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Diamond-based detectors for future chemistry experiments with superheavy elements

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Today's state-of-the-art alpha-decay- and SF-detection systems for artificially produced superheavy elements (SHEs) consist of silicon-based detectors. For recent chemistry experiments with SHEs a thermochromatographic channel comprised of silicon solid-state detectors in a sandwich-like geometry (e.g., Cryo On-Line Detector [COLD], Cryo Online Multidetector for Physics And Chemistry of Transactinides [COMPACT]) have been applied [1-5]. The crucial advantage of this method is that the surface of the detector serves directly as the stationary surface in the chromatographic process. Different detector coverages can be applied, e.g. SiO2, Au, Se. This technique allows for unprecedented detection efficiencies thereby giving access to crucial chemical information. Despite the success of this approach, the silicon-based detector setups can only be used for fairly volatile elements or their compounds with adsorption enthalpies ranging from $-\Delta$Hads ≈ 60 to 15 kJ/mol. The limiting factor here is the silicon material itself with its rather low band gap of 1.1 eV. As a result, the upper temperature limit for a reliable spectroscopic performance is encountered at around 40℃[6]. Furthermore, Si-based detectors need to be operated in complete darkness.
Due to its unique properties, diamond is a superior candidate for the replacement of silicon as semiconductor material for radiation detection. Diamond is a wide band gap semiconductor (5.4 eV), which allows diamond-based sensors to be operated theoretically up to 1000 ℃, even under intense UV/vis/IR-irradiation [7]. Currently, the upper temperature limit of diamond-based detectors for alpha-spectroscopic measurements is pinpointed at around 200 –300 ℃ [6, 8].
The application of diamond detectors is a promising prospect for a long sought after extension of the chromatographic range of detector arrays such as the COLD. Using diamond-based detectors with their before mentioned current temperature threshold, the upper limit of the observable adsorption enthalpy $-\Delta$Hads could be nearly doubled in comparison to today's detectors. In other words, this would give access to elements and compounds with stronger adsorption interactions with the chromatographic surface, such as to the one of Hg on Au. Such advancement is necessary for future chemical investigations of less volatile SHEs using the efficient method of thermochromatography.
Herein, we present a most recent investigation on heated diamond-based sensors aiming at highest possible operation temperatures for alpha-spectroscopic measurements. The prospects of their application in SHE experiments are discussed. Furthermore, we present a design study of a future COLD like detection system employing diamond-based detectors.

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Primary author: Mr KRAUS, Benjamin (Paul Scherrer Institute / University Bern)

Co-authors: Dr EICHLER, Robert (Paul Scherrer Institute / University Bern); Dr DRESSLER, Rugard (Paul Scherrer Institute); Mr HERRMANN, Dominik (Paul Scherrer Institute); Dr STEINEGGER, Patrick (Joint Institute for Nuclear Research); Dr AKSENOV, Nikolay (Joint Institute for Nuclear Research); Prof. TÜRLER, Andreas (University Bern); Dr GRIESMAYER, Erich (CIVIDEC Instrumentation GmbH); Dr WEISS, Christina (CIVIDEC Instrumentation GmbH)

Presenter: Mr KRAUS, Benjamin (Paul Scherrer Institute / University Bern)

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