Experimental report

12/09/2022

Proposal:	**3-14-423**	**Council:**	4/2021
Title:	Neutron diffraction from multilayer film gratings		
Research area:	Methods and instrumentation		

This proposal is a new proposal

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Samples: Bayfol photosensitive foil

Instrument	Requested days	Allocated days	From	To
PF2 VCN	20	20	11/05/2021	19/06/2021
			19/06/2021	23/06/2021

Abstract:

We use light sensitive materials 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. The experiment proposed here aims at testing holographic multilayer diffraction gratings based on commercially available light-sensitive photopolymer films manufactured into multilayer structures. The idea of making stacks of Bayfol foils to reach the desired thickness led also to tests of multilayer structures. In such structures, there is a non light-sensitive layer sandwiched between two photopolymer layers. In the holographic recording process a structure of perfectly aligned diffraction gratings, distanced by a layer of insensitive material is produced, which exhibits rapid oscillating and beating diffraction patterns also for neutrons.

Neutron diffraction from multilayer 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.

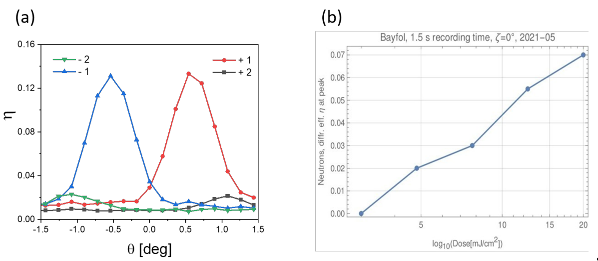

Figure 1: (a) Rocking curve (diffraction efficiency η vs. angle of incidence) of a grating recorded in a piece of Bayfol foil with photopolymer layer thickness of $d \approx 70\,\mu$m. (b) Variation of the measured diffraction efficiency for various Bayfol samples prepared with different radiation dosage during holographic recording.

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

In contrast to some custom-made nanoparticle-polymer composite materials, commercially available Covestro HX 200 Bayfol foils are very robust, versatile and easy-to-use materials (see Ref. [3]). 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), the 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 showed to be the best sample during our early-stage test experiments. The latter features fine diffraction efficiency for the first diffracted orders $\eta_{\pm 1}(\theta_B) \simeq 13\,\%$. During the experiment, we investigated possible optimization for further tests with the Bayfol material by varying the radiation dosage during the recording of the structures and measuring the corresponding variation of the diffraction efficiency as shown in 1 (b). An increase of η has been noted as we increase the dosage, it is though necessary to complete the study by measuring more sample to find the optimal value for this parameter.

On the other hand, a multilayer sample was prepared by the

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.

recording of a hologram in a stack of Bayfol foils seperated by a transparent substrate. The contained photopolymer layers in which the holograms are recorded are kept at constant distance from each other by the substrate. Such multilayer grating structures are, for instance, described in Ref.[4]. A rocking curve of such a structure was measured with a laser of 633 nm wavelength and very steep slopes produced by the rapid oscillations were observed. The same behaviour was reproduced experimentally by VCN diffraction, despite the large wavelength of the VCN spectrum (to be published). On the other hand, no measured signal was found for another similarly prepared sample that has a much larger thickness, probably because of the very quick oscillations of η (as a function of angle of incidence) from thick grating structures, which cannot be resolved with a VCN beam of comparably large divergence. Therefore, we intend to study this behaviour further during our next proposed experiment to try different stack of layers with different thicknesses in order to investigate the systematics.

[1] Y. Tomita, E. Hata, K. Momose, S. Takayama, X. Liu, K. Chikama, J. Klepp, C. Pruner, and M. Fally, Journal of Modern Optics **63**, S1 (2016), pMID: 27594769, https://doi.org/10.1080/09500340.2016.1143534 .

[2] E. Hadden, Y. Iso, A. Kume, K. Umemoto, T. Jenke, M. Fally, J. Klepp, and Y. Tomita, in *Photosensitive Materials and their Applications II*, Vol. 12151, edited by R. R. McLeod, I. P. Villalobos, Y. Tomita, and J. T. Sheridan, International Society for Optics and Photonics (SPIE, 2022) p. 1215109.

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

[4] M. Rodionov and E. Pen, (2010), 10.2316/P.2010.693-004.

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