Nuclear Instruments and Methods in Physics Research A 858 (2017) 30–35

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Evaluation of HOPG mounting possibilities for multiplexing spectrometers

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ARTICLE INFO

Keywords:
Neutrons
Neutron optics
Neutron scattering
Multiplexing
HOPG
Neutron spectrometer

ABSTRACT

Four different methods for mounting HOPG analyzer crystals on Si holders have been evaluated in the design process of the new multiplexing spectrometer CAMEA. Contrary to neutron optics used in standard spectrometers, the new instrument concept employs a series of analyzer segments behind each other where the neutrons have to pass through the bonding compound of the different analyzer crystals. The different methods, namely screws, shellac, indium soldering and clips, have been evaluated with regards to background, transmission, cooling, activation and handling. The results presented here will give valuable input for future CAMEA-type spectrometers currently planned and designed at various neutron sources.

1. Introduction

In neutron spectroscopy, e.g. on triple-axis spectrometers (TAS), Bragg reflection from crystals is the most common used method to select a well defined wavelength band from a white neutron beam [1]. For cold instruments, highly oriented pyrolytic graphite (HOPG) is the material of choice for both monochromator and analyzer devices since it has a high reflectivity [2] and can be described as an ideally imperfect non-absorbing crystal. The HOPG crystals are usually mounted on flat metal or silicon holders, which by mechanical rotation can then be used as a focusing device (see e.g. [3]).

In the past decades, two 'standard techniques' for mounting the HOPG have been established, namely glue and screws. Special glues based on a mixture of beeswax and colophonium or 2-component epoxy glue have been used [4], e.g. at the ILL, France, or at the cold TAS FLEXX at HZB, Germany. Often these glues are mixed with a neutron absorber, e.g. GdO_4 powder, to prevent unwanted background arising from scattering of the hydrogen content of the glue or the support material. Another glue material mainly used at PSI, Switzerland, and at some instruments at the MLZ, Germany, is shellac. The second attachment technique is screwing the HOPG crystals on the holder, as e.g. done at the MACS spectrometer [5], which automatically reduces the background. However, it entails certain other risks. First, a hole needs to be drilled into the HOPG crystal. This might result in a local deformation of the lattice and thus a worsening of the mosaic spread around the hole. Second, a certain amount of expensive crystal material is lost due to the drilling. If a spectrometer is at the end position of a neutron guide, the amount of fixing material behind the HOPG crystals of the monochromator, to a certain extent does not effect the downstream performance.

However, due to the excellent transmission properties of HOPG for longer wavelengths [6] there are several realizations where the monochromator of one instrument is placed upstream in the beam of a consecutive instrument, e.g. the RNR12 cold neutron guide at SINQ, PSI, where the instruments NARZISS, ORION, DMC and SANS-II (in downstream order) share one guide or at PELICAN, ANSTO, Australia [4]. In the latter case, the amount of material other than HOPG needs to be reduced to a minimum in order to minimize the number of neutrons scattered out of the beam of the following instruments. In the special case of PELICAN, even the single monochromator crystals are consecutively in front of each other. Here, an alternative fixation method was successfully implemented by using indium as a solder material [4] and realizing large HOPG crystal by soldering smaller pieces together. Since there are only 3 consecutive monochromator

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http://dx.doi.org/10.1016/j.nima.2017.03.031
Received 16 January 2017; Received in revised form 27 February 2017; Accepted 15 March 2017
Available online 19 March 2017

stages and the solder spots are small and thin, the rather large neutron absorption of the indium can be neglected. Furthermore, since a monochromator of a spectrometer is normally not changed often, the activation of the indium in the direct, white beam is likewise not a problem. The method was also successfully implemented at KOOKABURRA, ANSTO, Australia [7] by soldering the HOPG crystal of the pre-monochromator to a Si base plate.

Recently, several instruments of a new generation of multiplexing spectrometers, which use a consecutive series of upwards scattering analyzer arcs to optimize the efficiency for in plane scattering, have been proposed. This concept has become know as Continuous Angle Multiple Energy Analysis (CAMEA) [8,9]. Types of this backend are under construction at the cold TAS RITA-II [10,11] at the PSI, Switzerland, [9] and in the design phase for the future ESS source [8] and the cold TAS PANDA [12–14] at the MLZ, Germany [15]. Furthermore, the CAMEA-type multiplexing backend MULTIFLEXX [3] has been commissioned [16] at the recently upgraded cold TAS FLEXX at HZB, Germany, [17,18] after successful prototype measurements [19]. CAMEA uses a large amount of HOPG crystals mounted in series behind each other in the beam and has a rather open design, i.e, the detectors are sensitive to background arising from neighbored analyzers. It is thus necessary to evaluate existing and new fixation methods for this kind of spectrometer.

In the course of the design process of the CAMEA backend at PSI, different fixation methods have been investigated with regard to background, transmission, operation in vacuum and durability under cooling. Here, the results for the evaluation of HOPG fixed with glue, screws, solder and mechanical clips are reported.

2. Requirements

The principal CAMEA instrument would consist of a series of focusing analyzer arcs where each arc is set to a fixed final energy. In reality, these arcs are modeled by angular modules where one module contains several analyzer segments which are placed behind each other to cover the different final energies. A detailed description of the CAMEA concept, the backend constructed at PSI and focusing conditions can be found in [9]. The horizontal opening angle of the angular module (7.5°) and the Bragg conditions of the analyzer segments determine the useful length of the individual HOPG crystals. For the analyzer closest to the sample ($E_f = 3.2$ meV, $2\Theta_A = 97.8°$) the HOPG length is much smaller than for the analyzer furthest from the sample ($E_f = 5$ meV, $2\Theta_A = 74.2°$). Since frames of the front analyzer segments should not be in the beam in general and especially not in front of the rear crystals, it is not possible to mount the HOPG crystals directly to the frame for CAMEA (HOPG length first and last analyzer segment: 72 mm and 140 mm, respectively). The option of extending the HOPG crystals more than necessary is discarded, since it is expensive, mechanically challenging and increases the background due to neutrons directly scattered into the shielding. Thus, additional supports are needed for the HOPG crystals. For CAMEA, Si was chosen as the holder material since it is stable and large single crystals, which have an excellent transmission for cold neutrons and produce almost no background, are available. The corresponding blades are cut out of standard double side polished (1 0 0) wafers with the (0 1 0) orientation along the long axis. With this orientation the (1 1 1) reflection does not cause any spurious signals in the energy range used for CAMEA. The wafers are nearly perfect single crystals with a mosaicity in the range of a few arc seconds.

Fig. 1 shows the design drawing of an angular segment for the CAMEA spectrometer currently constructed at PSI. Here, the HOPG (blue) is mounted on Si blades (green), which are mounted in aluminum frames (yellow). A detailed design drawing of the most outer analyzer segment (HOPG length of 140 mm, $E_f = 5$ meV) is shown in Fig. 2. Here the HOPG crystals are fixed with the clip solution discussed in Section 3.4. The total HOPG length of 140 mm is achieved by the composition of two 70 mm long HOPG crystals due to the fact, that at the time of the design of CAMEA a maximum HOPG crystal length of 75 mm with the required homogeneity in mosaic spread was available. In fact, such a composition is necessary for all analyzer segments except for the first one (HOPG length of 72 mm, $E_f = 3.2$ meV).

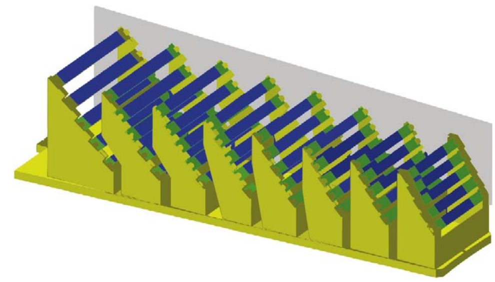

Fig. 1. Design of the analyzer segments of one module. The HOPG crystals (blue) are mounted on Si blades (green), which are fixed within aluminum holders (yellow). Figure taken from [9]. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

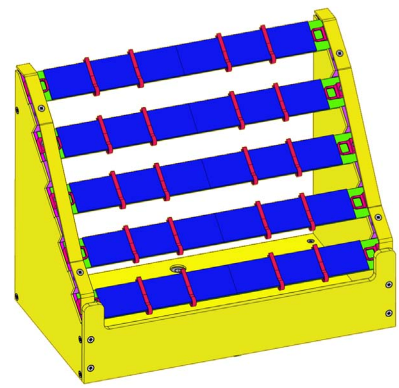

Fig. 2. Detailed design drawing of the most outer analyzer segment ($E_f = 5$ meV) as seen in Fig. 1. The total HOPG length of 140 mm is achieved by composing two 70 mm long crystals (blue, separation shown by black line). Here the crystals are fixed with the clip solution discussed in Section 3.4. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

Contrary to the frames, the fixation compound used to mount the HOPG crystals on the Si blades is in the neutron beam. Thus, the classic and new fixation methods need to be evaluated taking several conditions into account:

- Absorption: The compound should have a low absorption cross section to avoid a reduction of the flux on consecutive analyzer segments
- Scattering: The compound should have a low scattering cross section to reduce additional background and beam attenuation
- Vacuum compatibility: The analyzer will be mounted within a vacuum tank and thus the compound must be suitable accordingly

In the evaluation process, fixation by glue (shellac), screws, solder (indium) and mechanical clips was evaluated. For some of the compounds, the durability under cooling was tested. This is especially interesting for future instruments where the setups might get closer to back-scattering geometry. Here, a cooling of the analyzer crystals can help to suppress the Lorentzian Bragg tails [20].

3. Fixation methods

3.1. Screws

Examples for the fixation of HOPG analyzer crystal with screws are