Development of Resistive Electrodes for MPGDs

Task 7.3a

Piet Verwilligen

INFN Bari

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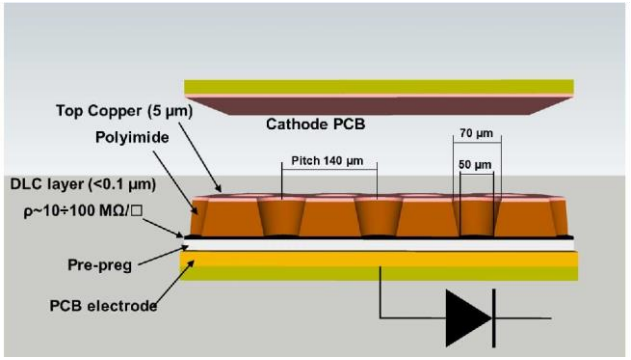
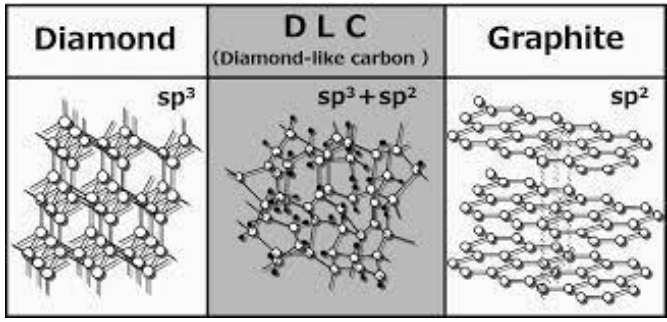
Introduction



Resistive electrodes improve detector stability of single amplification stage MPGDs (micromegas, µRWELL) and might be the bridge to higher gains (reach wire-chambers gain of ~10^5) and stable operation

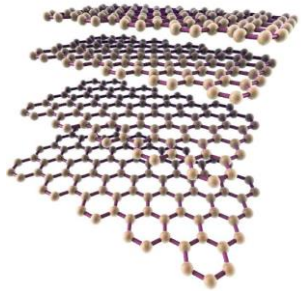
Resistive electrodes can be used for:

- Discharge quenching: *well established*
- Signal charge smearing: *being studied*
- Creation amplification structures: *hard, R&D ongoing*



Diamond Like Carbon (DLC) coating techniques are currently **explored by several groups** to develop new structures and new detectors profiting from coating properties (e.g. robustness, resistivity,…) and on the possibility of controlling them.

Explore **innovative resistive coatings** such as **Multi-Layer Graphene (ML-Graphene)** that are very strong, have high conductance and low material budget



Work within AIDAinnova

Task 7.3. Development of resistive electrodes for MPGDs and Industrial engineering of high-rate μ-RWELL detector

- Production of Diamond Like Carbon (DLC) with ion beam deposition and pulsed laser deposition
- Study of the resistance of graphene to polyimide etching liquids
- Characterisation of 10×10 cm2 foils by DLC and graphene
- Industrial production of small-size prototypes and their characterisation
- Industrial production of large-size prototypes (# 0.5 m2) and their characterisation

Tasks

Task #	Task name	Task Leader
7.3	Development of resistive electrodes for MPGDs and Industrial engineering of high-rate μ-RWELL detector	

MS #	Milestone name	Lead beneficiary	Due Date (in months)	Means of verification
MS26	Production of DLC with ion beam deposition and pulsed laser deposition	21 - INFN	23	Report (Task 7.3)

D #	Deliverable name	Lead beneficiary	Type	Due Date (in months)

Partners

	Institute	Type	Country	contact person	email
EU beneficiaries	INFN Bari	Research Institute	Italy	Piet Verwilligen	piet.verwilligen@ba.infn.it
	INFN Lecce			Annapoala Caricato	annapoala.caricato@le.infn.it
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EU non-beneficiaries (collaborating institutes)	CNR Nanotec	Research Institute	Italy	Giuseppe Valerio Bianco	giuseppevalerio.bianco@cnr.it
	CNR IFN			Gaetano Scamarcio	gaetano.scamarcio@cnr.it

Benificiaries:

- INFN Bari: Ion Beam Deposition DLC, Detector Design & Testing, Task Leader
- INFN Lecce: Pulsed Laser Deposition DLC
- INFN Pavia: Detector Testing

AIDA innova collaborators (not included in Proposal, but essential contributors):

- CERN: Micro-Pattern Technology (MPT) Workshop: Rui De Oliveira

Collaborating Institutes:

- CNR Nanotec (Bari) ML-Graphene Deposition, ML-Graphene Etching
- CNR IFN (Bari) Photo-Lithography, Patterning

Futher possibilities *(already ongoing collaboration within INFN R&D activities)*

- CNR Nanotec (Lecce) Photo-Lithography, Patterning, DLC Etching

Non-EU close contacts: USTC (Hefei, CN) – Magnetron Sputtering - Resistive DLC collab RD51

Status 03-2023: Milestone

Production of DLC with ion beam deposition and pulsed laser deposition

A.P. Caricato; A. Valentini; P.Verwilligen

Diamond-Like Carbon (DLC) resistive layers are a key ingredient for increasing the rate capabilities of Micro-Pattern Gaseous Detectors (MPGDs). Their production method and related quality is studied by ion beam deposition and pulsed laser deposition. The current DLC sample size will be scaled up gradually to 10×10 cm^2, their quality is assessed for the production of detector-grade amplification structures.

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Communities:
AIDAinnova

22 pages – 15 figures – Introduction to various PVD techniques for DLC

Irradiation of Pulsed Laser Depositioned DLC

CEDAD
CEntro di Fisica applicata, DAtazione e Diagnostica

- 3 MV Tandetron Accelerator
- $^{1}H+$ 3-4MeV – 1um beam
- ion species ^{1}H, ^{4}He, ^{12}C, ^{28}Si, …
- 0.2-10 MeV beam energy

Samples	Energy (MeV)	H^+ Fluence ($ions/cm^2$)	S_e (keV/nm)	S_n (KeV/nm)	D_a (MGy)
A	Pristine	-	-	-	
B	2	$5x10^{13}$	0.024	$1.4x10^{-5}$	1.13
C	2	$5x10^{14}$	0.024	$1.4x10^{-5}$	11.3
D	2	$1x10^{15}$	0.024	$1.4x10^{-5}$	22.6

- Irradiation of the Pulsed Laser Deposition (PLD) DLC samples to investigate effect of radiation on structure of DLC
- Non-doped (hydrogen-free) DLC
- Resistivity 100MOhm/sq
- Resistivity ∝ sp3/sp2 ratio
- Sp3/sp2 ratio constant over dose
- Irradiated with 2MeV $^{1}H+$ up to 22 MGy
- Cfr: max dose HL-LHC for Triple-GEM CMS => 250krad = 2.5kGy

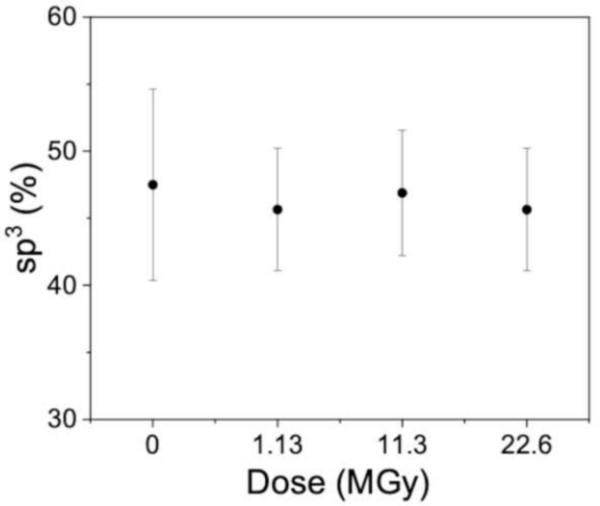
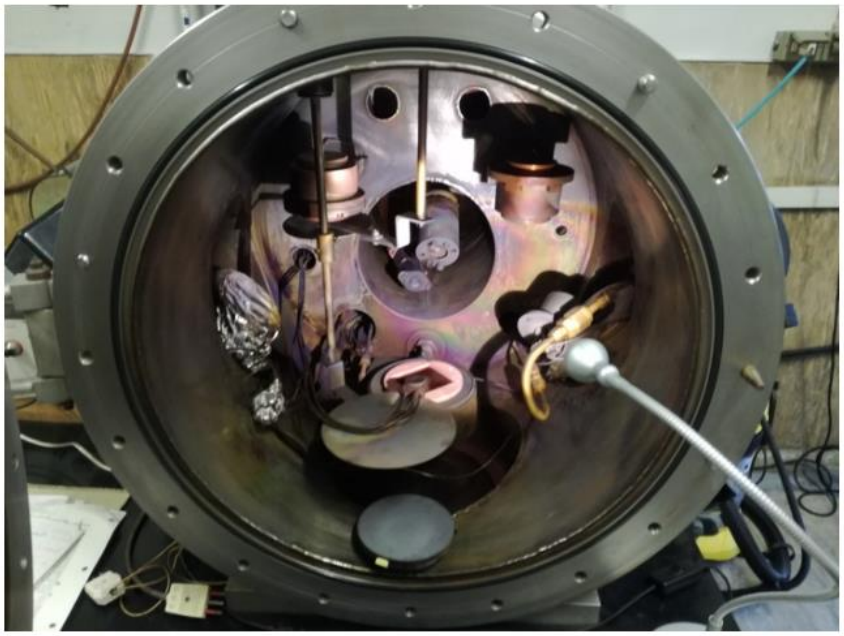


Figure Courtesey:
A. Serra, D. Manno et al.
Submitted to Vacuum

Skill Transfer Ion Beam Deposition setup for DLC



- **Ion Beam Deposition setup in BARI**
  - Custom build (1990ies)
- *Run by single expert*
  - A. Valentini – retired professor
  - Unfortunately partly out due to some health problems in 2023
- Setup was in *maintenance in 2023*
  - Repair of Kaufmann sources
  - Intervention on main VAC pump
- Reorganization of Labs @ INFN Bari
  - searching for long-term solutions

Started depositions for “Knowledge Transfer” to younger generation of scientists

- We have one new PhD student who started November 1st

Future will likely see a movement of the setup – and this will require small campaign to verify the quality of the foils after movement

2024 Plan - Collaboration with MPT Workshop

- **Magnetron Sputtering (MS) @ CERN**
  - Properties
    - Useful size 1.7m x 0.6m
    - 6 targets – 3 gas inputs
    - Plasma cleaner
    - More details in talk M.Giovanetti
  - Currently in use to find right parameters for the procuction of DLC for LHCb muon upgrade with high-rate uRWELLs
    - Mostly concentrated on:
      - Right value of resistivity
      - Uniformity of this resistivity

Thereafter can start work to transfer knowledge for production of more adherent double DLC foils (Cu-DLC-PI-DLC-Cu)

- Adherence more important because DLC is exposed to etching liquids

Plans for 2024:

- complementary proposal w.r.t. ongoing work
- Investigate structural properties DLC
  => Confront PLD and IBD DLC to MS DLC
  => same characterization (INFN Lecce)
- Participate to R&D for double DLC coated
- Involvement of new PhD student at Bari (Nov 2023 – Oct 2026)

Extra: Kaunas University of Technology collaboration

- In 2022 I was contacted by the Kaunas university of Technology (Lithuania)
- They have capabilities and expertise in:
  - thin film deposition with Magnetron sputtering
  - Micro-etching with Laser
- Wrote a project together for their national funding agency
  - Were funded in 2023 and started working on DLC and laser etching
  - Entering DRD1 collaboration

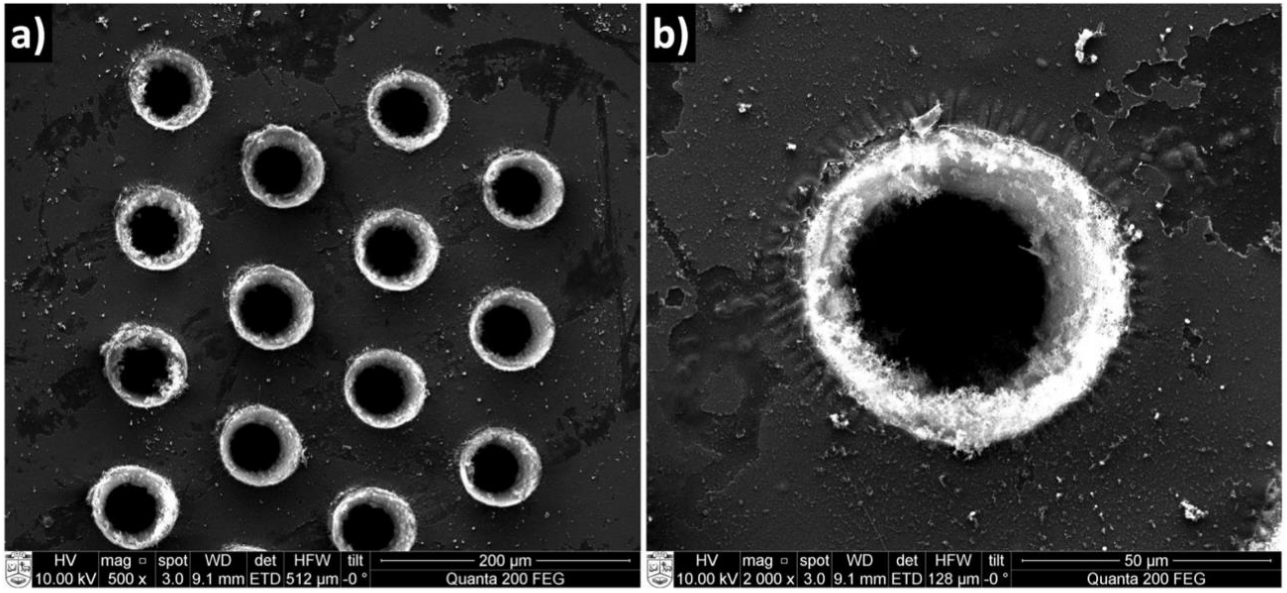


Figure 13. SEM micrographs of holes formed in KAPTON coated with DLC: a) small fraction of hole array formed by removing DLC prior to drilling, b) a single hole from the array, showing DLC crumpling

Figure Courtesey:
S. Tamulevicius, B. Abakeviciene

- first DLC coated Kapton foil that was laser ablated
- More samples are being produced to be evaluated on their electrical properties (resistance between two electrodes, capacity to keep high-voltage) and on the cleanliness of the samples

Summary

- **Pulsed Laser Deposition setup**
  - Irradiation of Pulsed Laser Deposition created DLC Foils at CEDAD (Mesagne)
  - Electrical and structural properties of DLC unchanged under 22MGy irradiation
- **Ion Beam Deposition setup**
  - Mostly out of use in 2023:
    - Maintenance of the setup
    - Discussions on future of the setup (new location)
    - Started Skill transfer to operate the setup (new PhD student)
- **Magnetron Sputtering - 2024 Plan**
  - Collaboration / knowledge transfer with CERN MPT workshop Magnetron Sputtering Setup
    - Currently dedicated at R&D for LHCb high-rate uRWELLs
    - Thereafter will be possible to concentrate on double-DLC foils
    - Involvement of new PhD student to work / evaluate quality of foils
- **Extra: collaboration with Kaunas University of Technology**