Texture Control in Thin Films through Organic Monolayer Templating

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Motivation

- Modify the grain nucleation and growth of metallic overlayers (Ta, Ti and Au) using organic self-assembled monolayers (SAMs) as underlayers.
- The presence of organic underlayers could change the interfacial energy of top layer/substrate systems.
- Interactions between top layers and underlayers can be manipulated by using different molecules and/or different sputtering variables (to vary the kinetic energy of adatoms). This will induce changes in grain size, texture, and orientation are expected.

Experiments

- All films were magnetron sputtered onto n-Si(100) substrates, with a surface native oxide layer. All SAMs were made by the dipping, rinsing and drying method.

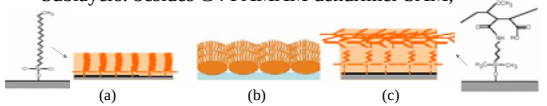
For Ta films:

- Sublayers: -NH_2 terminated PAMAM dendrimer SAMs on Si(100) substrate - D/Si (D: G0, G4 and G8)
- Deposition conditions and deposition rates:

P_{Ar} (Pa)	2.67				0.67			
V_{dc} (W)	30	80	140	200	80	140	200	320
R (Å/s)	1.7	4.4	7.6	10.4	4.5	7.9	11.3	17.8

For Ti films:

- Sublayers: besides G4 PAMAM dendrimer SAM,



(a) (b) (c)

(a) - SAM of linear molecules of $CH_3(CH_2)_{18}Si(Cl)_3$

(b) - SAM of G4-50%C_{12}, i.e., G4 PAMAM dendrimer with 50% amine groups, bond to Si substrate, and 50% [*N*-(2-Hydroxydodecyl)] groups away from substrate

(c) - SAM of APS & Gantrez - APS bonds with the native oxide and the Gantrez bonds with the terminal amine of the APS layer

- Sputtering deposition: all at 5 mTorr and 15 sccm Ar, but with different dc power of 75 W, 125 W, and 175 W

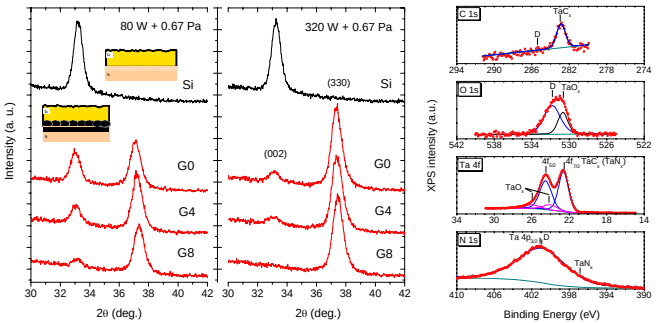
For Au films:

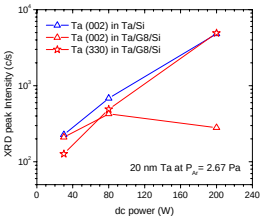
- Sublayers: SAMs from copper ions and metal nanoparticles loaded G4 dendrimer molecules - G4/Si, G4(Cu^{2+})/Si, G4(Cu)/Si
- Deposition: 40 W dc power + 5 mTorr Ar, ~2.6 Å/s

X-ray techniques (Cu K_α sources except XRD of Ti films)

- Normal 2θ/θ scan for texture identification
- Pole figure and χ scan for grain orientation distribution

Ta texture tailoring by dendrimer monolayers (G0, G4, G8) under different sputtering variables (20 nm Ta films)

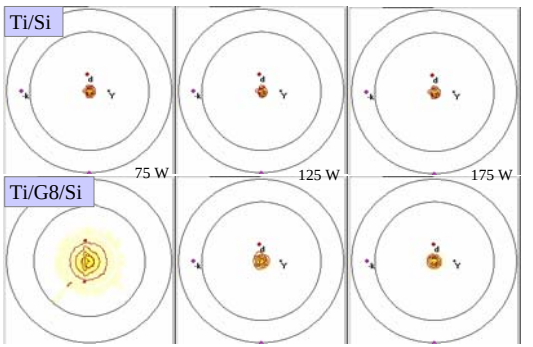




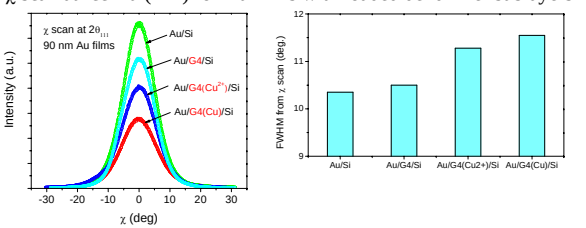
- Dendrimer sublayers induced a (330) texture in tetragonal Ta films (XRD).
- The ratio of peak intensity of (330) to (002) increased with the increase of dendrimer generation (sublayer thickness).
- A abnormal competitive growth of (330) texture occurred with the increase of dc power.
- Ta/dendrimer chemical interaction occurred, with the formation of carbide and oxide (XPS).
- At higher dc power, higher kinetic energy of adatoms could enhance Ta/dendrimer interactions and thus improved the (110) grain nucleation.

Grain orientation distribution change in Ti and Au films with dendrimer based organic underlayers

Pole figures of hcp Ti (002) with denrimer sublayers

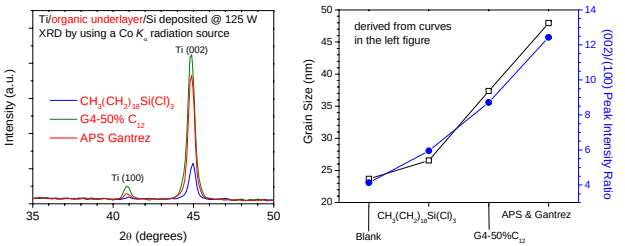


χ scan at fcc Au (111) for Au films with loaded dendrimer sublayers



The pole figures of Ti films and the χ scans on Au (similarly on Cu films) showed the broadened grain orientation distribution, when using dendrimer monolayers or Cu^{2+} or Cu nanoparticle loaded dendrimer sublayers.

Ti films (100 nm) with different organic sublayers



Grain size and $I_{(002)}/I_{(100)}$ increased with the sublayer thickness and carbon chains.

Conclusion

- The presence of organic sublayers induced a new (330) textures in Ta films, broadened the grain orientation distribution of Ti and Au films, always changed the peak intensity ratios from different planes.
- The interfacial chemistry interaction could possibly tailor the interfacial energy, and thus, the nucleation of grains with a certain orientation is favored, which is different from the preferred orientation according to the lowest surface energy.
- The modification became more significant when the kinetic energy of sputtering pieces and/or the sublayer thickness (always in the regime of several nm) increased.

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