Since the incident $He(2^3S)$ atoms are electron-spin polarized in a selected direction, the spin of the electron which fills the He^+ 1S hole is know.For a given incident spin direction, all electrons emitted from the metal produce one electron due to the filling of 1S hole.The actul measured yield is smaller than because not all electrons escape in to the vacuum .However, the escape probability with depend only on energy and not spin so that *P(EA)* is not effected . We therefore neglect the escape probability in this paper.

surface with an energy higher than some energy E_A are collected, regardless of spin.The spin of He atoms is reversed and again emitted electrons with energy higher than E_A are collected. A He^+ ion with a 1S hole of spin σ(σ') incident on surface will

We use an expression for the matrix elements given by Easa and Modinos (S.I.Easa,1986) for the Auger neutralization process and an approximate elliptical formula for the surface density of state assumed as (T.A.

Selman,2000), $$\rho_{l\sigma(\sigma')}(\varepsilon) = \frac{1}{\pi\beta}\sqrt{1-(\frac{\varepsilon-b}{2\beta})^2}$$

where, b is the energy position at the maximum diameter of elliptic shape which is chosen to be the Fermi energy level position and β is an energy parameter related to the energy band width ($\approx 4\beta$).

In Fig. (2) we show the asymmetry of spin polarization of the emitted electrons from He^+ ion incident on Ni(110) surface, the figure shows high polarization at high Auger electrons energy, also it represents the effect of incident energy of He^+ ions.

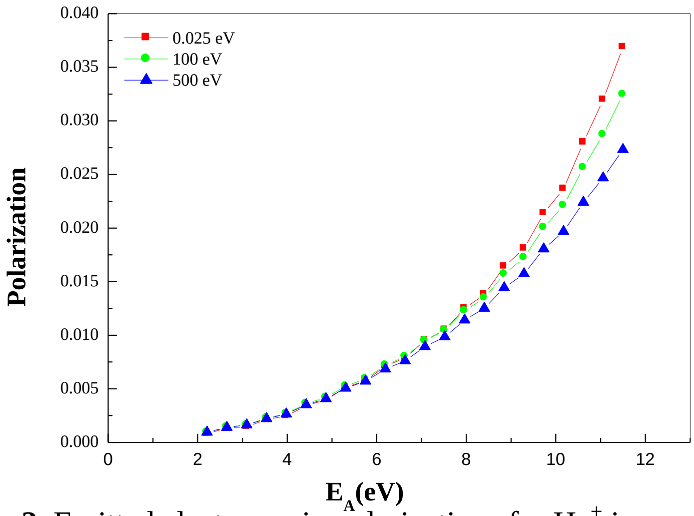

Fig.2. Emitted electron spin polarizations for He^+ ions with different incident projectile energies at Ni(110)surface.

A good agreement between our results and the experimental data(M.Onellion et al ,1984) shown in Fig.(3),the results normalized with experimental data at 9 eV energy.

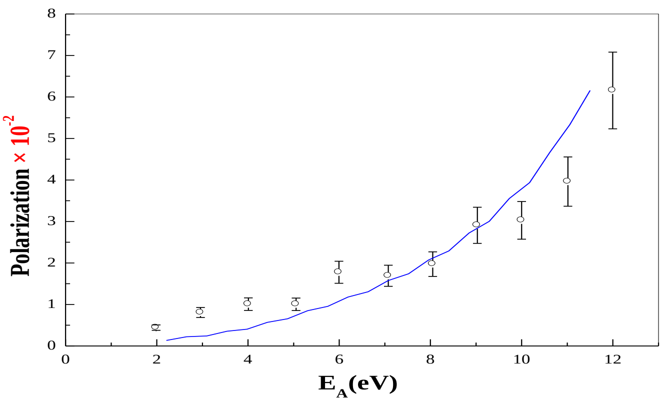

Fig.3. Polarization of electrons emitted with larger than E_A Theoretical results are shown by solid line.The open circles are experimental data for the polarization of the electrons e-mitted in the neutralization of He^+ ions in front of Ni(110) surface ,with incident projectile energy 0.025 eV.

Fig.(4) represents the neutralization rate per unit distance for the He^+ ions at Ni(110)surface (equation 27), it shows high incident energy less neutralization rate.

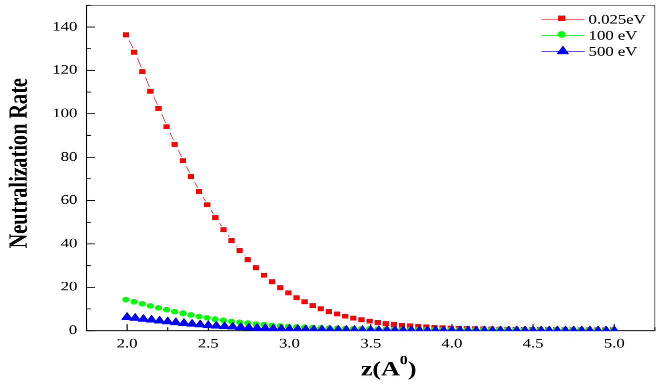

Fig.4. The neutralization rate per unit distance for Ni(110) surface.

The neutralization probability was shown in Fig.(5) for different incident energy of the He^+ ions at the Ni(110) surface.

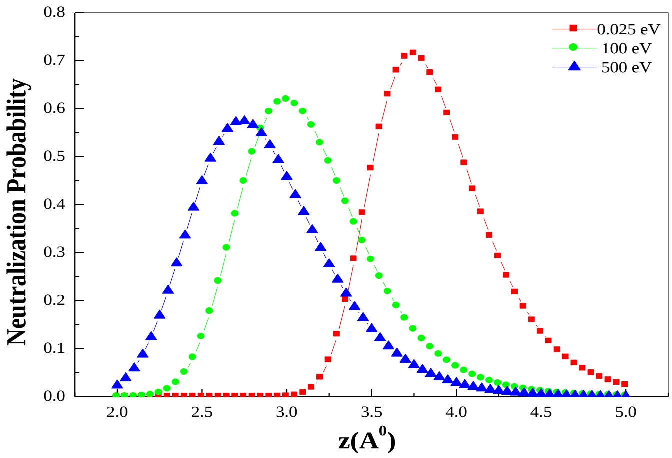

Fig.5. The neutralization probability for He^+ ions at Ni(110) surface.

Fig.(6) shows the relation of the number of He^+ ions(survival probability) as a function of the ion-surface distance.

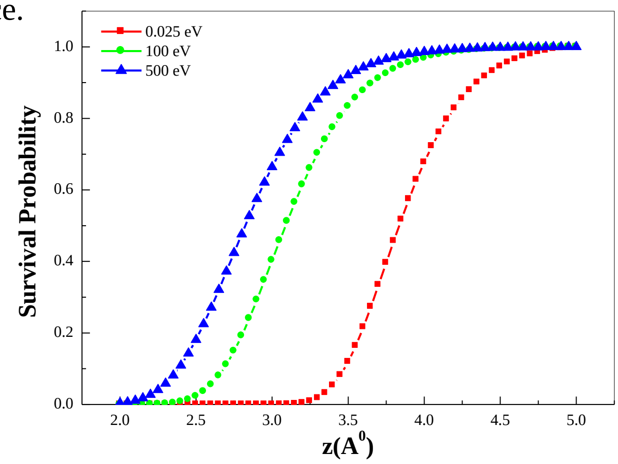

Fig.6. The survival probability for He^+ ions at Ni(110)surface

The same study has down for different surface Al(100). Fig.(7),(9),(10) and Fig.(11) have the same property of Fig.(2),(4),(5)and Fig.(6) but Fig.(8) for the polarization shows good agreement at high energy of the emitted electrons but differ at low energy(J.C. Lancaster et al , 2003).

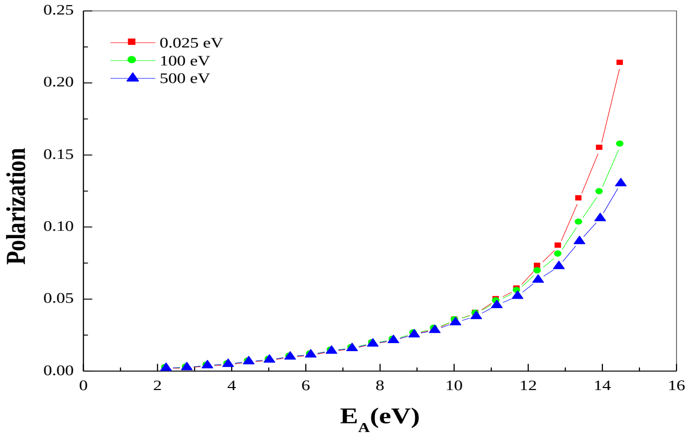

Fig.7. Same as Fig.2,but the results are for the Al(100) surface.

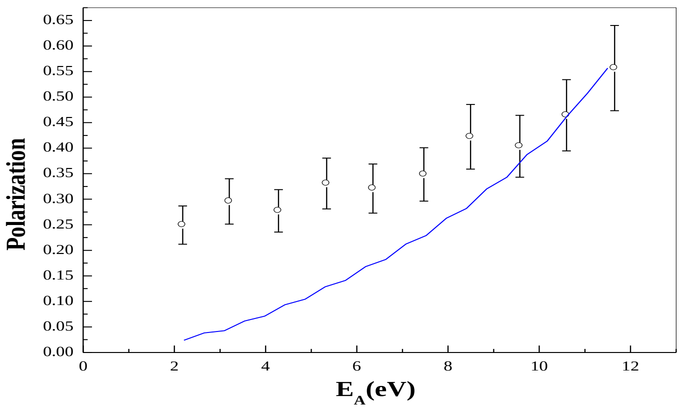

Fig.8. Same as Fig.3 , but the experimental results for the Al(100)surface,with incident projectile energy 15 eV.

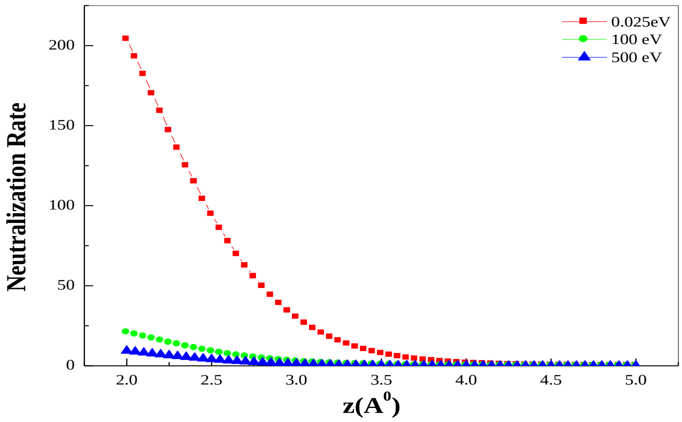

Fig.9. Same as Fig.4,but the results are for the Al(100) surface

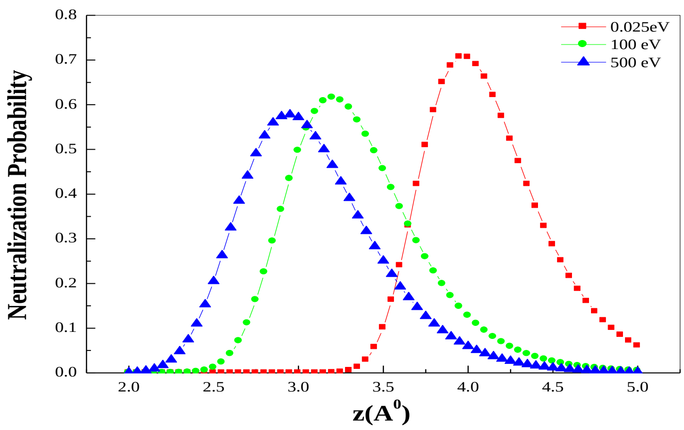

Fig.10. Same as Fig.5,but the results are for the Al(100) surface

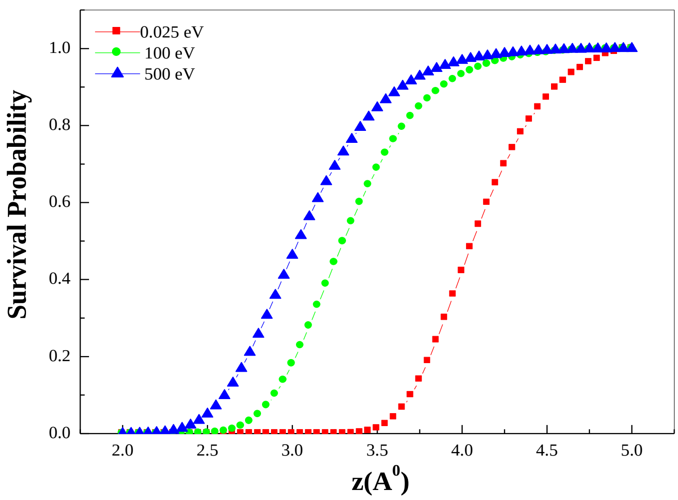

Fig.11. Same as Fig.6,but the results are for the Al(100) surface

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تأثير طاقة سقوط الايون على اللاتماثل في استقطاب البرم لالكترونات أوجيه

طالب عبد النبي سلمان ، احمد مظفر عبد الأمير
قسم الفيزياء – كلية العلوم – جامعة البصرة – البصرة - العراق

المستخلص

أعد أنموذج نظري يحوي سمات استقطاب البرم لألكترونات أوجيه ويسمح لنا هذا الأنموذج بتفسير نتائج استقطاب البرم لألكترونات أوجيه المنبعثة نتيجةً لتفاعل آيون الهيليوم He^+ مستقطب البرم مع سطوح المعادن.
إذ أن استقطاب البرم لالكترونات اوجيه المنبعثه يمكن إرجاعه إلى الصفات الخاصة بحالة الفجوة لأيون الهيليومHe^+ .
تأثيرات طاقة سقوط آيون الهيليوم He^+ ، على استقطاب البرم تم حسابها ومناقشة نتائجها.
أظهرت نتائج حساباتنا النظرية لاستقطاب البرم لالكترونات اوجيه المنبعثة من سطوح Ni(110) و Al(100) تطابقاً جيداً مع النتائج المقاسة عملياً.

استقطاب البرم ،سطح النيكل Ni(110)، تعادل اوجيه، ايون الهيليوم مستقطب البرم ، الكترونات اوجيه المنبعثة