sCVD diamond detectors for the use in heavy-ion reactions

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Single-crystalline diamond detectors formed by chemical vapor deposition (sCVD) have received significant interest in high-energy nuclear physics as charged particle and neutron detectors due to high radiation hardness, fast response time, and good energy resolution (sub 1% for 5.5 MeV alpha particles) [1,2]. Near 100% charge collection has also been observed with these detectors [3]. These interesting physical properties make sCVD diamond detectors a good candidate for the use in low energy, heavy-ion reactions, particularly with high rates of incident radiation. ΔE-E telescope detectors are commonly implemented in heavy-ion reactions for the purpose of particle identification (PID). Cesaroni et al. have shown alpha particle identification using a prototype diamond telescope with an ^{241}Am source [4]. However, PID capabilities for diamond telescopes with $Z > 2$ have not been well established. It is the purpose of this work to investigate PID for $Z > 2$ with diamond telescope detectors in heavy-ion reactions.

To examine the suitability of these detectors in heavy-ion reactions, we have procured a Knopf B12 sCVD detector and a telescope detector with two sCVD diamond sensors from CIVIDEC Instrumentation GmbH. The B12 is 500 µm thick, with a sensitive area of 4.5 x 4.5 mm^2. The telescope detector has the following configuration: the transmission sensor (ΔE) is 20 µm thick and the stopping sensor (E) is 500 µm thick. Both sensors are 4 mm in diameter [5].

We investigated the performance of the Knopf B12 detector using CIVIDEC's Cx spectroscopic shaping amplifier by collecting ^{228}Th source and direct beam data. The energy resolution was approximately 1% for the 8.79 MeV alpha peak with the ^{228}Th source. We used a cocktail beam of ^{4}He, ^{12}C, and ^{16}O at 2.5 MeV/u in order to examine the detector's response to higher energy particles. Regardless of the particle identity, the response was linear with the energy deposited into the sensor (see discussion below on pulse height defect). We ran this beam at rates ranging from 10^3 to 10^8 pps (as determined on the Faraday cup) to observe the degradation of the detector's performance. We found that after an hour of an average of 10^7 pps on the detector, the energy resolution degraded by approximately 0.3 percentage points.

In a later experiment, the diamond telescope was tested for heavy-ion PID. With the telescope detector located at approximately 8 degrees from the beam axis, we ran a ^{20}Ne beam on ^{12}C target at 20 MeV/u. The signals were processed using two, single-channel model 1984 Canberra preamplifiers with Tennelec spectroscopic shaping amplifiers. In ^{228}Th source tests, the energy resolution on both sensors was near 1%.

Fig. 1 presents the ΔE vs E spectrum collected from this reaction. The spectrum shows clear elemental resolution, as well as isotopic resolution. Isotopic resolution was obtained for nuclei with Z less than or equal to magnesium. Isotopic resolution may also be present in the band for aluminum; however, it is difficult to identify any Al isotopes in this case due to the low number of counts in this region. The red circle on the left plot indicates the suspected peak for the elastically scattered beam (^{20}Ne). The energy calibration using the ^{228}Th source underestimates the location of this peak at 300 MeV with a linear fit. Using a calibration based on LISE calculations for punch-throughs, the location is now at

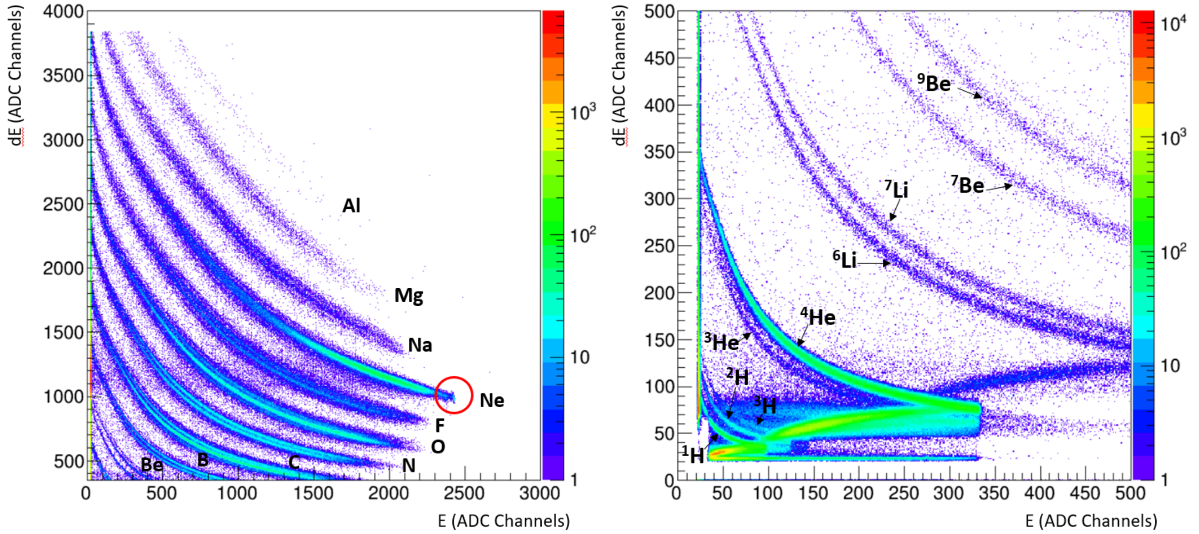

Fig. 1. dE vs E spectrum zoomed in at different locations. Left: The bands shown are identified as Be up to Al. Shown in the circle is Ne elastic peak (See text for further details). Right: Protons up to Be, the various isotopes of the lighter nuclei produced in this reaction are labelled as well.

approximately 350 MeV. However, the thicknesses of the sensors may not be exactly what is reported by the manufacturer, which may account for this. Additionally, these detectors have been reported to suffer significantly more from pulse height defects than Si detectors for high energy heavy ions [6]. This, of course, means that the detector response is not as linear as what we have observed with the lower energy beam on the B12 detector. Further analysis needs to be done in order to examine the effects of pulse-height defect in greater detail.

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