I. **Introduction**

Thin metal film deposition techniques with various processing plasmas have been studied for fabrication of integrated circuits. In general, properties of deposited metal films are strongly influenced by the plasma parameters and substrate characteristics, such as ion and electron energies, plasma densities, and lattice constants. Among these, one of the most important factors affecting deposited metal thin film properties is considered to be the ion energy. The ion energy effects on crystalline growth have not been fully understood to date. In this study, we have deposited Au thin films using a low energy mass selected ion beam system in order to investigate the ion energy dependence of crystalline orientation of deposited films. Au was chosen as the target material because of its inertness, which allows us to avoid additional effects of oxide or nitride formation due to residual gases in the system. The film structures were examined by RHEED, XRD and AFM analyses.

II. **Experimental Setup**

Extremely Low Energy Ion-beam Deposition System

- Mass Selecteur
- Mass Spectrometry
- Ion Extractor
- HV DCPS
- Control computer

**Ion Mass /amu**

- 500au
- 60au
- 19au
- 127au
- 139au
- 197au
- 198au
- 199au
- 200au

**Energy**

- 0.25eV to 200eV

**Temperature**

- 300K

**Simulation period**

- 2ps

**Environment**

- Less than 10 Pa

**Absorption**

- In lower energy range (E < 100eV), no difference is found among the three low index surfaces.
- In higher energy range (E > 150eV), Au(111) surface exhibits lower sputtering rate than other low index planes.
- Calculation results for the Au(100) and Au(111) surface present similar trend.

**Features of the system**

- High selectivity of ion species by mass selector
- Generation of Au ions in Freeman type ion source by sputtering
- Energy deviations were about ±10eV
- Untreated Si(100) substrate minimize the effect of lattice misfit.
- Generation of Au ions in Freeman type ion source by sputtering
- Temperature : 300K
- Simulation period : 2ps
- Ion beam energy : 0.25eV to 200eV
- Environment : Less than 10 Pa

III. **Results**

The crystalline structure and surface profiles of deposited Au films were examined by Reflection High Energy Electron Diffraction (RHEED), X-Ray Diffraction (XRD) and Atomic Force Microscopy (AFM). The dependence of crystalline orientation on the incident ion energy is clearly seen.

- The peak of an Au(111) plane is visible for all injection energies.
- The presence of Au(220) planes is shown at 55eV and 100eV.
- The Au(200) peak at 100eV is remarkable large.

- Polycrystalline Au films are deposited on the untreated Si(100) wafer.
- Untreated Si(100) substrate minimize the effect of lattice misfit.
- Activation by ion energy (50 – 100eV).

IV. **Molecular Dynamics Simulation**

Molecular dynamics simulation using a glue model was carried out for determination of the mechanism of preferred orientation in low energy ion beam deposition.

- Number of Injection : 1,000 times
- Simulation period : 2ps
- Temperature : 300K
- Ion Energy : 20 – 200eV
- Applying a periodic boundary condition for x and y direction
- Each simulation was performed independently.

Simulation results with glue model

**Features of Au low index crystal surfaces**

- Activation by ion energy enhances crystalline growth. (50eV)
- Self-sputtering was caused in higher energy (100eV -)
- Activation by ion energy (50 – 100eV).
- The most open channel in Au decrease self-sputtering, (100eV -)
- Preferred orientation in wide energy range.

**Potential Energy for Au(100), Au(111) and Au(220) surfaces**

- Possibility of controlling crystal structure by selecting adequate ion energy.

V. **Discussion**

- Absorption in low energy range (~20eV)
- Stability of surface dominate the crystal growth.
- Migration of adatoms and enhancement of crystal growth (100eV -)
- Implantation causes surface roughness.
- Damage from generation of Frenkel pair and sputtering (100eV -)
- Self-sputtering is dominant.

- The difference of Ion Energy Effectivity for Penetration on Three Low Index Surfaces

**Ion Energy**

- 100 eV
- 100 eV
- 100 eV

**Absorption**

- Migration
- Impingement
- Frenkel pair
- Sputtering

**Potential energy for Au(100), Au(111) and Au(220) surfaces**

- Close-packed Au(111) surface decreases penetration rate, Au(110) has more open channel in Au.

**Potential > Ion energy**

- Penetration

**The dependence of energy dependence of ion energy**

- Energy dependence of ion energy penetration of each low index plane calculated with the glue model.

VI. **Summary and Conclusion**

Au thin-film deposition was carried out with the low-energy mass-selected ion-beam deposition method. The ion-energy dependence of crystal structures was investigated with XRD and AFM.

- The experiments have shown that the crystalline orientation can vary with the incident ion energy.
- AFM measurements show columnar structures of deposited films.
- The planes with relatively high surface energies were shown to be formed due to the ion-energy effect.
- Activation and self-sputtering caused by ion energy affects crystal growth.
- The possibility of controlling the crystalline structure of the deposited films by selecting adequate ion energies was pointed out.