Magnetron Sputtering with controlled primary ion energy

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Motivation

In direct ion beam sputtering it is a well known effect, that the ion energy of the sputtering ions influences the particle energy of the sputtered target atoms. Earlier [1] and later publications of this [2] show, that the energy distribution of sputtered target atoms is shifted to higher energies by varying the primary ion energy between 250 and 1000 eV. By this way the mean energy of the sputtered particles grows typically from 3 to 6 eV up to 6 to 10 eV, having some influence to the corresponding layer growth. Moreover an increased flux of reflected neutral sputter atoms is generated by increasing the primary sputter energy.

The aim of this work is to show, that with a modified magnetron (Dual Target Magnetron, DTM) the same, extended and controlled primary ion energy range up to 1000 eV can be realized.

Experimental

Fig.1 shows the used setup in cross section. A modified sputter magnetron (Dual Target Magnetron) with two target parts was used. Several target materials had been installed. The sputter plasma was ignited and generated by the DC-generator U_1, applied between anode and target 1.

The target part (erosion zone, target 2) where most sputtering occurs, was isolated against target 1 and powered by an additional negative voltage U_2.

A Retarding Field Analyzer (RFA) [3] was integrated into target 2 to measure the ion energy distribution.

The thickness of the deposited layers was measured to give the corresponding deposition speed.

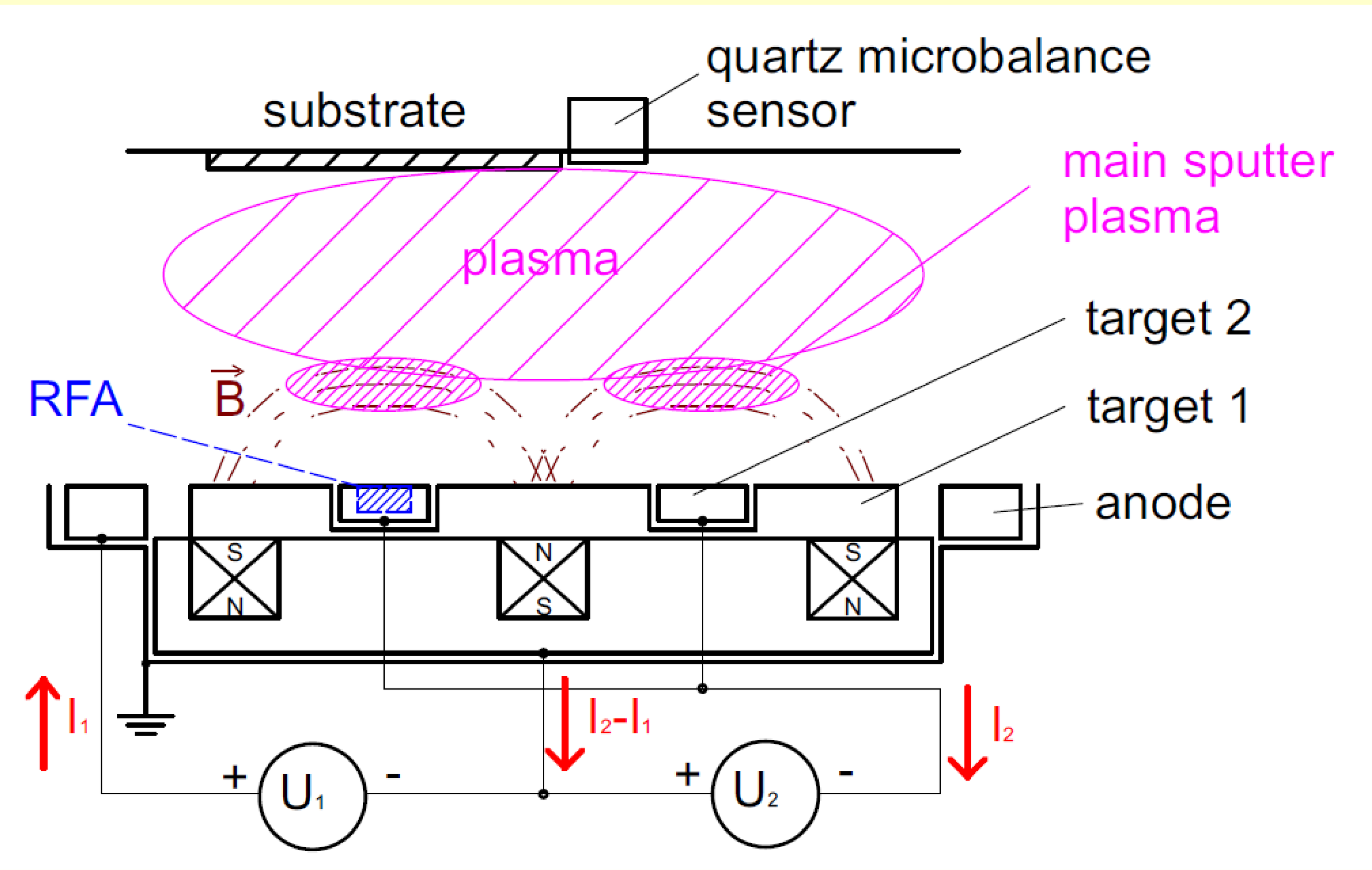

FIG.1: *Principal arrangement of sputtering with the Dual Target Magnetron in cross section*

By this method the energy of the primary argon ions, impinging on target 2, could be varied from 250 up to 800 eV . Application of more primary ion energy increases the deposition speed (increased sputter yield).

Generator 1 did power 80 W, voltage 2 was varied from 0 V up to 800 V. The total target area was 10 x 12 = 120 cm^2. The growth rate at the substrate at 50 mm distance was between 10 and 100 nm/ min.

FIG.2: *Dual Target Magnetron in operation (argon, 10^{-2}mbar, 80 W)*

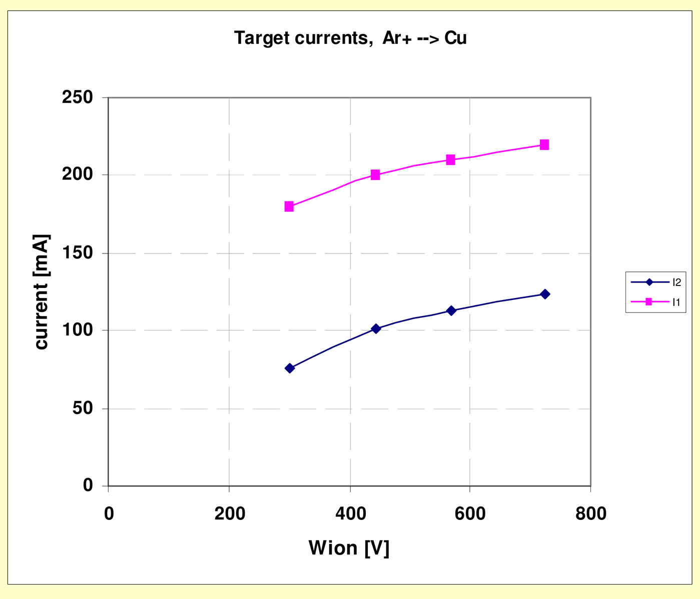

FIG.3: *Target currents of the Dual Target Magnetron in dependence from the primary ion energy (argon, 10^{-2}mbar, 80W)*

Fig.2 shows the DTM in operation and Fig.3 the target currents in dependence from the primary ion energy. The only small increase of Target 2 current I_2 demonstrates, that there occurs only a more or less collision less acceleration of the primary sputtering ions and not some additional plasma generation.

Results

Fig.4 shows the ion energy spectra measured at target 2 in dependence from the additional voltage U_2. The generator voltage U_1 was in all cases 375 V. The main peak of the energy spectrum is nearly complete shifted by the additional voltage U_2 to higher ion energies. So the ion energy at target 2 could be estimated by the formula:

$$W_{ion} = e*U_1 - e*U_{anode} + C*e*U_2 \qquad (1)$$

with U_{anode} = 40V and C= 0.9.

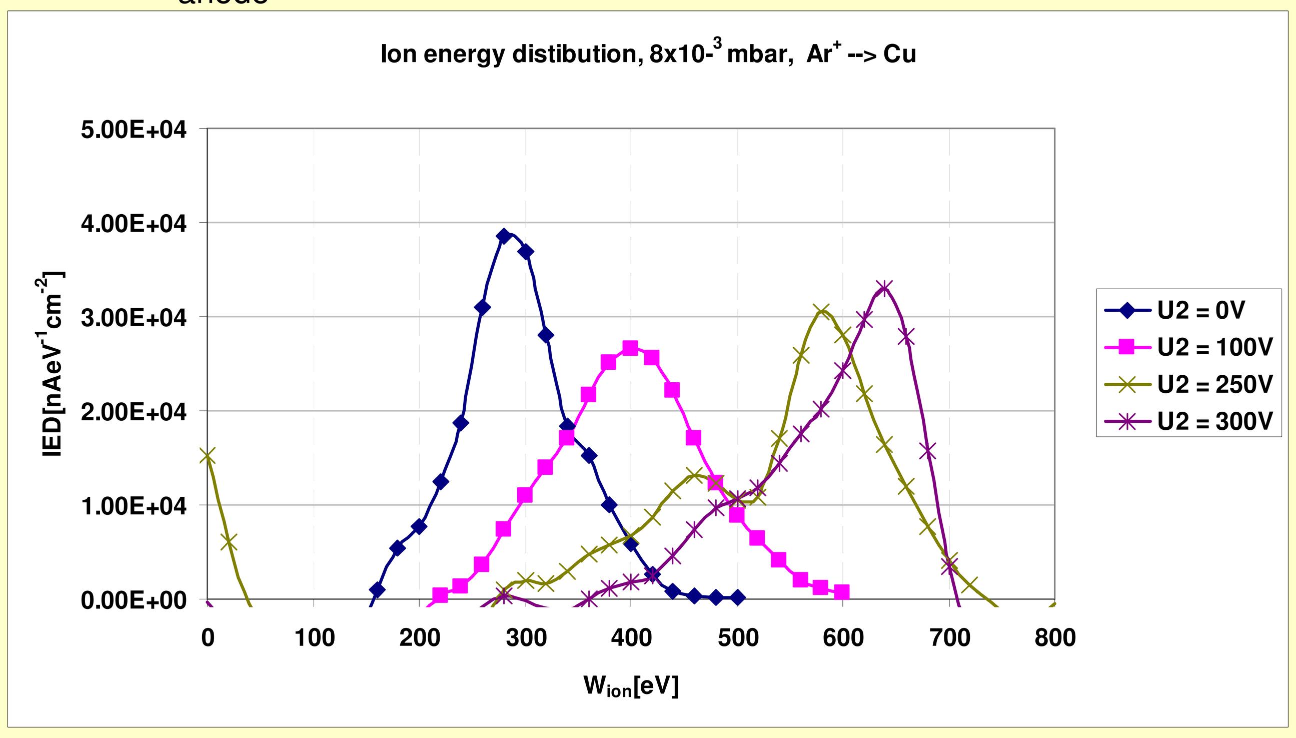

FIG. 4: *Ion energy distributions of the primary ions at sputtering of copper with argon measured with a Retarding Field Analyzer arranged at target 2.*

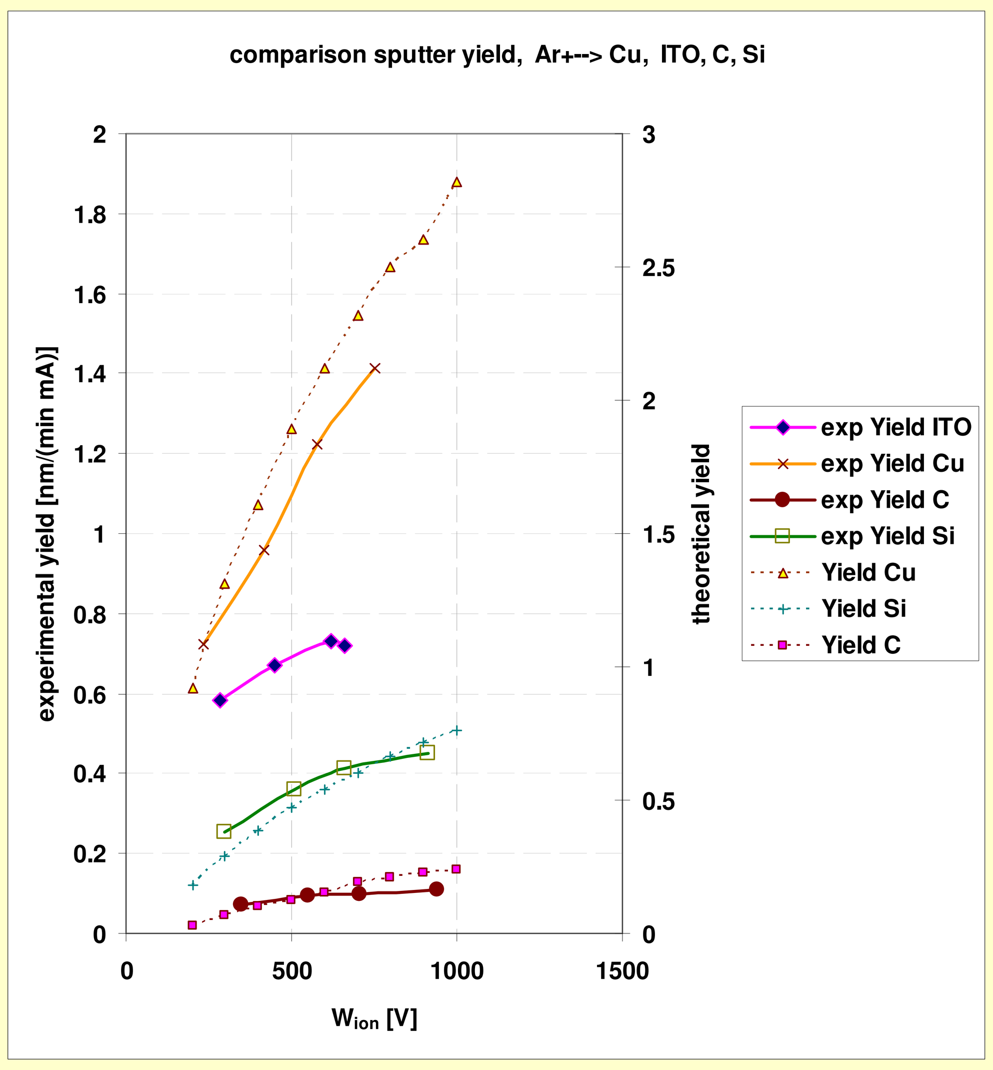

FIG. 5*: Comparison of theoretical and estimated sputter yield at target 2 for different target materials in dependence on the primary ion energy.*

The sputter yield, reached in this experiments, was estimated from the primary ion current I_2 at target 2 and the deposition speed at substrate level near target 2.

Fig.5 shows, that the so determined sputter yields are in good agreement with the theoretical values [4]. The primary ion energy was determined by applying equ. (1).

Summary/Outlook

In this work the principal function of the new developed Dual Target Magnetron is demonstrated with:

- demonstration of the primary ion acceleration to target 2 in dependence from the voltage U2 by measuring the corresponding ion energy distributions,
- demonstration of the increase of the sputter yield in dependence from the primary ion energy for several target materials.

First layer deposition test show, that the electrical conductance of copper films could be improved or the crystalline growth of silicon layers is increased by increasing primary ion energy (see this conference Poster #579 [5].

Further development should be done by:

- More investigation of layer properties, deposited by the DTM with varying the primary ion energy,
- further magnetron development (tube target versions, optimized DTM´s),
- RF-sputtering with the DTM for deposition of dielectric layers like oxides, nitrides, etc.

References

[1] Stuart R.V., Wehner G.K., J. Appl. Phys., 35, 1819, (1964),

[2] M. Stepanova, S.K. Dew, “Estimates of differential sputtering yields for deposition applications”, J. Vac. Sci. Technolog. A 19, 2805, (2001),

[3] http://www.jenion.de/Plasma-Analysis/

[4] https://www2.iap.tuwien.ac.at/www/surface/sputteryield

[5] Schlemm, H. PSE 2024, Poster #579, “Copper- and silicon Layers, sputtered with a magnetron with controlled primary ion energy”

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