Si diffusion in ultra-thin tetrahedral amorphous diamond-like carbon films

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Tetrahedral amorphous diamond-like carbon (ta-DLC) films serve a vast scope of applications in a multitude of engineering materials. Particularly in the magnetic recording hard disk drives industry, ta-DLC films protect both ferrous head components and media from corrosion and tribological wear [1], even though the films are now targeted in the sub-20Å regime to enable further spacing reduction which ultimately translates in areal density recording increases. Before ta-DLC is deposited using filtered cathodic arc, a Si-based seed layer is applied. In a previous study [2], we demonstrated the influence of ta-DLC thickness as protection of a Fe-rich, Ni-Fe head component by TEM/EELS and Conductive Atomic Force Microscopy, where the thinner the ta-DLC layer, the higher the amount of oxidation of Fe/seed layer as well as the higher the amount of Si diffused out to the ta-DLC/air interface. In the present study, a random-walk Monte Carlo simulation is built to demonstrate the Si diffusion effect. It is assumed that some SiC and metal silicide are formed during the energetic deposition process, and that SiO2 is readily formed as Si meets the ta-DLC/air interface. The mobility of the free-Si is very high compared to that of all other Si compounds. The simulation model explains the appearance of a bimodal distribution in the EELS-Si spatial profile due to SiO2 trapping (Fig. 1).

In the present study we also show that the total amount of free-Si available to diffuse through the ta-DLC, giving rise to SiO2 trapping at the surface, appears to depend on the Si bonding of the seed layer. Three types of Si-seed were studied: sub-stoichiometric SiNx (Fig. 2a) with N/Si = 0.44, stoichiometric Si3N4 (Fig. 2b) with N/Si = 1.33, and Si-only seed (Fig. 2c). Although a high-Ni, Ni-Fe head component substrate was used in this evaluation, the Ni-Fe/seed interaction is equivalent to that of the previous study [2]. It is clear that in the case of the stoichiometric Si3N4 seed, no Si diffusion was observed. However, the sub-stoichiometric SiNx allowed for about half of the Si to diffuse out to the surface of the ta-DLC, where the system stabilized leaving the remaining SiNx with N/Si = 0.85. Although the Si-only seed underwent similar level of diffusion, however, most of the originally deposited Si was strongly bonded to the Ni-Fe substrate, an interaction that is not observed as evidently in the case of the SiNx seed. TEM phase contrast image of the sub-stoichiometric SiNx seed sample shows nano-scale surface roughness resulted from SiO2 trapping, which is not observed in the case of the stoichiometric Si3N4 sample.

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References

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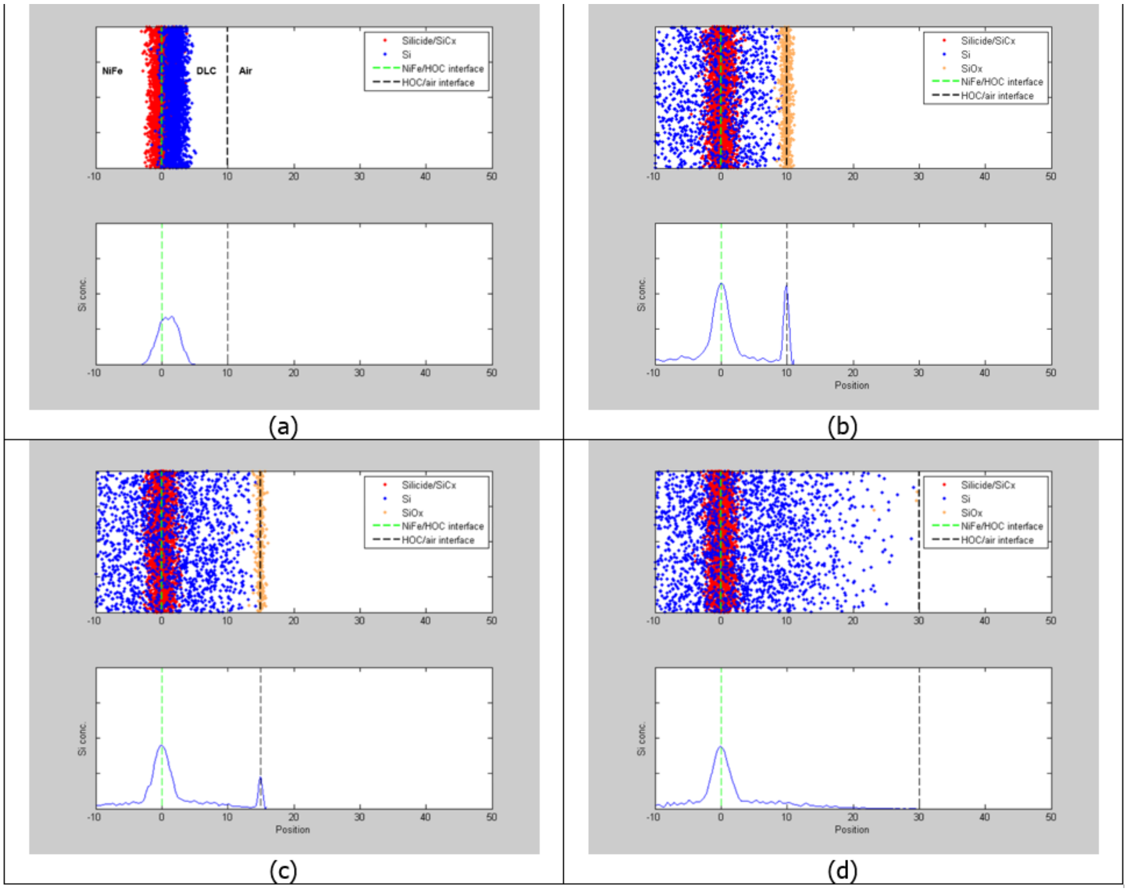

Figure 01 - Random-walk Monte Carlo simulation of the Si diffusion effect. As-deposited film stack on a 10 Å DLC film is shown in (a). After Si diffusion, the end-states are shown for DLC: (b) 10 Å, (c) 15 Å and (d) 50 Å. The acronym HOC refers to head overcoat, or the totality of seed layer plus DLC protective system.

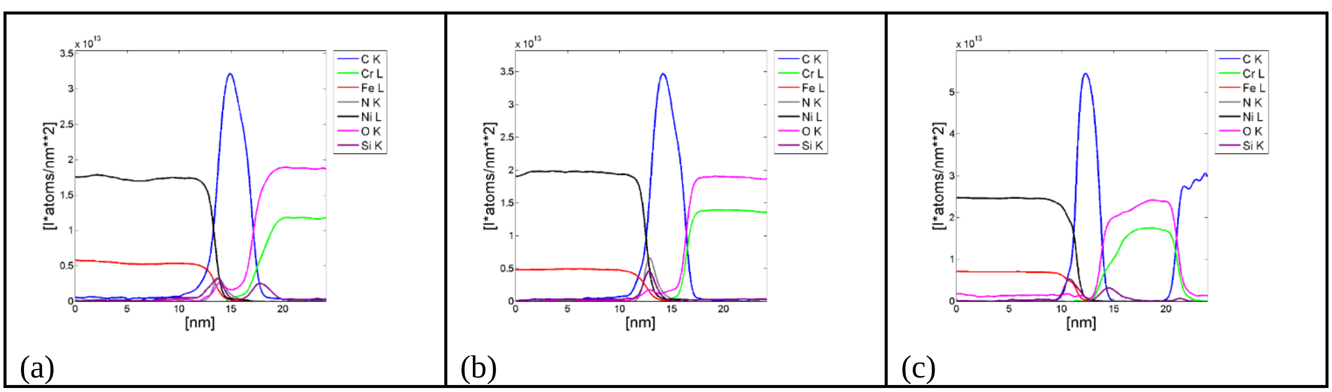

Figure 02 - EELS elemental profiles showing three types of Si-containing seed were studied: sub-stoichiometric SiNx with N/Si = 0.44 (a), stoichiometric Si3N4 with N/Si = 1.33 (b), and Si-only seed (c).