Experimental report

07/04/2021

Proposal: **3-14-409** **Council:** 4/2020

Title: Neutron diffraction from commercially available Bayfol photopolymer film gratings

Research area: Methods and instrumentation

This proposal is a new proposal

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Samples: photopolymer on triacetate substrate

Instrument	Requested days	Allocated days	From	To
PF2 VCN	16	16	27/01/2021	01/03/2021
			01/03/2021	30/03/2021

Abstract:

We use materials that are sensitive to light combined with holographic techniques to develop diffraction gratings for long-wavelength neutron optics. After holographic exposure, the treated materials exhibit a periodic neutron refractive-index pattern, arising from a light-induced redistribution of the constituents. 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 (VCN) interferometry.
The experiment proposed here aims at testing diffraction gratings based on commercially available light-sensitive photopolymer films routinely used to produce phase holograms for light optics.

Neutron diffraction from commercially available Bayfol photopolymer film gratings

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The experiment proposed and carried out aimed at testing diffraction gratings based on commercially available light-sensitive photopolymer films routinely used to produce phase holograms for light optics.

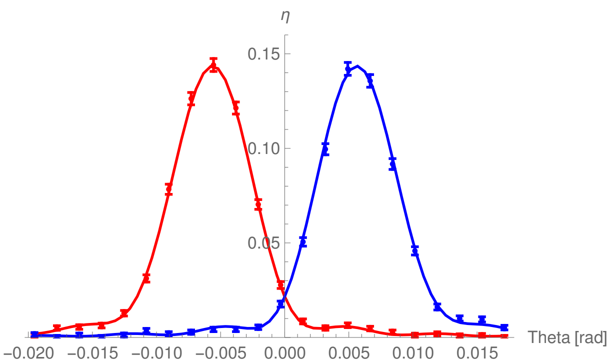

Figure 1: Rocking curve (diffraction efficiency η vs. angle of incidence) of a grating recorded in a piece of Bayfol foil with photopolymer layer thickness of $d \approx 70\,\mu$m.

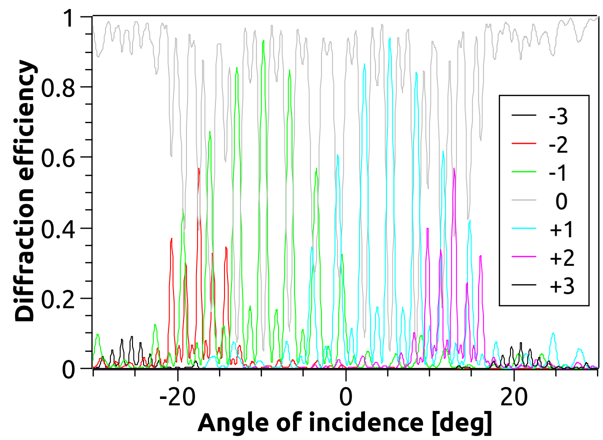

Figure 2: Rocking curve of a multi-layer structure recorded in Bayfol foil with photopolymer layer thickness of $d \approx 16\,\mu$m measured with a laser.

We use materials that are sensitive to light and apply holographic techniques to record diffraction gratings for light as well as for long-wavelength neutron optics in such materials. We have developed a series of holographic neutron-optical devices incorporating nanoparticle species with high neutron-refractive index [1, 2].

Recently, we have learnt about the commercially available material Bayfol HX 200 manufactured by the company Covestro (see Ref. [3]). Bayfol is a very robust, versatile and easy-to-use material which we consider as complementary to our high-end nanoparticle-polymer composite materials. Bayfol can be used for quick proof-of-principle tests prior to dedicated development of more involved nanodiamond (for instance) gratings. However, once optimized with respect to hologram recording parameters (recording time, dosage), depending on durability and quality of the produced holograms and their diffraction efficiency η for neutrons, Bayfol foil materials could become a promising material class for neutron optics by itself.

In Fig. 1, a very-cold neutron (VCN) rocking curve of a simple sinusoidal hologram recorded in a 70-microns-thick piece of Bayfol foil in our lab in Vienna is shown together with a wavelength-averaged fit of Kogelnik's diffraction theory for volume holograms [4] (two-wave approximation, neglecting the small, overlapping contribution of second order diffraction here) is shown. It is surprising that we have immediately reached a diffraction efficiency of about 15 % without investing much time in optimization of the recording process. In the meanwhile, we have started to investigate such optimization for further tests with the Bayfol material.

For example, multilayer structures can be recorded in such materials by forming stacks of multiple foil layers and recording a hologram throughout the created layer structure. The contained photopolymer layers in which the holograms are recorded are kept at constant distance from each other. Such multilayer grating structures are, for instance, described in Ref. [5]. An example for a rocking curve of such a structure measured with a laser of 633 nm wavelength is shown in Fig. 2. Note the very steep slopes produced by the rapid oscillations that are observable using the laser. While it is clear that a neutron beam – and the VCN beam in particular – cannot reproduce such slopes, it is, nevertheless, interesting to investigate the possibilities of the Bayfol materials when it comes to production of rather unusual structures for neutron optics.

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[2] 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).

[3] F.-K. Bruder, T. Fäcke, and T. Rölle, Polymers **9**, 472 (2017).

[4] H. Kogelnik, Bell Syst. Tech. J. **48**, 2909 (1969).

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