Atomic Layer Etching with Gas Cluster Ion Beams

Abstract

We will introduce atomic layer etching (ALE) using gas cluster ion beam (GCIB), which is ultra low-energy ion beam of several eV/atom. By repeating self-limiting following process, (1) adsorption of reactive gas, (2) evacuation of residual gas, and (3) removal of surface layer with GCIB bombardment, low-damage and low-temperature ALEs are realized. In this study, halogen free ALE for metals are studied using acetic acid gas & GCIB irradiations.

Motivation of study

With the miniaturization of devices and development of 2D materials, atomic layer etching (ALE) attracts many attentions. In ALE, etching proceeds by repeating the self-limiting adsorption, evacuation of residual gas and self-limiting removal by ion bombardment. For removal process, low-temparature & low-damage are required. In this study, GCIB is employed for the atomic removal process for the first time.

Characteristics of Gas Cluster Ion Beam (GCIB)

GCIB is a giant particle with thousands of gaseous atoms bonded with Van der Waals force. It realizes ultra low-energy (several eV/atom), however, it also induces high energy density near the surface. These unique irradiation effects enhance the chemical reactions at low-temparature without irradiation damage, which is ideal for ALE.

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Cu etching by continuous GCIB with acetic acid had reported.
- ALE with acetic acid & O₂-GCIB was carried out for the first time
- Acetic acid supply with a needle valve (RGA monitor)
- Real-time thickness monitoring by quartz crystal microbalance

GCIB-ALE of metals with acetic acid vapor

➢ Near atomic layer of Cu (< 1 nm) was etched by 5 kV O₂-GCIB with acetic acid. Self-limit etch stop.
➢ Physical sputtering @ 20 kV O₂-GCIB (not self-limiting. Surface smoothing & oxidation occurs)
➢ Various metals (Pt, Ru, Ta, CoFe), which is difficult to etch can be processed by GCIB-ALE.

Summary
✓ Halogen free, Low damage & Low-temp. ALE with 5keV O₂-GCIB (~2eV/molecule) was demonstrated.
✓ GCIB-ALE can be applied for various metals.
✓ Applications for STT-MRAM, 2D materials etc.