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 [2,3] 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 [4], having some influence to the corresponding layer growth.

This effect is used in direct ion beam sputtering to reach by sputtering layer properties, which cannot be made with magnetron sputtering, because magnetron sputtering works normally with primary ion energies given by the plasma parameters in a range between 250 and 500 eV.

The aim of this work is to show, that with a modified magnetron (Dual Target Magnetron, DTM) an 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) [5] was integrated into target 2 to measure the ion energy distribution.

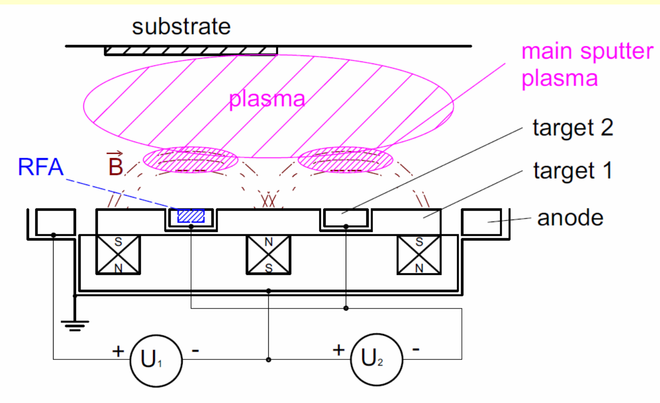

FIG.1: *Principal arrangement of sputtering with the Dual Target Magnetron in cross section*

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).

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

A Retarding Field Analyzer (RFA, [5]) was integrated into target 2 to measure the ion energy distribution of the sputtering primary argon ions .

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.

Results

Fig.2 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.

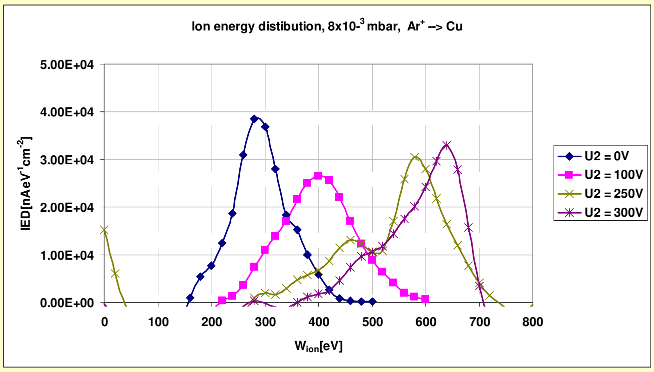

FIG. 2: *Ion energy distributions of the primary ions at sputtering of copper with argon measured with a retarding field analyzer arranged at target 2.*

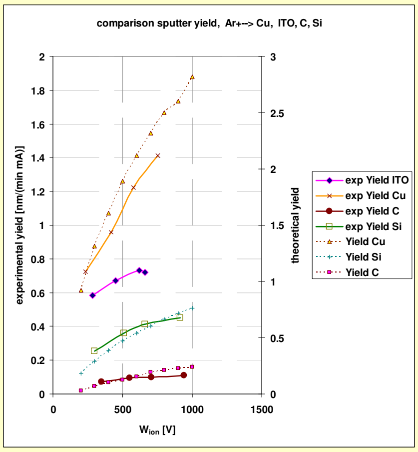

FIG. 3*: Comparison of theoretical and estimated sputter yield at target 2 for different target materials in dependence on the primary ion energy.*

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.3 shows, that the so determined sputter yields are in good agreement with the theoretical values [6]. The primary ion energy was determined by applying equ. (1).

Outlook

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.

Further development should be done by:

- More investigation of layer properties, deposited by the DTM with varying the primary ion energy,
- direct measuring of the energy distribution of the sputtered atoms generated by the DTM,
- further magnetron development (tube target versions, optimized DTM´s),
- RF-sputtering with the DTM.

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] C. Bundesmann, R. Feder, T. Lautenschläger, H. Neumann, „Energy Distribution of Secondary Particles in Ion Beam Deposition Process of Ag: Experiment, Calculation and Simulation", Contr. Plasma Phys. 55 (2015) 737-746,

[4] D. Depla, S. Mahieu, „Reactive Sputter Deposition", Springer Series in Materials Science, 109, (2010), 241,

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

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

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