Experimental report

17/09/2018

Proposal: **3-14-376** **Council:** 10/2016

Title: Ionic-liquids composites (ILCs) for holographic-grating neutron-optical elements

Research area: Methods and instrumentation

This proposal is a new proposal

Main proposer: **Juergen KLEPP**

Experimental team: Juergen KLEPP
Christian PRUNER
Martin FALLY

Local contacts: Tobias JENKE
Valery NESVIZHEVSKY

Samples: polymer+ionic liquid composite

Instrument	Requested days	Allocated days	From	To
PF2 VCN	17	17	07/06/2018	24/06/2018

Abstract:

We use materials that are sensitive to light, combined with holographic techniques to produce transmission gratings for neutron-optics. The treated materi-als exhibit a periodic neutron refrac-tive-index pattern, arising from a light-induced redistribution of the con-stituents. To keep rocking curves wide for adjustment and collimation reasons, novel materials should reach high reflectivity via increasing their con-stituents' contrast in coherent scattering length. One candidate material that has, so far, never been investigated with neutrons are composites of polymer and ionic liquids (ILCs). We intend to measure neutron diffraction from holographic gratings recorded in ILCs.

Ionic-liquids composites for holographic-grating neutron-optical elements

J. Klepp [1], M. Fally [1], C. Pruner [3],
[1] Faculty of Physics, University of Vienna, A-1090 Vienna, Austria
[3] Department of Materials Science and Physics, University of Salzburg, A-5020 Salzburg, Austria

The proposed very-cold neutron (VCN) diffraction experiment aimed at measuring the neutron diffraction efficiency (DE) of holographic gratings recorded in ionic-liquids composites (ILCs) and investigate if such materials are suitable for VCN optics. Several samples have been tested by VCN diffraction. The results are promising but it also became clear that gratings recorded in such materials still need to take a big step forward if they should one day be applied for neutron optics.

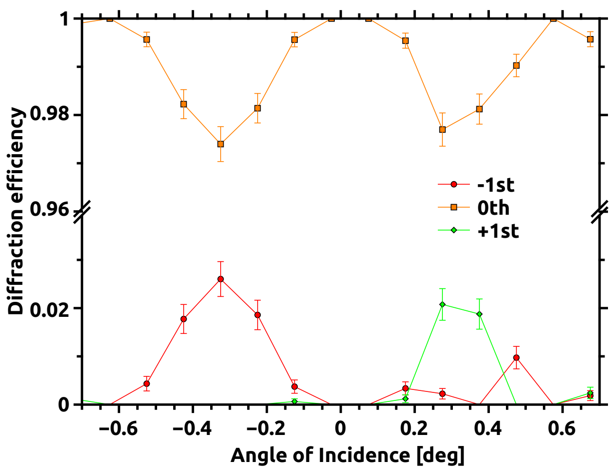

Figure 1: Rocking curveof a ionic liquid composite grating measured with VCN.

Neutron-optical phenomena, i.e., those arising from coherent elastic scattering, are governed just by the neutron refractive-index. Thus, an important task in the design of neutron-optical elements is being able to tune the neutron refractive-index of materials. For this purpose we use materials that are sensitive to light, combined with holographic techniques to produce transmission gratings for neutron-optics. 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 interferometry [1, 2].

The width of the rocking curve of gratings (the distance in angle of incidence between the minima adjacent to the central maximum, say) is approximately given by two times the grating period (typically 500 nm for our materials) divided by the grating thickness d (20-100 microns). The latter is a decisive parameter also for reaching high DE. Thus, trying to increase DE by increasing d leads to high DE at the cost of very narrow rocking curves, which makes such gratings difficult to adjust as parts of an optical system and inefficient in connection with badly collimated low-intensity beams. Therefore, novel materials should rather reach high DE via increasing their refractive index contrast. One candidate material that has, so far, never been investigated with neutrons are composites of polymer and ionic liquids (ILCs). Ionic liquids are organic salts in the liquid state at low temperature (room temperature or below). They have unique properties such as negligible vapor pressure, excellent thermal stability, are non-flammable and low or non-toxic. They exhibit high chemical stability, high ionic conductivity, and are able to dissolve numerous organic, inorganic, and organometallic compounds. Due to their many advantages, they are also investigated for light optics applications.

ILC gratings were recorded by holographic means in our lab. Light-diffraction experiments showed promising results [3]. We used a rotation stage and a 2D detector for setting up pinhole-SANS instrument. The setup was tested with a nanoparticle-polymer composite grating (see [4] for information about this excellent grating).

The best results are shown in Fig. (1). The grating had a period of 500 nm at a thickness of about 100 microns. The mean neutron wavelength of the rather broad distribution of the VCN beam at PF2 was about 5 nm, the divergence about 0.002 rad. While diffraction peaks could be observed easily, it is clear that the ILCs do not diffract as strongly as expected in our estimations of the refractive index modulation contrast. We suspect that this is due to rather strong inhomogeneity of the gratings across the sample area, which leads to averaging of the neutron diffraction signal when measuring with a neutron beam of several mm^2 cross section. We are aware that the wavelength distribution also plays a role. Still the signal is comparably weak. We must try to pursue methods to reach better sample homogeneity before trying to employ this material class for neutron optics.

[1] J. Klepp, C. Pruner, Y. Tomita, P. Geltenbort, I. Drevenšek-Olenik, S. Gyergyek, J. Kohlbrecher, and M. Fally. Materials **5**, 2788 (2012). doi:10.3390/ma5122788.

[2] 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). doi:10.1080/09500340.2016.1143534.

[3] M. A. Ellabban, G. Glavan, J. Klepp, and M. Fally. Materials **10**, 9 (2017). doi:10.3390/ma10010009.

[4] J. Klepp, C. Pruner, Y. Tomita, K. Mitsube, P. Geltenbort, and M. Fally. Appl. Phys. Lett. **100**, 214104 (2012). doi:10.1063/1.4720511.

Proposal-number: 3-14-376
Instrument: PF2 VCN