Study the Sputtering of Au atoms Irradiated by Ar , Kr and Xe Ions

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Abstract

The theoretical study of Sputtering for gold atoms irradiated by normal incidence of Ar , Kr and Xe ions depend on energy and atomic number (Z_1) of ions and atomic number (Z_2) of the target , the essential dependence of sputtering is the nuclear stopping power .

The Sputtering yield of Au atoms irradiated by Xe ions are larger than that of other bombarding ions. It was found that the sputtering yield of Au atoms increased up to 300 keV for Kr ions and 400 keV for Xe ions , after that , the sputtering yield is decreased , on the other hand , sputtering of Au atoms decreased for 100-1000 keV of Ar ions , this results depend on deposited nuclear energy (nuclear stopping power), which in turn depends on the masses of bombarding the ions and the target . It was also found that sputtering yield is directly proportional to the ratio (Z_1/Z_2) at constat incident ions energy for the same target.

This study is the tool to indicate what are the energy and kind of irradiated ions used for getting the required sputtering yield of gold atoms to apply for different technological uses .

Keywords: sputtering, sputtering yield , ion irradiation, stopping of ions in matter, nuclear stopping power.

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دراسة الترذذ الحاصل لذرات الذهب عند تشعيعها بايونات الاركون والكربتون والزينون

الملخص

يعتمد الترذذ الحاصل في ذرات الذهب المشعة بايونات الاركون والكربتون والزينون بطاقات 100-1000 كيلوالكترون فولت على الطاقة والعدد الذري للايونات وكذلك العدد الذري للهدف ، ويعتمد بشكل اساسي على قدرة الايقاف النووية.

ان عدد ذرات الذهب المترذذة عند تشعيعها بايونات الزينون يكون اكبر من عدد ذرات الذهب المشععة بايونات الاركون والكربتون.

عدد ذرات الذهب المترذذة والمشععة بايونات الكربتون والزينون تزداد لحدالطاقة 300 كيلوالكترون فولت لايونات الكربتون ولحد الطاقة 400 كيلوالكترون فولت لايونات الزينون، وبعدها تقل للطاقات الاعلى ، ومن جهة اخرى فان عدد ذرات الذهب المترذذة والمشععة بايونات الاركون تقل عند الطاقات 100-1000 كيلوالكترون فولت ، وتعتمد هذه النتائج على قدرة الايقاف النووية والتي تعتمد بدورها على الكتل الذرية وطاقات الايونات الساقطة. وقد وجد ايضا ان ناتج الترذذ يعتمد على النسبة بين العدد الذري للايونات الساقطة والعدد الذري للهدف عندثبوت طاقة الايونات الساقطةولنفس مادة الهدف.

تعتبر هذه الدراسة اداة لكيفية استخدام طاقة ونوع الايونات المستخدمة للحصول على الترذذ المطلوب من ذرات الذهب لتطبيها في التقنيات المختلفة .

Introduction

Sputtering is a process whereby atoms are ejected from a solid target material due to bombardment of the target by energetic particles[1]. It is happens when the kinetic energy of the incoming particles is much higher than conventional thermal energies (>> 1 eV). This process can lead, during prolonged ion or plasma bombardment of a material, to significant erosion of materials, and can thus be harmful. On the other hand, it is commonly utilized for thin-film deposition, etching , ion beam mixing , ion implantation and surface modification .

Physical sputtering is driven by momentum exchange between the ions and atoms in the materials, due to collisions[2].

The incident ions set off collision cascades in the target. When such cascades recoil and reach the target surface with an energy greater than the surface binding energy, an atom would be ejected, known as sputtering. If the target is thin on an atomic scale the collision cascade can reach the back side of the target and atoms can escape the surface binding energy . The average number of atoms ejected from the target per incident ion is called the sputtering yield and depends on the ion incident angle, the energy of the ion, the masses of the ion and target atoms, and the surface binding energy of atoms in the target[3,4] .

Stopping power

The stopping power depends on the type and energy of the particle and on the properties of the material it passes. Since the production of an ion pair (usually a positive ion and a (negative electron) requires a fixed amount of energy , the density of ionisation along the path is proportional to the stopping power .

'Stopping power' is treated as a property of the material, while 'energy loss per unit path length' describes what happens to the particle. However, numerical value and units are identical for both quantities; they are usually written with a minus sign in front:

$$S(E) = -\frac{dE}{dx}$$

where E means energy, and x is the path length.

The equation above defines the linear stopping power which may be expressed in units of eV/A°.

The deposited energy can be obtained by integrating the stopping power over the entire path length of the ion while it moves in the material [5].

Anderson Model[6,7,8]

Sputtering process involves a complex series of collisions involving series of angular deflections and energy transfers between many atoms in solid. The most important parameter in the process is the energy deposited at the surface as shown in the following equation:

$Y = \Lambda F_D (E_o)$ ----------------(1)

Λ is the material factor which represents by [4] :

$\Lambda = 4.2 / N U_0$ nm/eV -----------(2)

N is the atomic density (atom/nm^3) and U_0 is the surface binding energy (eV/atom) .

$F_D (E_o)$ is deposited energy per unit length into nuclear processes at the surface , and depend on the type ,energy and direction of incident ion with atomic number (Z1) and the target composition (atomic number Z2 , mass number M2 , and atomic density(N) [6] .

$F_D (E_o) = \alpha NS_n(E_0)$ -----------(3)

(α) is constant and depend on (M_2/M_1)[3], $S_n(E_0)$ is the nuclear stopping power which may represent by :

$NS_n(E_0) = dE/dx|_n$ --------(4)

$dE/dx|_n$ is nuclear energy loss (stopping power).

Substituting equations (2---4) into equation (1) ,we get :

$Y = 4.2\, \alpha\, dE/dx|_n / N U_0$ --------(5)

Equation (5) represents sputtering yield in units of (atom/ion) .

Results and Discussion

The stopping power of Ar ions ,Kr ions and Xe ions in gold (Au) are calculated by TRIM computer code[5], as shown in fig (1) , fig(2) and fig(3) , respectively . These figures show that the nuclear stopping power dominated till 300 keV of Ar ions ,after that electronic stopping power is dominated since $Z1 / Z2 < 0.5$(Ar-Au) ,but the nuclear stopping power is dominated for $Z1 / Z2 \geq 0.5$(Kr-Au,Xe-Au).

The sputtering Yeild of Au atoms irradiated by Ar,Kr and Xe ions are calculated by using equation (5) , as shown in figure (4), the sputtering yield of Au atoms iirradiated by Xe ions is larger than that of other irradiated ions , this is due to stopping power as discussed above.

In conclusion, the present results conclusively show that the sputtering yield is affected by the mass of the projectile ions and target and nuclear stopping power .

It was found that the sputtering yield of Au atoms increased for energies, up to 300 keV for Kr ions and 400 keV for Xe ions , after that , the sputtering yield is decreased, on the other hand, the sputtering of Au atoms decreased for energies 100 – 1000 keV of Ar ions .

The sputtering yield of Au atoms at ions energy 500 keV, have been found to be as high as 32.2 atoms/ions for Xe ions which is comparable with that of 18.74 atom/ion for Kr ions, and 9.95 atom/ion for Ar ions .

This study is the tool to indicate what are the energy and kind of irradiated ions used for getting the required sputtering yield of gold atoms to apply for different technological uses.

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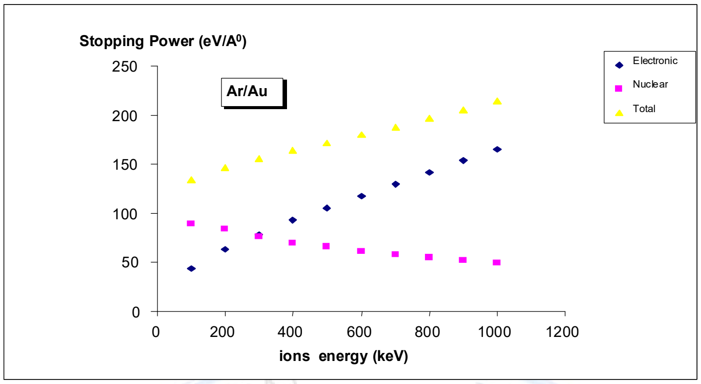
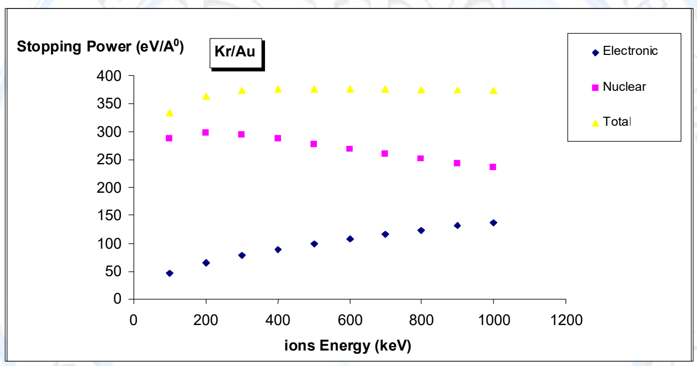
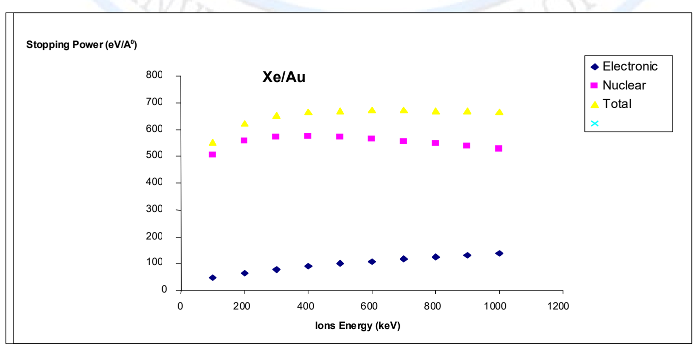


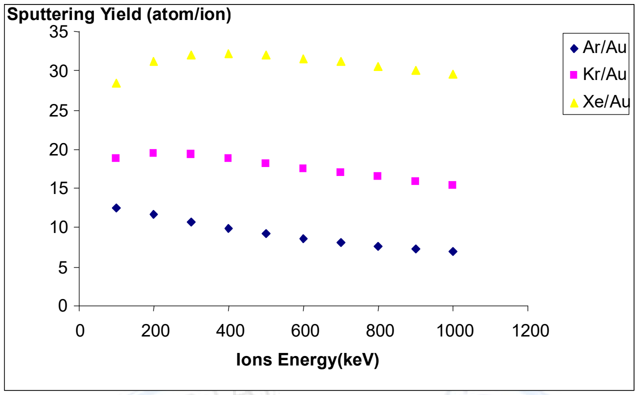
Fig(1):stopping Power versus Ar ions energy



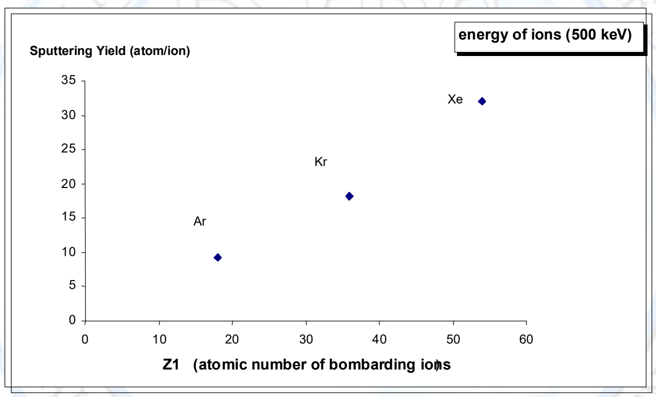
Fig(2):stopping Power versus Kr ions energy



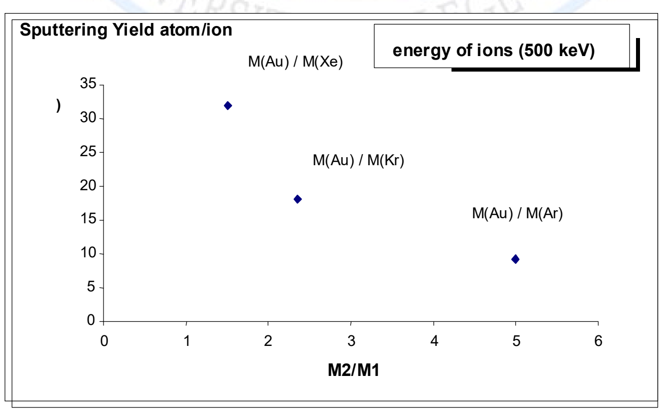
Fig(3):stopping Power versus Xe ions energy



Fig(4):sputtering yeild versus ions energy



Fig(5):sputtering yeild versus Z1 of ions



Fig(6):sputtering yeild versus M2/M1