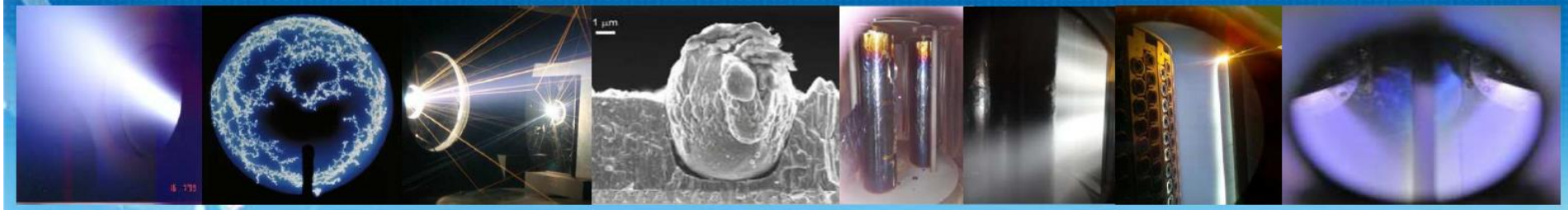

Overview of DLC coating technology (stress, adhesion, and bias)

Jong-Kuk Kim

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Implement Research Division
Korea Institute of Materials Science (KIMS), Korea

KIMS 재료연구소 Korea Institute of Materials Science

Carbon materials

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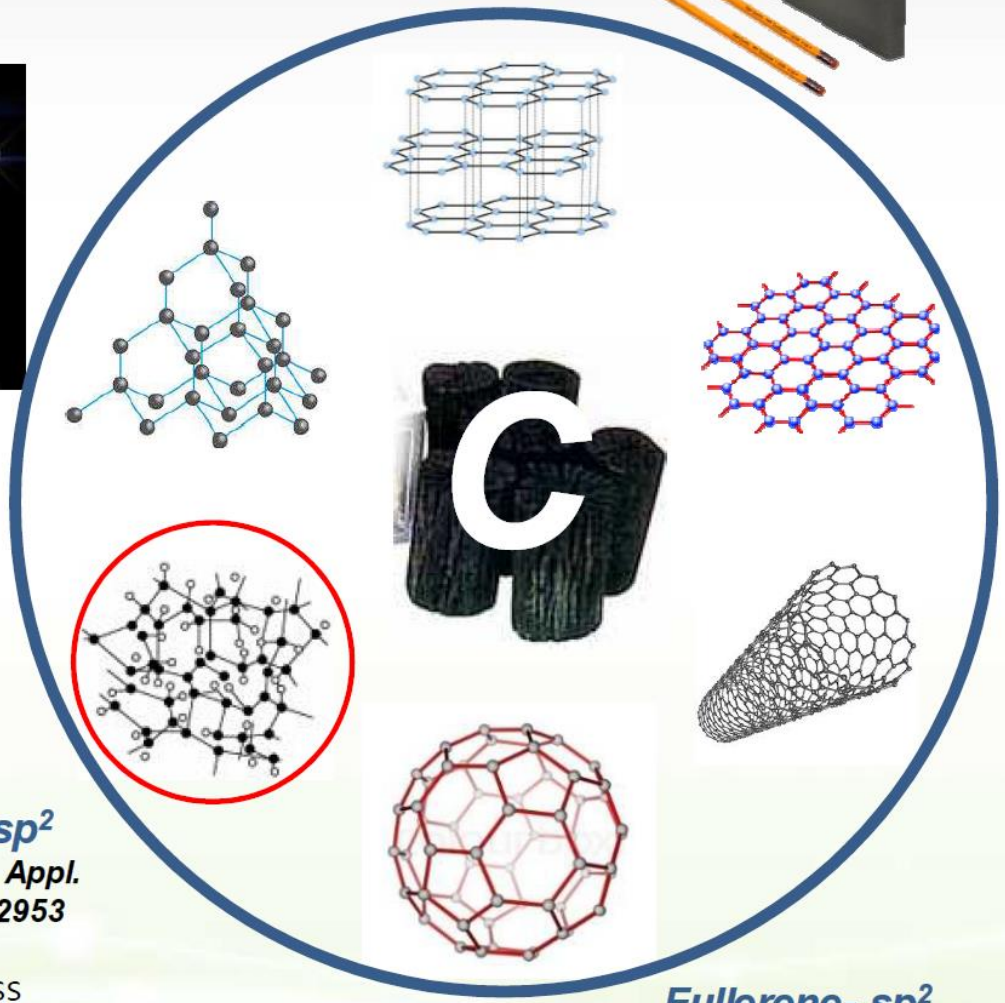
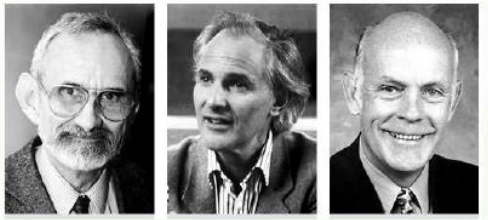
Graphite- sp^2
1779
Soft & Low Friction

Diamon- sp^3
F.P. Bundy, Nature, 176(1955)51
High Hardness
: 75 ~ 100 GPa



Graphene- sp^2
K. S. Novoselov. Science 306(2004)666
2010 Nobel Prize in Physics

CNT- sp^2
S. Lijima, nature, 1991, 354



Curi ***Kroto*** ***Smalley***

DLC- sp^3/sp^2
Aisenberg S, J. Appl. Phy. 42(1971)2953

Wide Hardness
: 15 ~ 80 GPa

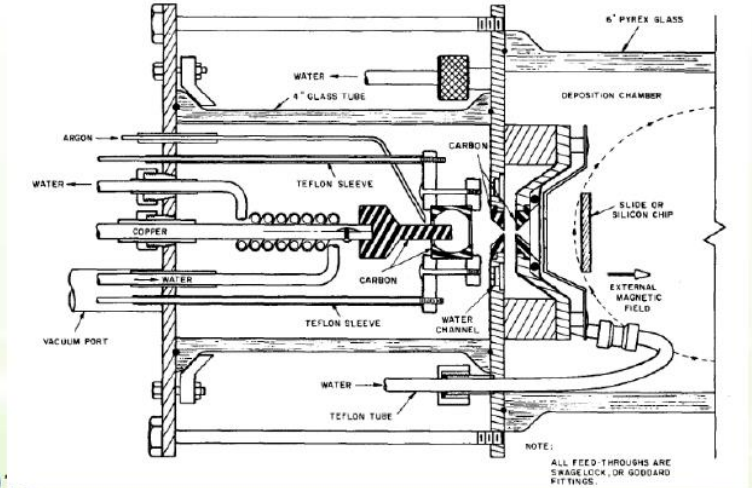
Fullerene- sp^2
Kroto H W, Nature, 318(1985)162
1996, Nobel Prize in Chemistry

JOURNAL OF APPLIED PHYSICS VOLUME 42, NUMBER 7 JUNE 1971

Ion-Beam Deposition of Thin Films of Diamondlike Carbon*,†

SOL AISENBERG AND RONALD CHABOT
Space Sciences Division, Whittaker Corporation, Waltham, Massachusetts 02154
(Received 2 September 1970)

An ion-beam deposition technique has been developed and was used to deposit thin films of insulating carbon on room-temperature substrates. It was established that the carbon films deposited using this technique are insulating and have the following characteristics similar to that of carbon in the diamond form: (1) transparency, (2) index of refraction greater than 2.0, (3) highly insulating, (4) able to scratch glass, (5) resistant to hydrofluoric acid for long periods of time, (6) at least partially crystalline and with a lattice constant similar to diamond as demonstrated by x-ray diffraction, (7) dielectric constant between about 8 and 14 (diamond is 16.5). A resistance to sodium ion diffusion has been experimentally demonstrated. Preliminary measurements at a dose of 1 Mrad indicated a radiation resistance from the point of view of stability of leakage resistance and of negligibly small flat band voltage shifts. Several coplanar thin-film transistors using the insulating carbon gate have been fabricated.



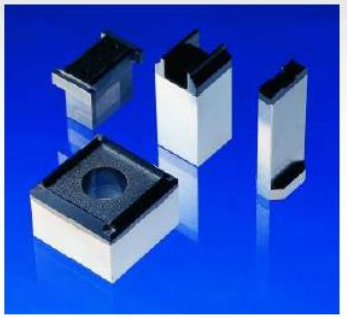
History of Diamond Like Coating Process

KIMS

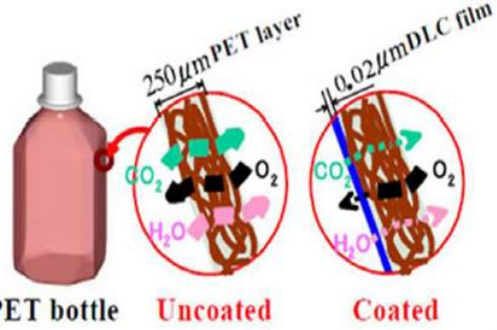
	YEAR	NAME	TYPE
Global	1971년	Aisenberg and Chabot	Arc Ion Beam
	1979년	Holland and Ohja A.A. Aksenov	PACVD Filtered Vacuum Arc
	1984년	Mori and Namba	Ion Plating
	1986년	Savvides	Sputtering
	1992년	*Collins et al*	Laser Ablation
	2000년	Fraunhofer IWS	LAM
	2000년 이후	- IBM에서 HDD상 수nm급 탄소막 증착 - 일본 닛산 자동차 타펫상 ta-C 코팅 응용	
KOREA	1990년	KIST K.R.Lee	비취색/블랙다이아몬드헤드 드럼개발 _ PECVD 방식
	1993년	생기원/범진화학	Magnetron Sputtering 방법
	1995년	**Samsung&KIMS Jongkuk Kim** Atech System	FVAS PECVD / Ion Plating
	1997년	JnL tech	PECVD법/Lion plating
	1998년	K-DLC	Ion Plating 법
	2001년	발져스 Korea	WC/C _ 스팟트링법
	2005년 이후	Ion Bond	Vacuum Arc법(공구코팅)
	2010년 이후	Dong-Woo HST	magnetron sputter법 (자동차 부품 양산화)
	2010년 이후	- 국내시장에서 대면적 상용화 요구 요청	

Applications of DLC films

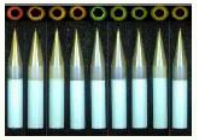
KIMS

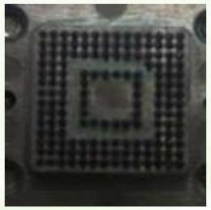


DAEWOO

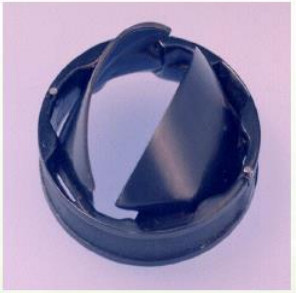


Rainbow coating





Black diamond coating

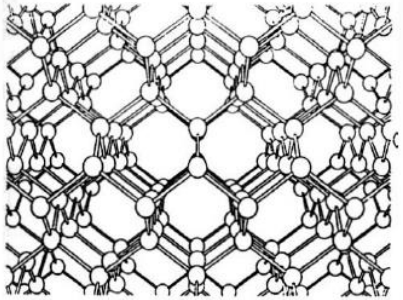


Classification of DLC

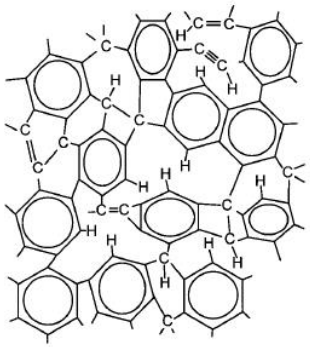
KIMS

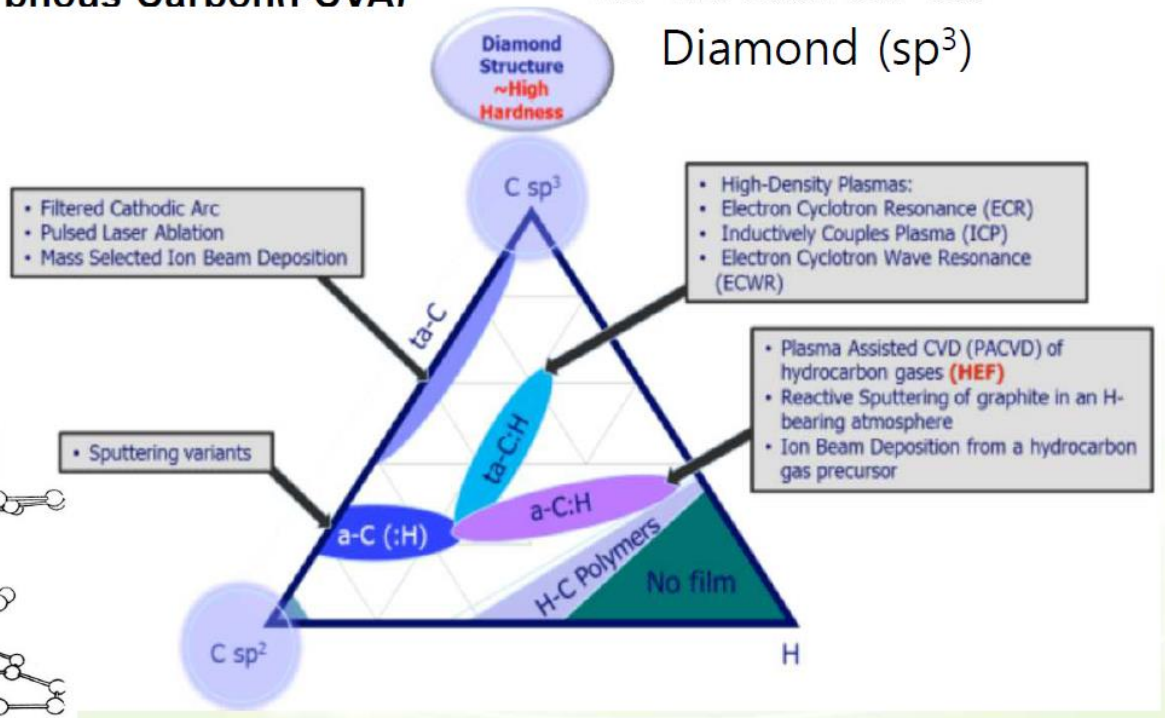
- **DLC*(Diamond-Like Carbon)***
  - Amorphous Carbon Coating
  - Mixture of sp^1, sp^2 and sp^3 hybridized bonds
  - High Content of Hydrogen (0-60%)

- **Synonym**
  - a-C:H : Hydrogenated amorphous carbon
  - a-C : amorphous carbon
  - ta-C: Tetrahedral Amorphous Carbon(FCVA)

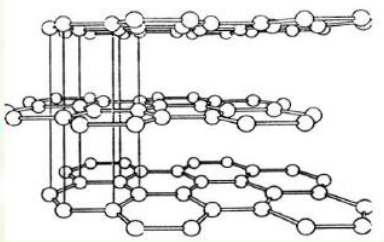


Diamond (sp^3)





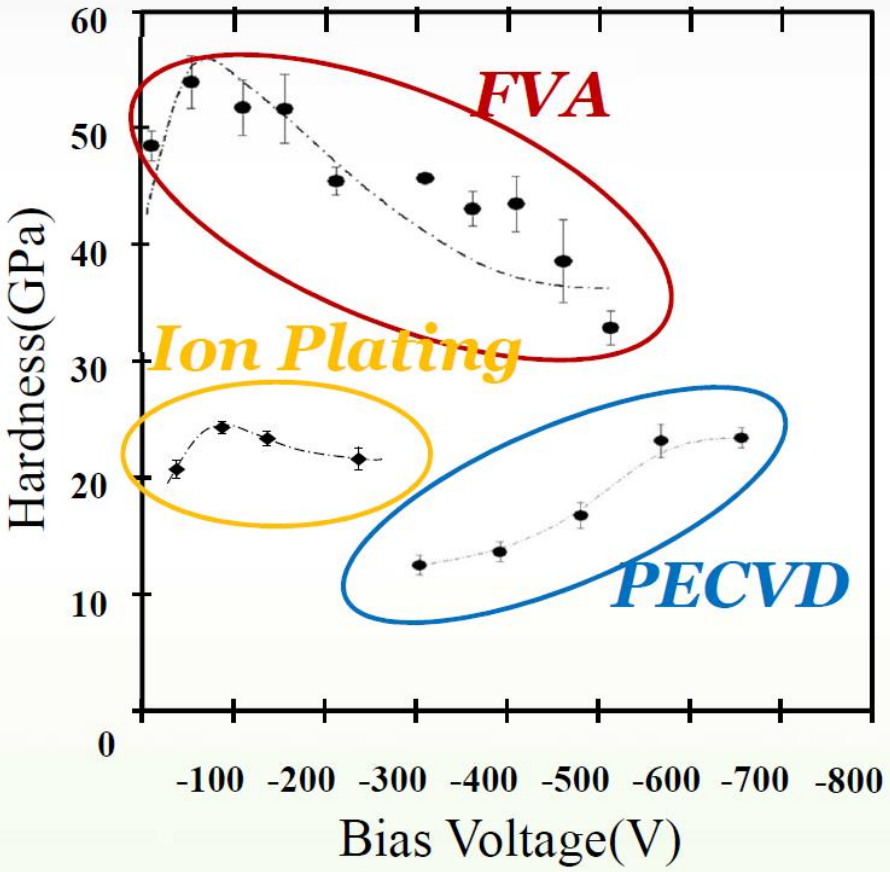
graphite (sp^2)

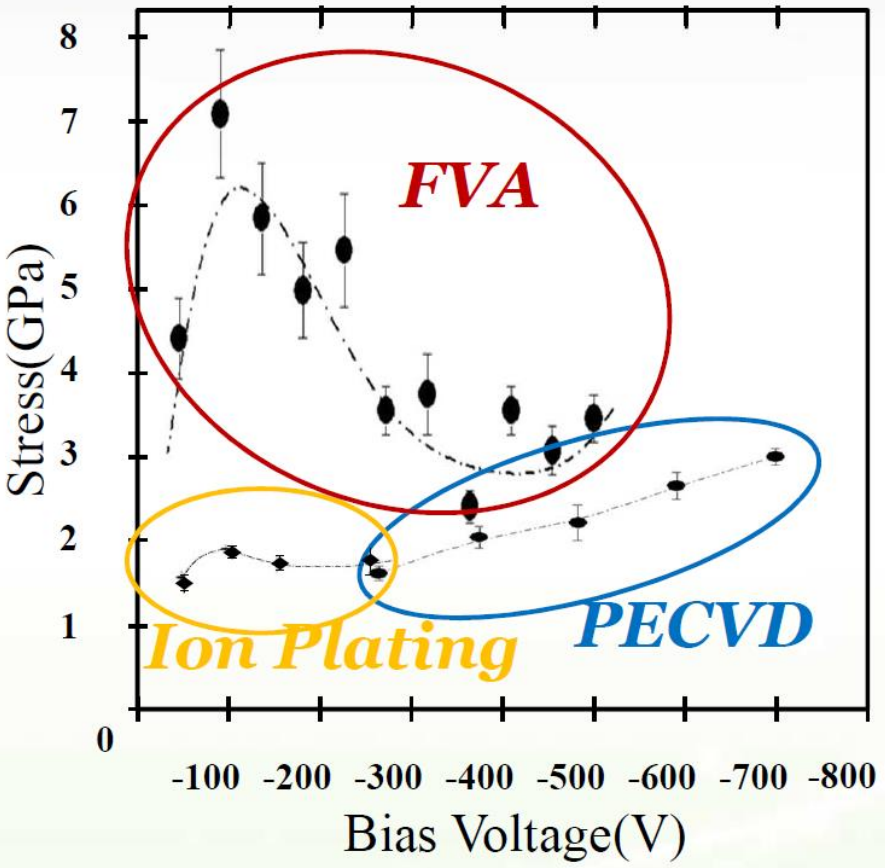


~ low Friction

DLC _Hardness & Internal Stress

KIMS

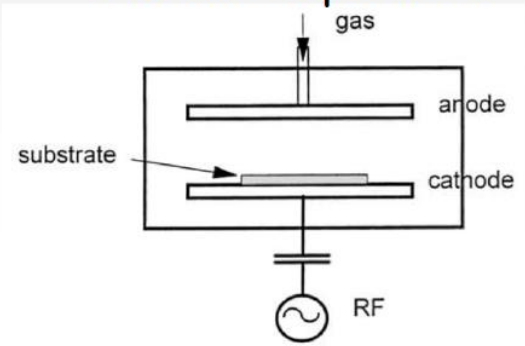




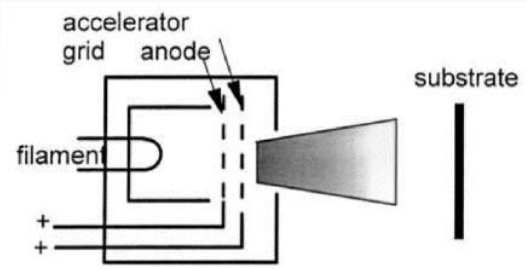
Coating Method of of DLC

KIMS

Plasma deposition

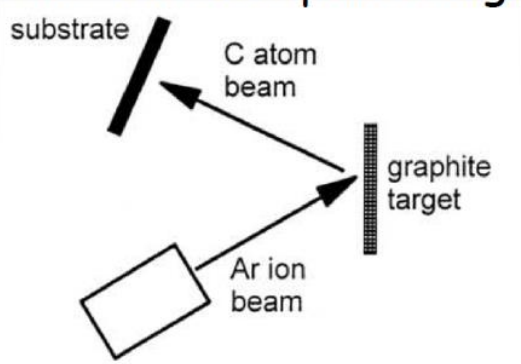


Ion deposition

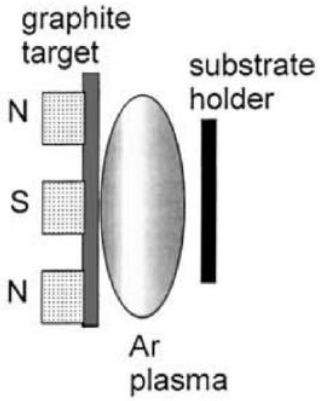


- Mass-Selected Ion Beam Deposition (MSIBD)

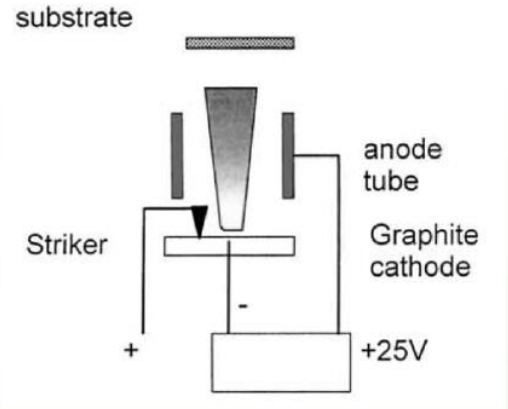
Ion assisted sputtering



Sputtering

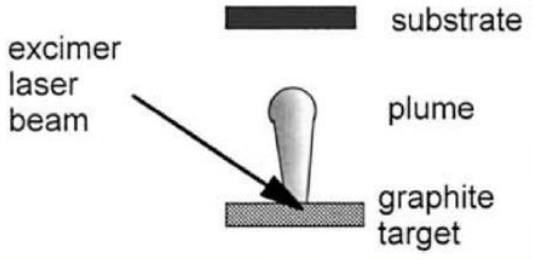


Cathodic Vacuum Arc



- Filtered Cathodic Vacuum Arc (FCVA)

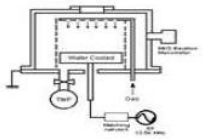
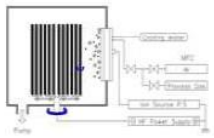
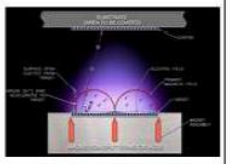
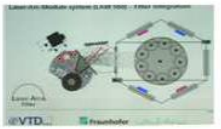
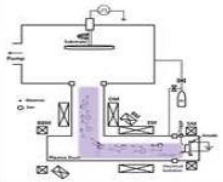
Laser ablation



- Laser Arc Module

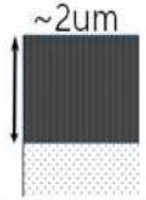
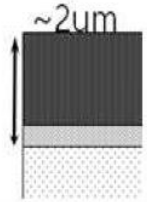
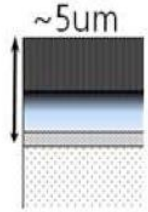
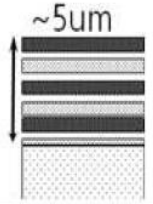
Coating Process and Application

KIMS

	모식도	공정 및 기타	장 단점	응용분야
PECVD		작업압력: ~ 10^{-2} torr 사용전압 : AC (20kHz ~ 20 MHz) Self Bias Voltage Precursor: CH_4, C_2H_2,TMS, HMDSO	장비 단순, 가격 낮음, 표면 조도 우수(경면코팅) 복잡한 형상을 가진 대상의 코팅이 어려움, 코팅의 접합력이 제한적.	 그라비아롤  CD 금형, 도광판등
Ion Beam (I o n Plating)		작업압력 : ~ 10^{-3} torr 사용전압 : DC Bias Voltage: pulse DC Precursor: CH_4, C_2H_2,TMS, HMDSO	장점 : 대면적화 유리, 방전 에너지 제어로 물성의 변경이 자유로움, 단점: 소스의 가격이 상대적 고가, 코팅의 접합력 제한적	 자동차 부품, 사출금형류
Sputtering		작업압력 : ~ 10^{-3} torr 사용전압 : DC Bias Voltage: Pulse DC 카본원: solid carbon	대형화 쉬움 높은 방전전압 낮은 증착률 쉬운 buffer층 설계	 자동차 동력전달 부품
Laser Arc		작업압력 : ~ 10^{-4} torr 사용전압 : Laser, DC Bias Voltage: pulse DC 카본원: solid carbon 2000년 Laser + arc 공법 혼합 연구	높은 경도, 낮은 증착률, 장비비 고가 거대입자 존재 (Vacuum arc 와 동일)	 자동차 부품, 금형부품
Filtered Vacuum Arc (FVA)		작업압력 : ~ 10^{-4} torr 사용전압 : DC Bias Voltage: DC 카본원: solid carbon	높은 경도 산화온도 : 550도 높은 응력, 낮은 증착률 대면적화 어려움	 자동차 부품, 공구,금형류

DLC _ Film Structure and composition

KIMS

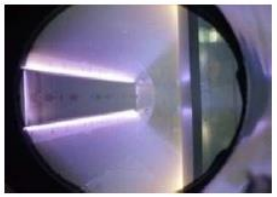
명 칭	구조 및 두께		조 성	경 도 (GPa)	응용분야
단층 DLC		DLC 50 Å ~2㎛ 기판(초경)	a-C:H	15~25	소성가공금형(초경), 섭동부품, 종이절단칼, 장식품,정밀 측정기 부품
			ta-C	45~80	절삭공구, 자동차 부품
중간층부 DLC		DLC ~2㎛ 중간층 ~0.2㎛ 기판	Me/a-C:H Si, SiC, Cr/Ti Cr, Nb..	15~80	소성가공 금형(강제) 플라스틱사출 성형 금형, 치공구, 장식부품, 각종 섭동 부품
경사조성 Me-DLC		DLC ~2㎛ 경사조성 ~3㎛ 중간층 ~0.2㎛ 기판	Me-C:M/a-C:H Ti≤10 at % Cr≤10 at % W≤10 at %	10~25	자동차 엔진 부품, 연료분사펌프, 톱니바퀴, 베어링, 펌프 screw, 인공관절, 사출 성형 금형, 치공구, 성동 부품 (n : 반복횟수)
다층막 Me-DLC		DLC ~5㎛ (~0.05㎛x n회) 중간층 ~0.2㎛ 기판	Me-C:M/a-C:H Ti≤10 at % Cr≤10 at % W≤10 at %	10~25	

DLC _ Function of Ion Energy

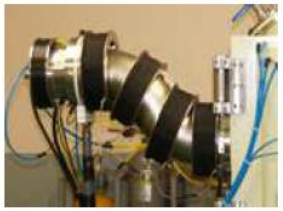
KIMS

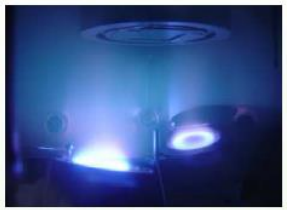
Carbon Coatings as a function of *Ion Energy*


Linear Ion source

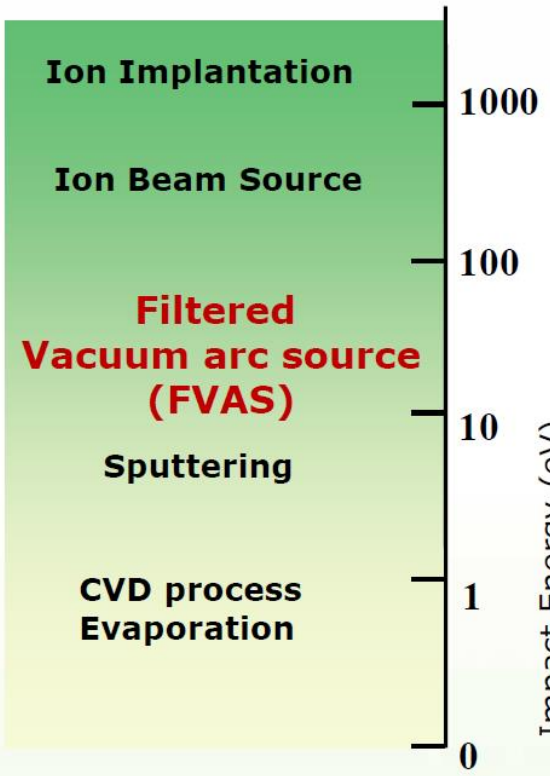

Linear Ion source


Filtered vacuum arc

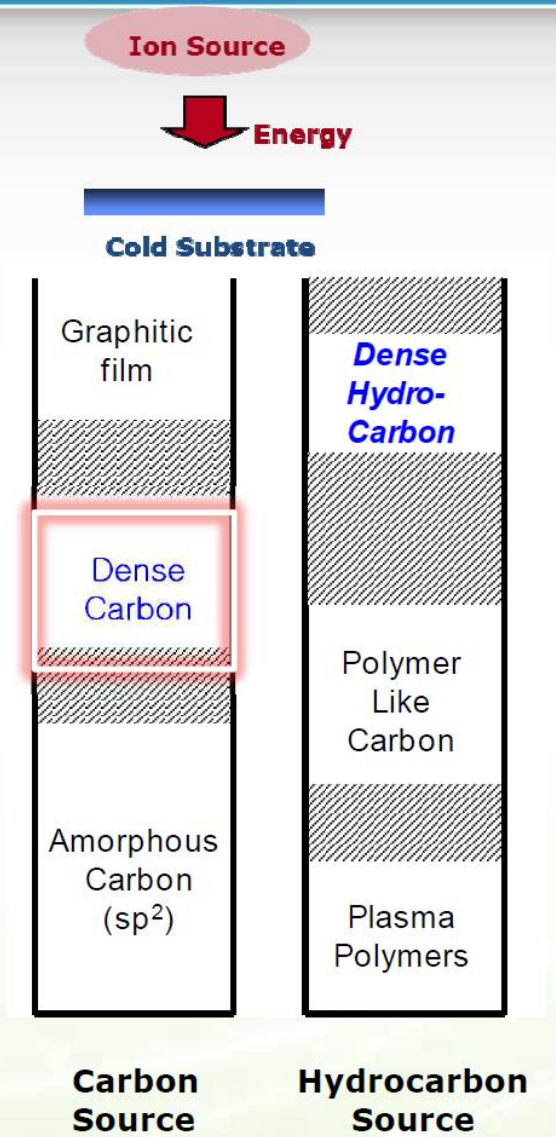

Filtered vacuum arc


Magnetron sputtering


Remote plasma sputtering



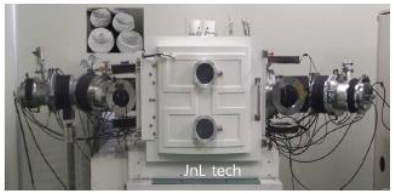
Ion Energy Distribution



Oxidation Temp.: 550℃ , 350℃

FVAS in Korea (18 set)

KIMS



아텍시스템(인천)
제이엔엘테크(안산)
보림시스템(안산)
K-DLC(군포)
에이엠글로벌(오산)

네오티스(충주)

삼성전자(구미)

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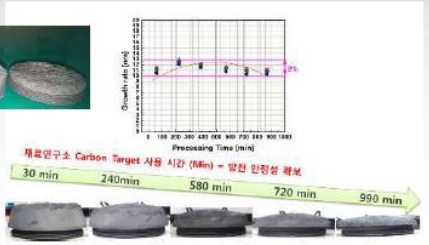
S홀딩스(광주)
엠피닉스 (광주)



Why is it difficult to thicken the ta-C coating?

How to deposit *thick films (ta-C coating more than* ***1 um of thickness****)*

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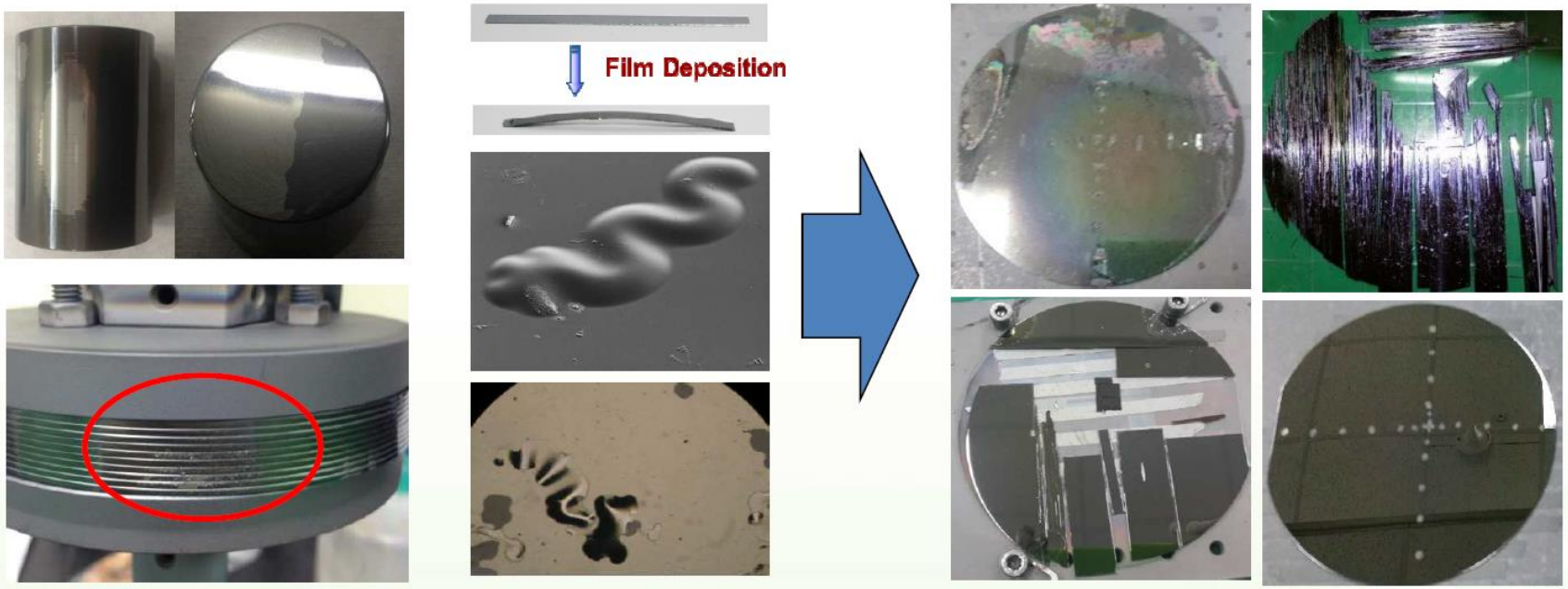

High Internal stress & Poor Interlayer