Experimental report

05/03/2021

Proposal: **3-14-408** **Council:** 10/2019

Title: Diamond nanoparticles in nanoparticle-polymer composite neutron diffraction gratings II

Research area: Methods and instrumentation

This proposal is a new proposal

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Experimental team: Juergen KLEPP

Local contacts: Tobias JENKE

Samples: Nanoparticle polymer composite

Instrument	Requested days	Allocated days	From	To
PF2 VCN	15	15	15/09/2020	22/09/2020
			22/09/2020	28/09/2020

Abstract:

This proposal is in principle a continuation of 3-14-392. However, 3-14-392 could not be carried out in September 2019 (as previously scheduled) because of an unforeseen delay of refurbishment works at the instrument PF2 VCN (work accident, please consult Tobias Jenke for further information). 3-14-392 was rescheduled to November 2019. Since 3-14-392 was not available in the user club system as of Monday, September 16, we could not upload an experimental report for it and could, therefore, not submit the present proposal as a "continuation".

Abstract: We use materials that are sensitive to light combined with holographic techniques to develop diffraction gratings for long-wavelength neutron optics.

The treated materials exhibit a periodic neutron refrac-tive-index pattern, arising from a light-induced redistribution of the con-stituents.

Our goal is to find the most versatile and efficient material to produce neutron-optical elements, such as wavelength-standards and gratings for

neutron phase-imaging or very-cold neutron interferometry. This proposal aims at testing improved (in comparison to 3-14-39) nanodiamond gratings.

Diamond nanoparticles in nanoparticle-polymer composite neutron diffraction gratings II

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We measured diffraction on several holographic diamond nanoparticle gratings. Our aim was to produce gratings that beat our own old record diffraction efficiency (DE) achieved with SiO_2 gratings, which was almost 90 %. We have achieved this goal and are working on the durability issue of our nanodiamond gratings (see report on experiment 3-14-392).

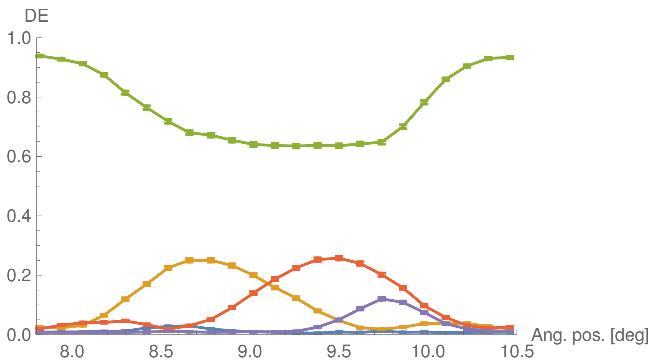

Figure 1: Rocking curve of a nanodiamond-polymer composite grating (thickness $\approx$ 29 μm, grating spacing = 0.5 μm). Note that the -2nd diffraction order was cut-off by the He tube we use to avoid neutron losses due to scattering and absorption by air molecules. The latter also causes the asymmetry seen in the 0th diffraction order.

We use materials that are sensitive to light in addition to holographic techniques to produce relatively large area transmission gratings for neutron-optics [1]. The treated materials exhibit a periodic neutron refractive-index pattern, arising from a light-induced redistribution of the constituents, which results in a modulation of the scattering length density.
The width of the rocking curve (DE vs. angle of incidence) of optically thick diffraction gratings (the distance in angle of incidence between the minima adjacent left and right to the central maximum) is approximately given by 2 times the grating period (typically 0.5 μm or 1 μm) divided by the grating thickness (typically below 100 μm). The latter is a decisive parameters also for reaching high DE. However, increasing DE by just increasing the grating thickness – as was put forward in a series of our previous experiments [1] – leads to high DE at the cost of very narrow rocking curves, which makes gratings difficult to adjust as parts of optical systems (interferometers, for instance) and inefficient at badly collimated low-intensity beamlines. Therefore, novel materials should preferably reach high DE at low thickness via increasing their constituents' scattering length contrast. For the above reasons, we have implemented diamond nanoparticle gratings, which supposedly have the best neutron optical properties, instead of the already very well-working SiO_2 nanoparticle gratings.
After measurements of nanodiamond gratings in January 2020 (see experimental report on 3-14-392) we improved the contrast between the material matrix (polymer and rests of photoinitiator chemicals) and the nanodiamonds, came close to our own record in the coherent scattering density modulation amplitude [2] and reached a value of about 9 μm^{-2}. Preliminary data are shown in Fig. 1. The data on beating our own record in DE will be presented in a dedicated publication. The surprising decay of the nanodiamond grating structure reported earlier has been tackled and it seems to be under control as we have tested one of the gratings produced during summer 2020 also in experiment 3-14-409 (February, March 2021). Of course, it is too early to know if the excellent durability of our SiO_2 gratings (reliably diffracting since 2012) can be reached with the present nanodiamond samples. A recent publication on production and light- and neutron-optical properties of our nanodiamond-polymer composite gratings is Ref. [3].

[1] Y. Tomita, E. Hata, K. Momose, S. Takayama, X. Liu, K. Chikama, J. Klepp, C. Pruner, and M. Fally, J. Mod. Opt. **63**, S1 (2016).

[2] J. Klepp, C. Pruner, Y. Tomita, C. Plonka-Spehr, P. Geltenbort, S. Ivanov, G. Manzin, K. H. Andersen, J. Kohlbrecher, M. A. Ellabban, and M. Fally, Phys. Rev. A **84**, 013621 (2011).

[3] Y. Tomita, A. Kageyama, Y. Iso, K. Umemoto, A. Kume, M. Liu, C. Pruner, T. Jenke, S. Roccia, P. Geltenbort, M. Fally, and J. Klepp, Phys. Rev. Applied **14**, 044056 (2020).

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