#### Introduction to Resistive DLC collaboration Atsuhiko Ochi Kobe University

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### **Resistive material for MPGDs**

- Resistive electrodes is one of best choice for reducing the sparks on MPGDs.
  - e.g. Many presentations in WG1,2,6 concerning with the resistive electrodes
- However, it is not easy to find the "resistive material" for Micro Pattern.
- In case, surface resistivity of  $1M\Omega/sq$ . is needed;
  - In general, the electrodes for MPGDs has  $0.1\mu m 10\mu m$  thickness.
  - Those correspond to bulk resistivity of  $0.1\Omega m 10\Omega m$ .



# Conventional way for making resistivity

- Carbon black loaded paste/sheet have been used for resistive material
  - Carbon black: small particles, made from mainly graphite.
  - Those are used by mixing in plastic, epoxy, solvent etc.
  - Mechanism of resistivity development



- Carbon black particles contact each other on point, and it makes electrical path.
- We need very small carbon black particles for fine structure of MPGD electrodes.

# Carbon dry sputtering $\rightarrow$ DLC

- Sputtered carbon
  - Diamond like, and amorphous structure
  - It means, carbon particles of molecular size!
- Fine structure with proper resistivity is available
  - with liftoff method





Random mixture of sp3 (diamond like) and sp2 (graphite like) carbon makes conductive paths of molecular size.

### Resistivity vs thickness (June, 2014)

- For 3.2%  $N_2$  content foils
  - 2400Å  $\rightarrow$  55k $\Omega$ /sq.
  - 700Å  $\rightarrow$  700k $\Omega$ /sq. (42min. sputter)





### **DLC for MPGDs**

Properties of the resistive electrodes by carbon sputtering

- Fine structure
- Chemical and physical toughness
- Very thin (50nm 500nm)
- Large area is available (1m x 4.5m)
- Demands for DLC is growing up in new MPGD developments
  - MicroMEGAS
  - GEM
  - **RWELL**
  - Micro-PIC
  - Field cage for



#### DLC production availability for MPGDs

- Japan
  - Be-Sputter Co, Ltd., (Industrial company)
  - Max size ... 1m x 4.5m (foil)
- China
  - Lanzhou institute has their own spattering machine
  - Max size ... 25cm x 25cm (to be enhanced)





# The problems to overcome for further R&D

- Resistivity control
  - It is hard to make aimed resistivity
    - Where same deposition thickness and dope, the resistivity is not same in different batch
    - We need to survey the effect of conditions and materials.
  - Uniformity in one foil
    - It strongly depend on conditions. We have to figure out and control the conditions.
- Metal electrodes on DLC foil
  - We have to develop strong and reliable attachment of metal electrodes on DLC
    - Cu sputter on DLC has very weak adhesion
    - Using Cr is better, but father investigation will be need.
- Long time stability
  - We found resistivity change for  $> 100 M\Omega/sq.$  high resistivity foils.

# DLC Common project (2018–)

- LICP: on the basis of theoretical calculation and simulation, give USTC team a guidance of the work
- USTC: produce different bare DLC foils with different surface resistivity and also DLC foils with Copper coating (DLC+Cu)
- Kobe University: produce large size DLC & DLC+Cu foils in order to study the reproducibility of the process tuned on smalk prototypes and the uniformity of the surface resistivity of the DLC
- CERN: study the behavior and changes of DLC properties under manufacturing processes foreseen for MPGD construction (i.e. µRWELL, resistive GEM and THGEM)
- LNF-INFN: study stability of bare DLC properties under current drawing on bench (w/irradiation)
- CERN: produce detectors with DLC foils
- LNF-INFN: perform aging and spark test of DLC based detectors (with different radiation)



## Followed by presentations

- Progress of DLC resistive electrode
  - Yi Zhou
- uRwell DLC detectors under high rate at PSI
  - Marco Poli Lener