Diamond-like carbon nanocomposites

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MOTIVATION

Diamond-Like Carbon coatings have superior properties that can be tailored to meet the specific requirements of electronic applications. DLC films have ***very strong tolerance for X-ray irradiation***, ***IR transparency***, and ***chemical inertness***.

Mechanical properties of DLC such as *high hardness* and *low friction coefficient* are now used in numerous industrial applications, including razor blades, magnetic hard discs, critical engine parts, mechanical face seals, scratch-resistant glasses, invasive and implantable medical devices and microelectromechanical systems.

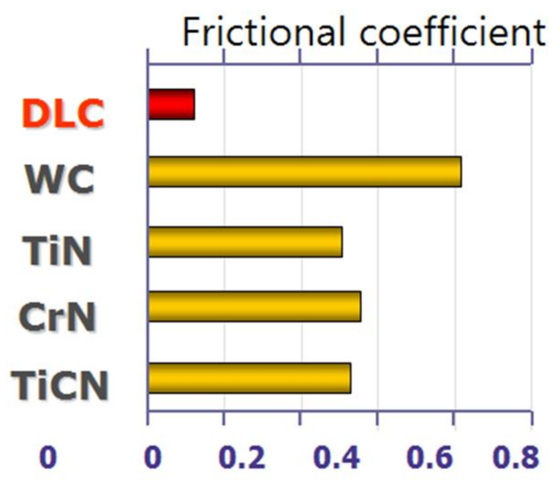
In order to expand area of application, **metals** have been **incorporated into DLC**, giving way to ***a new generation of nanocomposite coatings.***

AIM of PRESENT WORK :

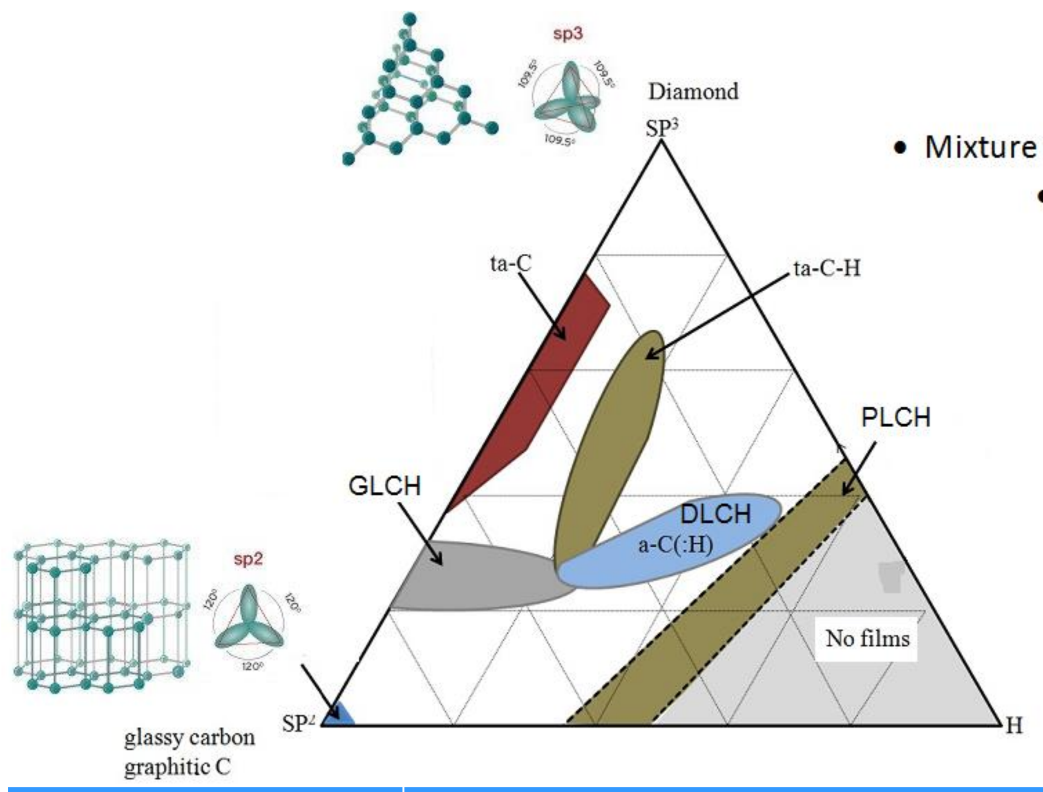
to describe properties of diamond-like carbon films with nanocrystalline metal inclusions as a new generation of nanocomposite coatings as well as last advances of their application.

Diamond-Like Carbon (DLC) Specifications

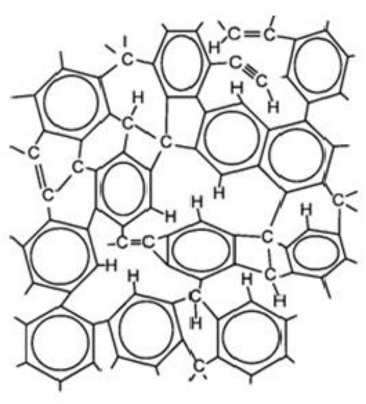
- High surface hardness: 1500 ~ 8500 Hv
  → wear resistant coating
- Low frictional coefficient: 0.01 ~ 0.2
  → solid lubricant coating
- Chemical safety: acid & basic free reaction
  → a high corrosive substance
- Low temperature coating: < 70 °C
  → no material transformation out of heat while coating



Ternary phase diagram of bonding in amorphous carbon-hydrogen alloys



Diamond-like Carbon:
- Amorphous Solid Carbon Film
- Mixture of sp1, sp2 and sp3 Hybridized Bonds
- High Content of Hydrogen (20-60%)

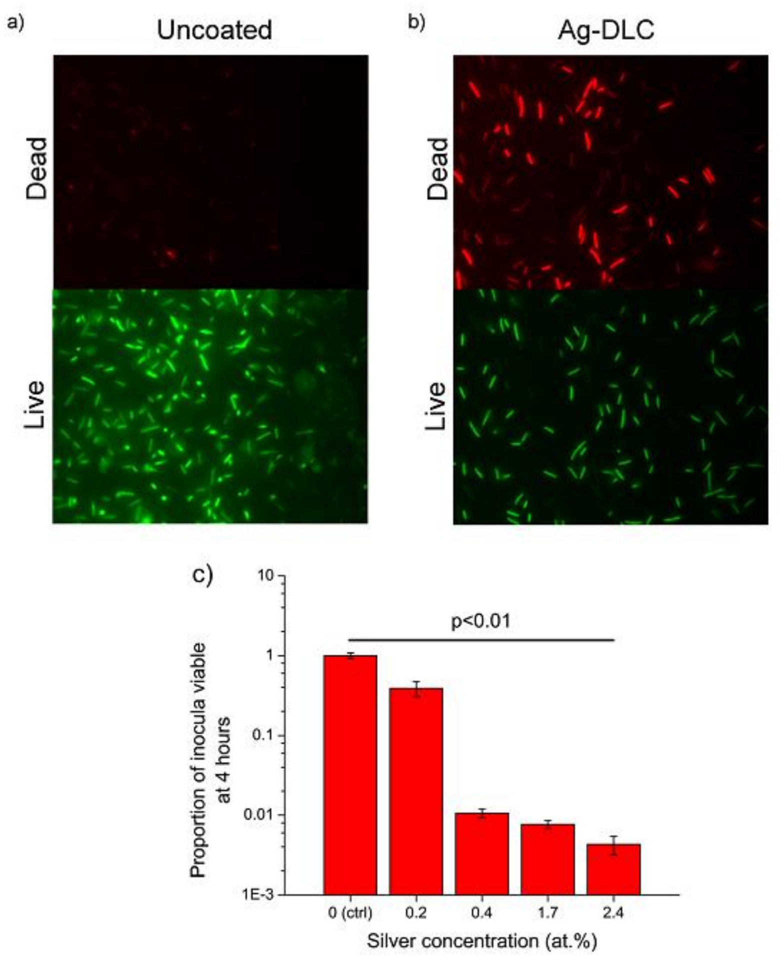


polymer-like a-C:H (PLCH)	**H content (40–50%) up to ~60% sp3 bonds**
diamond-like a-C:H (DLCH)	H content (20–40%) lower sp3 content, but C-C sp3 bonds greater than 60%
tetrahedral amorphous carbon films (ta-C:H)	the C-C sp3 content can be increased while keeping a fixed H content
graphite-like a-C:H (GLCH)	H content less than 20% with high sp2 content and sp2 clustering

Metallic elements incorporated into DLC, giving way to a new generation of DLC nanocomposite coatings.

Metallic elements (ME) incorporated into DLC	DLC:ME properties
Ti, W, Ni	graphitization
Ag Mo	plasmonic properties, antibacterial activity the blood compatibility
Cu, Ni	the decrease in band gap
Ni	superparamagnetic behavior
Cr, Au, Ag, Ti, W	tuning the tribological performance & mechanical properties
Complex structures: DLC/W-DLC, G-TiO_2/DLC, Ti/Al-DLC, Ti/C-DLC, (Cr, N)-DLC/DLC	tuning the tribological performance & mechanical properties

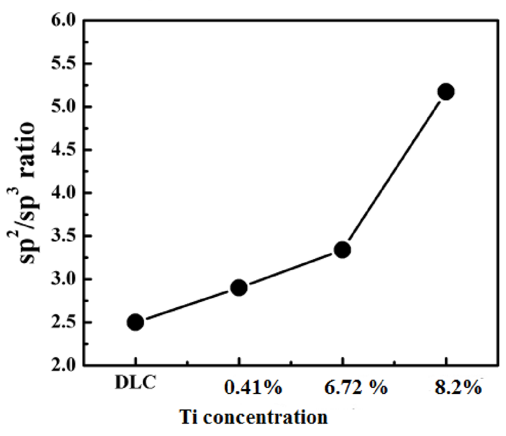
Ag-DLC nanocomposite coatings



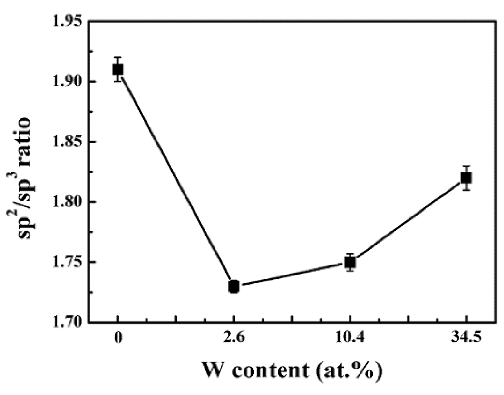
Antibacterial activity of Ag-DLC coatings against *E.coli.*

doi:10.1116/1.4871435

Metallic nanoparticles as catalytic centers accelerating the graphitization of DLC

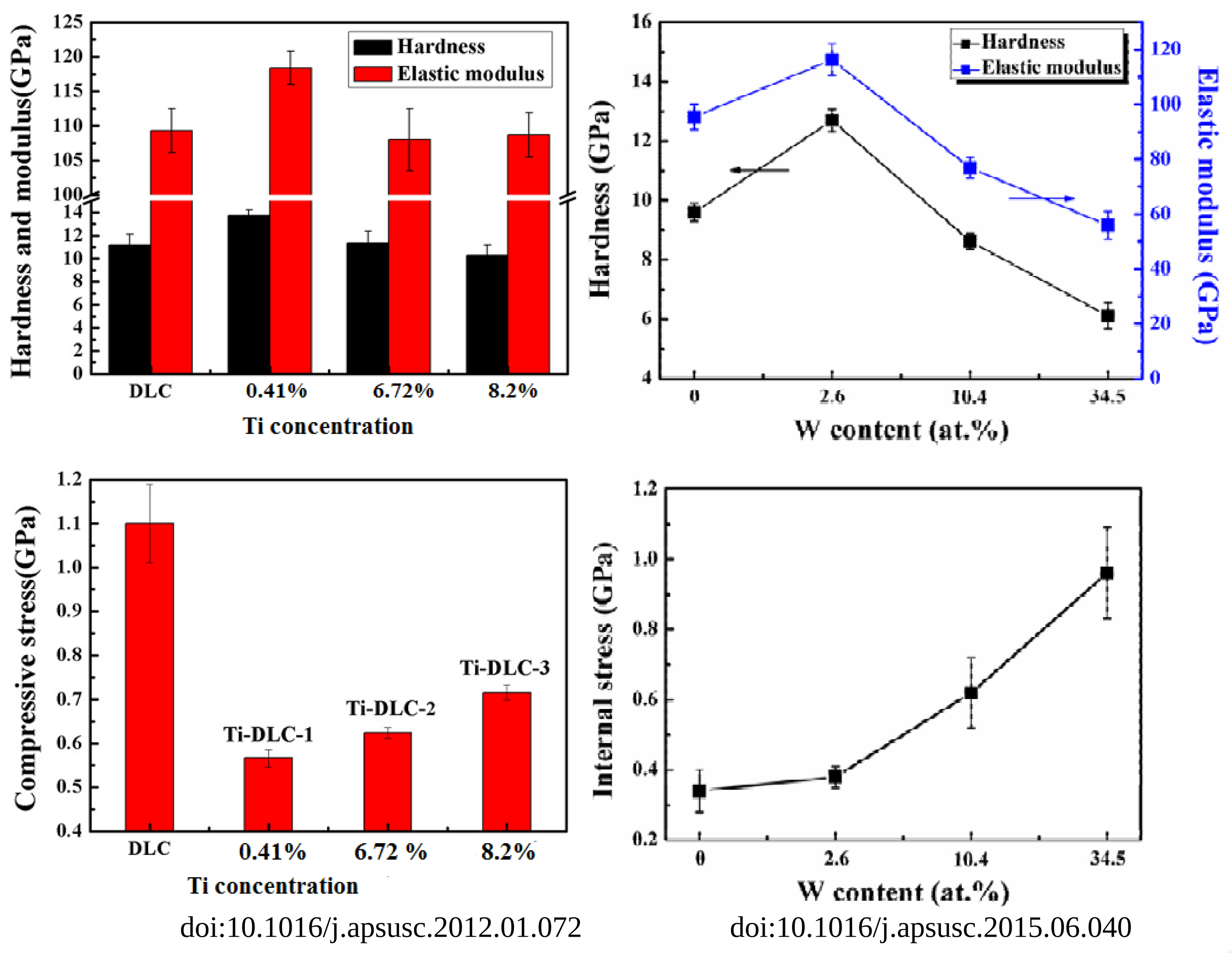


doi:10.1016/j.apsusc.2012.01.072



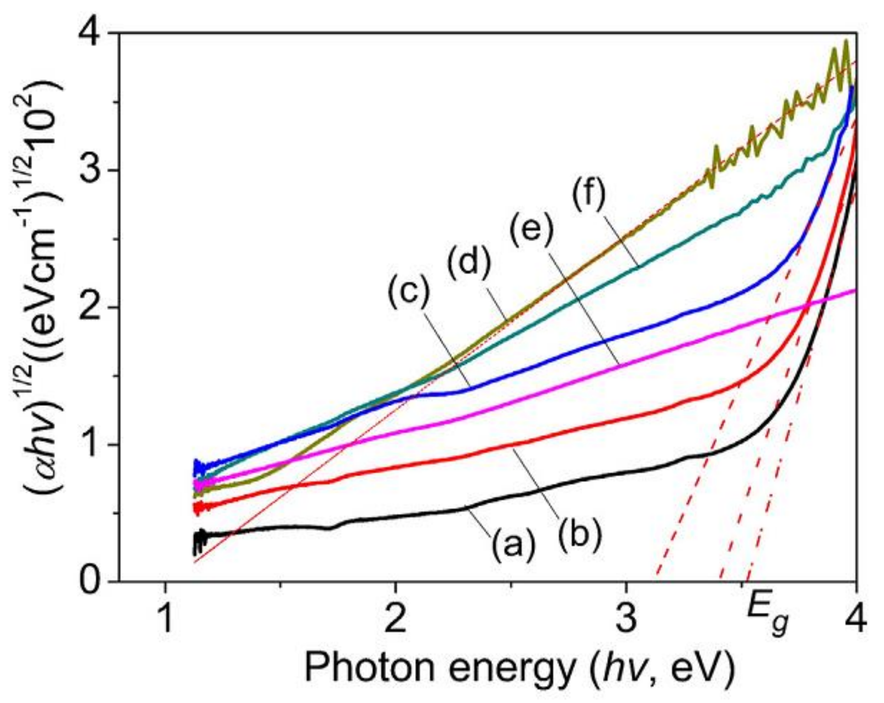
doi:10.1016/j.apsusc.2015.06.040

Mechanical and tribological properties of DLC films with different content of Ti & W



doi:10.1016/j.apsusc.2012.01.072 doi:10.1016/j.apsusc.2015.06.040

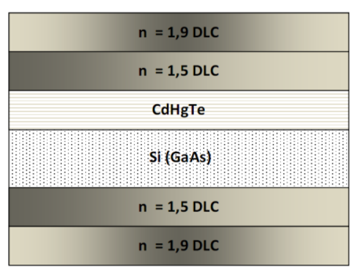
Optical properties of ME-DLC nanocomposites



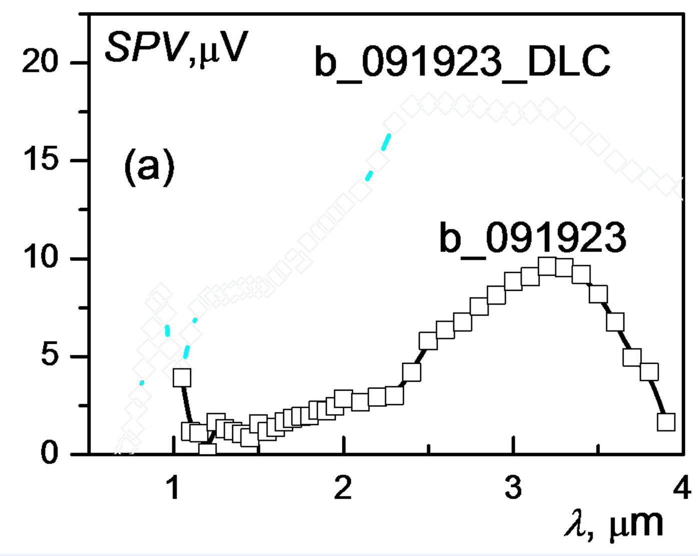
Tauc plotof $(\alpha h\nu)^{1/2}$ versus photonenergy hν for Cu-DLC composite films with different copper contents. Dotted line has a linear fitin the energy range from 2 eV to 4eV.
(a) DLC;
(b) Cu8.3%-DLC;
(c) Cu12.6%-DLC;
(d) Cu20.8%-DLC;
(e) Cu22.4%-DLC;
(f) Cu27.9%-DLC.

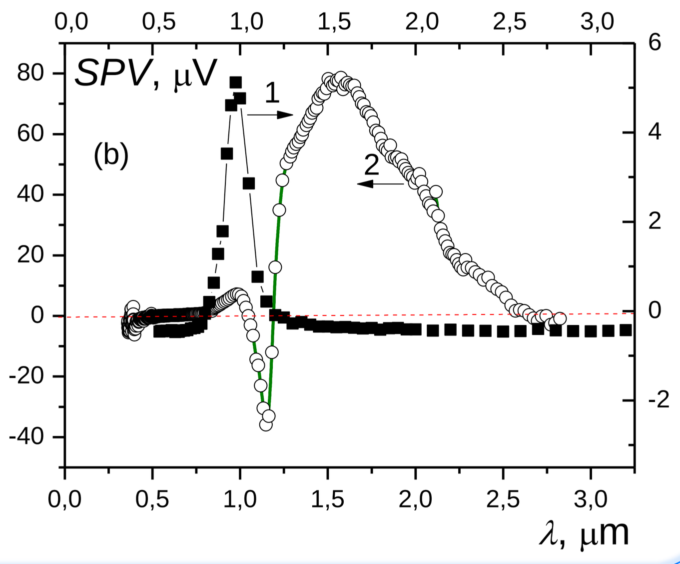
10.1016/j.diamond.2016.09.004

DLC and DLC+Ag coating for optimization of HgCdTe-based IR detector



Surface photovoltage spectra of HgCdTe-based IR detector
(a) initial and with DLC gradient coating
(b) 1 – after Ag implantation, 2 – with DLC+Ag coating





CONCLUSIONS

❑ The properties of DLC films strongly depend on sp3/sp2 ratio. By varying sp3/sp2 ratio, its hardness, optical band gap and conductivity can be tuned over wide range.

❑ Metals incorporated in DLC film are separated into carbide-forming elements (Ti, Cr, etc.) and such that are clustered in the carbon matrix. The latter include copper and silver. The formation of Ag clusters can be primarily attributed to the low affinity of silver with the carbon matrix and the high cohesive energy of silver. In addition, Cu is inert to carbon atoms without the formation of carbide. The Cu, doping in DLC films, will embed into the carbon matrix in nano-crystallite form.

❑ Metallic nanoparticles act as catalytic centers accelerating DLC graphitization. Moreover, metals incorporation into DLC is giving way to a new generation of nanocomposite coatings with tuned tribological perfomance, mechanical and optical properties, plasmonic and supermagnetic behavior, antibacterial activity, etc.

❑ This work also highlight our achievement in the synthesis, characterization and application of DLC-Ag nanocomposit coating for HgCdTe-based radiation detector improvement.