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Neutron dIffraction from holographic nanoparticle-polymer composites

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Scientific Objectives

This series of experiments had the aim of gaining new insight on holographically patterned nanoparticle-polymer composites as neutron optical components. Preparation of the SiO_2-nanoparticle-polymer samples and holographically recording a grating was conducted by Y. Tomita's group along the formulation described in Ref. [1]. This procedure leads to a distribution of nanoparticles and the formation of a polymer corresponding to the holographic interference pattern: in dark regions the nanoparticle density increases whereas in the bright regions it decreases. Neutron diffraction was employed to obtain detailed information on the mechanism of this separation process and a tentative application of these material class for neutron optical devices.
Following earlier experiments on the SANS-2 using nanoparticle-polymer composites [2] a new series of samples with a different grating spacing (Λ=0.5 µm) and filling volume (34%) was produced. Those values have been chosen in an attempt of optimisation. The varying parameter in this set of samples was the thickness of the gratings which ranged from d=84 µm to 180 µm.
The proposed intention of this experiment included also the analysis of further H-PDLC samples following the experiments in 2006-2008 [3-5], but technical difficulties in the Vienna labs made the production of those samples impossible

Experimental Technique

Small-angle neutron diffraction experiments were performed at SANS-2. We used neutron wavelengths of 10Å, 13Å and 15.9Å with a spread of $\Delta\lambda/\lambda$=10%. We employed the full available collimation length of 16m except for the first collimator which couldn't be used because of a technical error. The used diaphragms had a width of 20 mm and 6 mm at the entrance and the sample, respectively. Because of the small diffraction angles $\Theta_B=\lambda/2\Lambda\sim1$ mrad the maximum sample to detector distance (21m) was employed.

The investigated nanoparticle-polymer composites were part of a series from a single batch. The modulation of the scattering length density due to the spatial nanoparticle-polymer distribution constitutes the contrast for neutron diffraction [6].

Achievements and Main Results

Complete rocking curves were conducted on the nanoparticle-polymer samples, i.e., that the angular dependence of the diffraction efficiency η (diffracted intensity over incoming intensity) was measured. We were able to demonstrate profound diffraction efficiencies for the samples with varying thickness, however, by far not as good as expected from previous measurements.

Fig. 1 shows the angular dependence of the diffraction efficiency for the zero and first orders for one of the investigated samples.

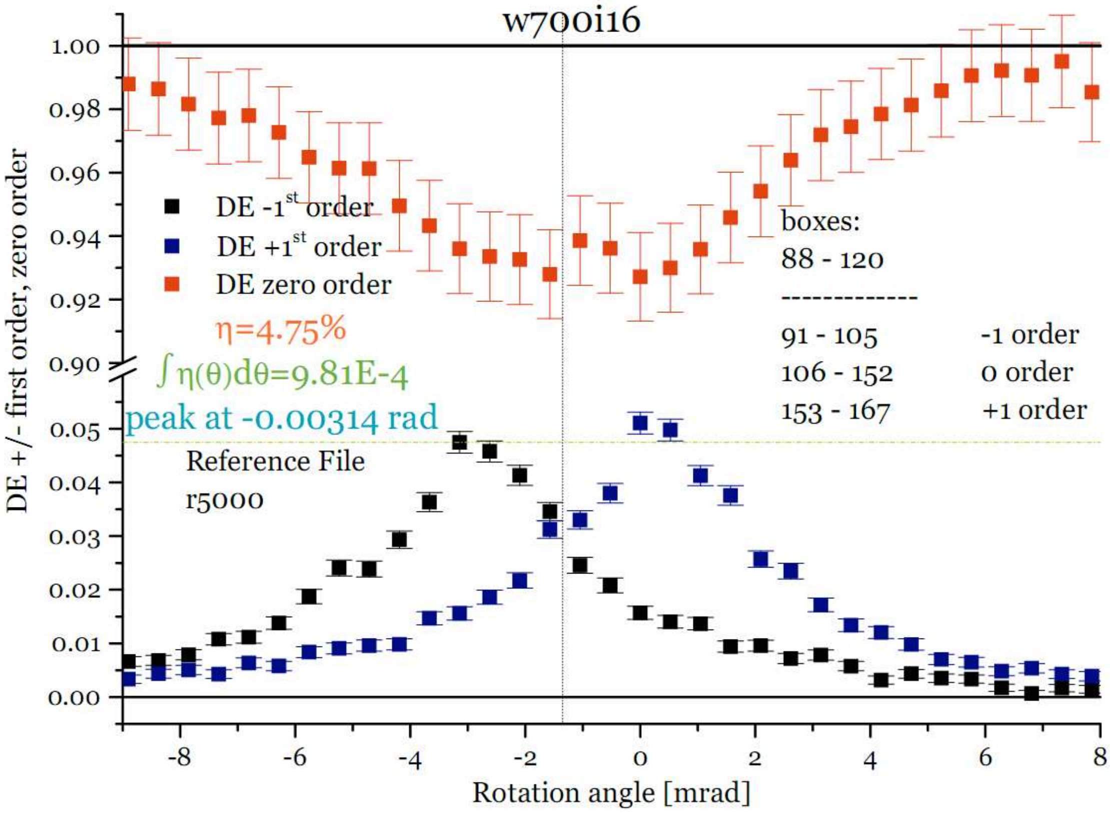

Fig.1: Angular dependence of the diffraction efficiency at λ=15.9 A for a sample with a nominal thickness of *d*=180 µm, Λ=0.5 and a filling volume of 34% SiO_2 nanoparticles

A systematic study of the diffraction efficiency of the four samples with various thicknesses was performed with our experiments. Samples with larger thickness (180 µm) show higher diffraction efficiencies (4.5% vs 0.9%) as expected but suffer from lack of quality of the gratings. The latter is due to the strongly enhanced holographic scattering during recording of the grating [7]. Definitely, better gratings are mandatory to employ them in neutron optics.

Nanoparticle-polymer composites are promising candidates for the fabrication of neutron optical devices (gratings, lenses, mirrors,..) for cold neutrons due to their versatility (nanoparticle species, filling volume). Still the photopolymerization and phase-separation process needs further investigations to optimize the materials for light and neutron optical purposes.

References

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