Fluctuation Microscopy Studies of Medium-rangeOrder Structures in Amorphous Diamond-like Carbon Films

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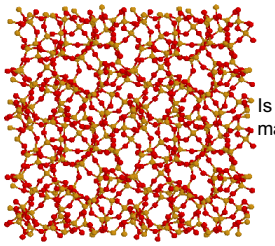
Hydrogen-free amorphous diamond-like carbon films have stimulated great interest because of their useful properties, such as high hardness, chemical inertness, thermal stability, wide optical gap, and negative electron affinity. Consequently, they may have various potential applications in mechanical and optical coatings, MEMS systems, chemical sensors and electronic devices. Amorphous diamond-like carbon films often contains significant amount of four-fold or sp^3 bonded carbon, in contrast to amorphous carbon films prepared by evaporation or sputtering which consist mostly of three-fold or sp^2 bonded carbon. The ratio and the structure configurations of these three-fold and four-fold carbon atoms certainly decide properties of these amorphous diamond-carbon films. Although the ratio of three-fold and four-fold carbon has been studied with Raman spectroscopy and electron-loss-energy spectroscopy, very little has been understood regarding key questions such as how the three-fold and the four-fold carbon atoms are integrated in the film, and what structures those three-fold carbon atoms take. These questions cannot be simply answered by normal diffraction technique because they involve structures beyond short-range order.

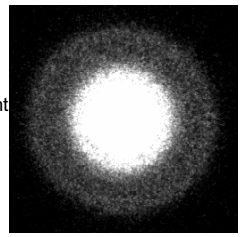
Amorphous materials: lack of long-range order



Is it a right map?

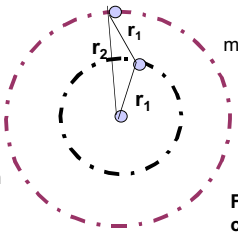
A map for SiO_2

Describing amorphous structures (1): short-range order



A typical diffraction pattern from amorphous materials

Radial distribution function

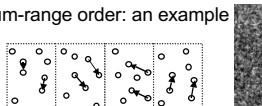


Information: the average bond length, the average bond angle

Describing amorphous structures(2): medium-range order

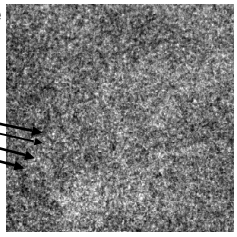
Short-range order information is not good enough

medium-range order: an example



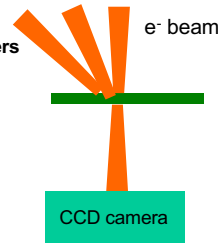
Fluctuation of intensity correlates with medium-range order

Fluctuation microscopy



a speckle image from amorphous materials

Experimental set-up: dark-field scanning mode



(1) input parameters

(2)scan through reciprocal space

(3)take images

(4)save images

Data analysis

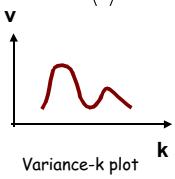
(1)remove mtf

(2)remove shot noise

(3)frequency filter

(4)measure the variance

$$v = \frac{\langle I^2 \rangle - \langle I \rangle^2}{\langle I \rangle^2}$$

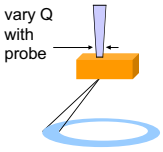


Variance-k plot

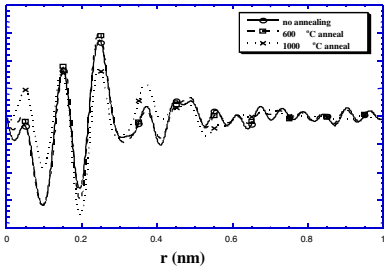
Other approaches:

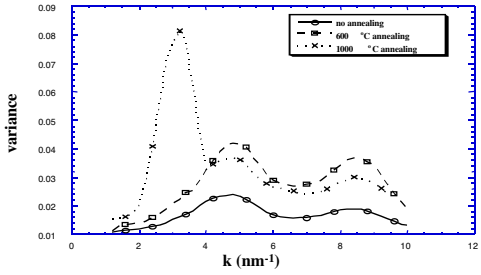
Hollow-cone scanning mode

STEM



amorphous diamond-like carbon films



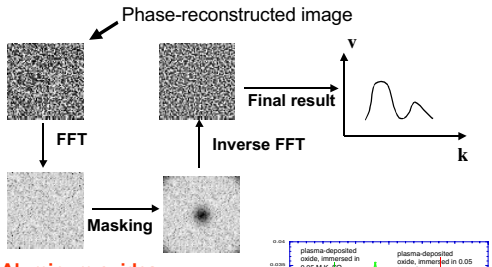


Radial distribution functions measured from electron diffraction present no differences between annealed films and unannealed films, showing they exhibit the same short-range order while have dramatically different properties.

Fluctuation microscopy measurements show the evolution of the medium-range order as a function of the annealing temperature. This increment of the medium-range order is correlated to changes in electrical and mechanical properties in those amorphous diamond-like carbon films

Future directions:

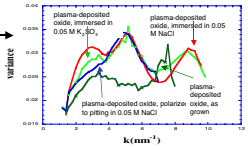
Measuring the intensity fluctuation from a reconstructed wave front



Aluminum oxides

How Cl- initiates pitting is unclear

Does the structure of the oxide change when Al is undergoing corrosion?

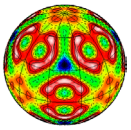


Polymers

(a) How polymers crystallize (b) the presence of microcrytallites in the amorphous phase? (c) persistence length of polymers?

Our studies shed light on how medium-range order structures evolve in amorphous diamond-like carbon films for the first time and also establish the connection between medium-range order structures in those films and their electrical and mechanical properties. Fluctuation microscopy has proven to be a powerful technique to unravel mysteries in amorphous structures and we are applying this technique in studying other amorphous materials, such as aluminum oxides, dielectric oxides and polymers.

"Fluctuation microscopy studies of medium-range ordering in amorphous diamond-like carbon films" by Xidong Chen, J. P. Sullivan, T. A. Friedmann, and J. Murray Gibson, submitted to Applied Physics Letters, August, 2003



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This work was supported by the U. S. Department of Energy, Basic Energy Sciences. Microscopy work was carried out at the Electron Microscopy Center, Materials Sciences Division, Argonne National Laboratory.

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