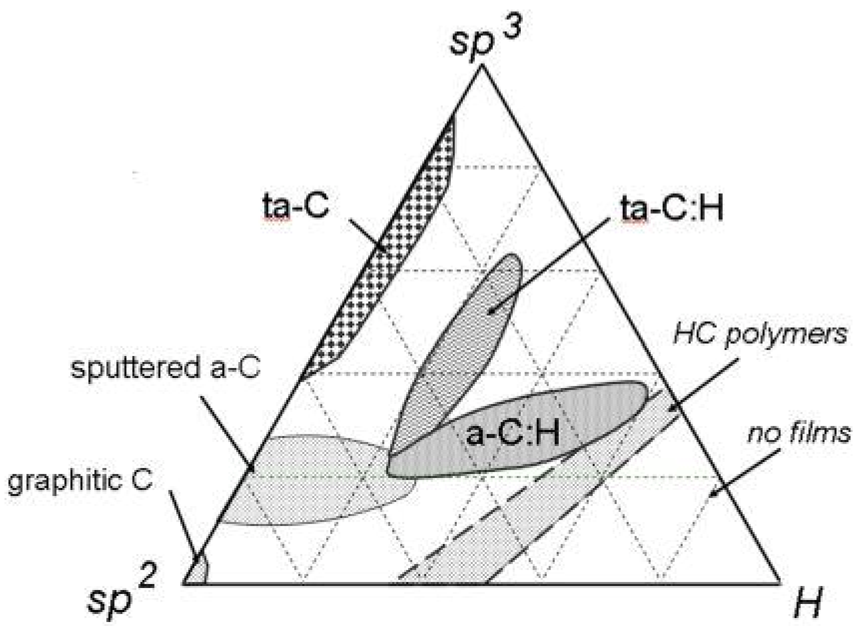
- **What is the difference between Sputtered a-C and ta-C?**

Sputtered a-C (sputtered carbon) and ta-C (tetrahedral amorphous carbon) are forms of non-hydrogenated carbon films. Sputtered a-C has more sp^2 bonded carbon atoms compared to ta-C. Tetrahedral amorphous carbon (ta-C) can have up to 85% sp^3 bonded carbon atoms as shown in the ternary phase diagram below.



J. Robertson, Materials Science and Engineering, 2002 (129-281)

- **Define DLC. Write a short note on DLC describing its properties and applications.**

Diamond-like carbon (DLC) is a form of amorphous carbon, with or without hydrogen, which contains a significant fraction of sp^3 bonded carbon atoms. DLC films:

1. have very high hardness and stiffness,
2. are chemically inert and impervious to most acids and saline media,
3. are electronically insulating and can be made optically transparent to visible and ultraviolet light,
4. are structurally amorphous in nature with sp^2 and sp^3 bonded carbon atoms.

DLC films may contain significant amounts of hydrogen depending on the source of carbon and deposition process. Hydrogen-free DLC coatings are prepared by solid carbon or graphite targets with arc physical vapor deposition, pulsed laser deposition, and magnetron sputtering techniques. Electrical and mechanical properties of diamond-like carbon films can be manipulated by doping them with various elements like fluorine, nitrogen, oxygen, silicon, niobium, tungsten, and titanium. Graphitization of DLC films above 300°C can be decelerated by doping with certain dopants like boron, tungsten, titanium, and silicon. DLC film structure and properties are largely dependent on the hydrogen content and the ratio of sp^2 to sp^3 bonded carbon atoms.

DLC films are often used in the form of protective coatings for biomedical implants, magnetic storage devices, optical windows, micro-electro-mechanical systems (MEMS) devices, automotive parts, etc.

- **Name the two most important variables that affect the structure and properties of DLC films.**

The two most important variables that affect the structure and properties of DLC films are (i) the hydrogen content and (ii) the ratio of sp^2 to sp^3 bonded carbon atoms.

- **What properties of DLC films are affected by the presence of hydrogen?**

The hydrogen content mostly affects the mechanical and optical properties in DLC films. Hydrogen decreases the hardness and the Young's modulus of the carbon films. It also decreases the density, the amount of mechanical stresses generated during the fabrication process, and the thermal stability of the carbon films. It decreases the refractive index, but increases the bandgap and the electrical resistivity in DLC films.

- **How does the hydrogen content in DLC films affect their hardness and electrical properties?**

Hydrogen decreases the hardness and the Young's modulus of the carbon films. It also decreases the density, the amount of mechanical stresses generated during the fabrication process, and the thermal stability of the carbon films. It decreases the refractive index, but increases the bandgap and the electrical resistivity in DLC films.

- **Why are DLCs doped? Name some common doping elements in DLCs.**

DLC films are doped to manipulate their electrical and mechanical properties. They are also doped to improve their high temperature durability. Some of the common dopants are fluorine, boron, nitrogen, oxygen, silicon, niobium, tungsten, and titanium.

- **Name some methods for depositing DLC films.**

  Pulsed laser deposition, cathodic arc or arc physical vapor deposition, chemical vapor deposition, plasma enhanced chemical vapor deposition, and magnetron sputtering are some common methods for depositing DLC films.

- **Name two different sources of carbon in CVD of DLC films.**

  Methane and acetylene are two sources of carbon in CVD of DLC films.

- **What kind of substrates provide good adhesion to DLC films?**

  Substrates made of carbide-forming elements (or strong carbide formers) and silicide-forming elements (or strong silicide formers) provide better adhesion to DLC films.

- **How can you improve the adhesion of DLC films to silicide forming substrates?**

  The adhesion of DLC coatings to silicide forming substrates can be improved by depositing a thin (normally 2-4 nm) interfacial layer of amorphous silicon between the substrate and the DLC film. The silicon layer thus produced makes stronger carbides at the interface (between the silicon interfacial layer and the DLC film) and improves the adhesion.

- **What are nanostructured carbon films, how are they produced, and what are their applications?**

  Nanostructured carbon films (aka diamond like nanostructured carbon films) are produced by arc plasma vapor deposition (cathodic arc) and magnetron sputtering at relatively high gas pressure. Thermionic vacuum arc (TVA) in high vacuum and Supersonic cluster beam deposition [Universitá di Milano, Italy] are another methods reported to produce nanostructured carbon films.

  Nanostructured carbon films can be used for electrochemical applications, supercapacitors, fuel cells, and sensors.