The Compact Muon Solenoid Experiment

Conference Report

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

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Overview of the CMS beam loss monitoring system (BCML) and diamond detectors surface modification

Vitalii Okhotnikov for the CMS Collaboration

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Overview of the CMS beam loss monitoring system (BCML) and diamond detectors surface modification

V. Okhotnikov^{a,*}, S. Linnik^a, on behalf of the CMS collaboration^b

^aTomsk Polytechnic University, Tomsk, Russia

^bCERN, Geneva, Switzerland

Abstract

In CMS a beam loss monitoring system (BCML) is in place to protect the CMS Tracker from potentially damaging, high intensity beam loss events. Above a pre-defined detector current the LHC beams are automatically dumped. Detectors for this system require high radiation tolerance for stability over time, sufficient signal over noise at a given particle rate and a linear response up to the abort threshold. Poly-crystalline (pCVD) diamond sensors are used as detectors. Additionally sapphire based and diamond-on-iridium prototype sensors were installed during 2017 to investigate more radiation tolerant detectors. This report discusses the BCML system, as well as promising ways of solving problems with adhesion to the detector's plates by using the diamond surface modification with doped diamond sublayers.

Keywords: Diamond, detectors, doped diamond, safety system

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1. Introduction

The BCML¹ detectors measure the current created by ionization in sensors. This signal current is proportional to the ionizing particle flux through the active detector material thus providing a relevant measurement for the radiation load in detectors at that location. The abort system consists of 16-pCVD detectors. In addition, 6-sapphire, 2-diamond on iridium (DOI), one 3D diamond detectors prototypes are also installed for testing purposes. Figure 1 shows the locations of this detector system inside CMS² and the distances from the Interaction Point (IP) and radius from beam pipe [1].

The main purpose of this system is to protect from potentially dangerous beam loss events. When the detector's current rises above a predefined threshold the LHC beams are automatically dumped. Because of this the BCML system has to work properly and be enough sensitive to catch dangerous processes fast and be stable to avoid the false beam dumps.

Figure 1: BCML - Beam Condition Monitor Leakage system, installed in CMS.

pCVD diamond detectors were chosen because of the highest radiation hardness, high charge carrier mobilities and efficiency without the need for cooling [2, 3]. However, the decrease of detector efficiency turned out much higher than expected in comparison to lab measurements (RD42 collaboration CERN) as Figure 2 shows [4].

*Corresponding author

Email address: vitalii.okhotnikov@cern.ch (V. Okhotnikov)

¹Beam Condition Monitor Leakage safety system of CMS

²Compact Muon Solenoid (CMS) is a general-purpose detector at the Large Hadron Collider (LHC)

Figure 2: Comparison of the expected signal RD42 and experimental data [5].

Figure 3: The main description of the pCVD diamond detector obtaining and also the potential weak points which can be effected at the final results

2. Materials and Methods

This effect now are under the investigation. And trying to reduce this effect we should solve the problems of diamond detectors producing. There are many problems that may occur during the production of sensors, such as surface defects and cavities and some inner deformation, stress and impurities. Figure 3 shows how diamond detectors are grown and where undesirable defects can be found.

2.1. Surface modification

One of the potential way to improve the pCVD diamond sensors radiation hardness is to remove the cavities between the diamond detectors surface and metallization. The bad adhesion of any metallization to diamond leads to cavities appearing at the junction of these layers. That may have effect on the electron-holes pair ways to drain or even catch this charge carrier into the traps. Using of the diamond boron doped interlayer can help to create Ohmic contact to metallization and reduce the amount of potential defects and traps.

Figure 4: Detection of individual particles

The full process contains more than 20 steps of cleaning/pre-treatment/modification/deposition processes where we attempt to reduce the effect of defects on the final detector, the treatment processes and partly described in [6]. Surface treatment is a very important step to prepare the diamond for future deposition. In this process we carry out final cleaning to reduce the defects on the surface and to increase the adhesion to next layers. Right after the etching process (in the same chamber without diamond evacuating) we provide a boron doped pCVD deposition process for applying an inter-layer between diamond detector body and metallization plates. The thickness of diamond interlayer based on getting continuous film and equal around $2\mu\text{m}$. The gas mixture of this process is $\text{H}_2:\text{CH}_4:\text{C}_3\text{H}_9\text{BO}_3$ (100:6:2 purity of gases: H_2 , 99.9999%; CH_4 , 99.99%, evaporated $\text{C}_3\text{H}_9\text{BO}_3$, 95%). And after the boron doped diamond interlayer a Ti/Cu metallization in 350nm/200nm thickness is applied by magnetron sputtering.

3. Conclusion

Promising diamond detectors with boron doped diamond interlayers have been produced and prepared for installation into CMS for testing. The new technique of diamond interlayer and metallization application in one chamber without removing the sample from the chamber also should to reduce the effect of surface defects appearing during the detectors preparation.

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