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E. Sváb, S. Borbély, Gy. Mészáros, S. Ishmaev, R. Glas. Small-angle neutron scattering study of amorphous isotopic Ni-Nb system. Journal de Physique IV Proceedings, 1993, 03 (C8), pp.C8-291-C8-294. 10.1051/jp4:1993857 . jpa-00252288

HAL Id: jpa-00252288

<https://hal.science/jpa-00252288>

Submitted on 1 Jan 1993

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Small-angle neutron scattering study of amorphous isotopic Ni-Nb system

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Abstract

Inhomogeneities in amorphous Ni-Nb samples prepared from various Ni-isotopes are investigated for two compositions, Ni-44 at% and Ni-62 at% by small-angle neutron scattering (SANS) in the scattering vector range from 0.007 to 0.45 Å⁻¹. A strong increase in the structure factors is observed below 0.04 Å⁻¹ whereas above 0.06 Å⁻¹ they smoothly become constant. In order to clarify the origin of SANS the total structure factors are separated into the Bhatia-Thornton partial structure functions. It is shown that, the inhomogeneities are both topological and chemical in character. A characteristic correlation length of about 180 Å is obtained.

Introduction

In most cases, amorphous alloys obtained by different rapid quenching methods are not homogeneous, they contain quenched-in inhomogeneities formed during solidification. The dimension of these inhomogeneities lies in the sensitivity range of small-angle scattering, i.e. from about 10 to some 200 Å [1-6].

In this study small-angle neutron scattering (SANS) measurements are presented on amorphous Ni-Nb isotopic samples. In order to clarify the topological and chemical origin of the observed inhomogeneities the partial structure functions are separated and analysed on the basis of the Bhatia-Thornton formalism [7].

Experimental details and data evaluation

Amorphous Ni₄₄Nb₅₆ and Ni₆₂Nb₃₈ ribbons [8-10] of 2 mm width and 20 μm thickness were prepared by the melt spinning technique from various Ni-isotope mixtures with different coherent neutron scattering amplitude. For both compositions three Ni-isotopic samples were investigated: from ⁵⁸Ni (enr. 99.8 %), from ⁶⁰Ni (enr. 99.7 %), and from ⁰Ni. The last of these was prepared from a mixture of ⁶²Ni (enr. 99.4 %) and ⁶⁰Ni in such a way as to give zero average coherent neutron scattering amplitude for Ni. In the case of Ni₆₂Nb₃₈, a fourth sample was also prepared from ⁶²Ni and ⁶⁰Ni to give zero average scattering amplitude for the sample. For simplicity the samples will be denoted as ⁵⁸Ni, ⁶⁰Ni, ⁰Ni and zero alloy.

Measurements were performed at the PAXE spectrometer in LLB Saclay [11]. In order to cover the wide q-range from 0.007 to 0.45 Å⁻¹, scattering curves were measured at two neutron wavelengths, viz. 8 and 4 Å with 5 and 1.2 m sample-to-detector distance, respectively. Small pieces of amorphous ribbons weighing about 5 g were pressed between two vanadium plates of

0.15 mm thickness. Transmission varied from 50 to 80 % dependent on the isotopic content of the sample and on the wavelength used in the measurement. The scattered intensity was corrected for background, absorption, incoherent scattering and was then normalized to incoherent scattering from a 1 mm thick water standard to eliminate the detector efficiency. The coherent scattered intensity was converted to absolute units using the method outlined by Teixeira [12], based on the direct determination of the intensity of the primary beam .

The Bhatia-Thornton total structure function $S_{tot}^{BT}(q)$ was calculated from the coherently scattered intensity $I_{coh}(q)$ as

$$S_{tot}^{BT}(q) = \frac{I_{coh}(q)}{\langle b^2 \rangle}, \quad (1)$$

where $\langle b^2 \rangle = c_a b_a^2 + c_b b_b^2$; b_a , b_b and c_a , c_b are the coherent scattering amplitudes and concentrations of a and b types of atoms, respectively. The total structure factor is represented as a weighted sum of three partial structure functions

$$S_{tot}^{BT}(q) = \frac{\langle b \rangle^2}{\langle b^2 \rangle} S_{NN}(q) + \frac{c_a c_b (b_a - b_b)^2}{\langle b^2 \rangle} S_{CC}(q) + \frac{2\langle b \rangle (b_a - b_b)}{\langle b^2 \rangle} S_{NC}(q), \quad (2)$$

where $\langle b \rangle = c_a b_a + c_b b_b$; $S_{NN}(q)$ represents the contribution from correlation between density fluctuations, $S_{CC}(q)$ correlation between chemical concentration fluctuations, and $S_{NC}(q)$ correlation between density and concentration fluctuations.

The partial Bhatia-Thornton structure functions were calculated for both concentrations by solving the equation system

$$[S_{tot,i}^{BT}(q)] = [w_{NC,i}^{BT}] [S_{NC}^{BT}(q)] \quad (3)$$

where $S_{tot,i}^{BT}(q)$ with $i=1,2,3$ are the total structure factors measured on ^{58}Ni , ^{60}Ni and ^0Ni , respectively. The numerical values of the weighting factors, $w_{NC,i}^{BT}$ used in the calculation are given in Table 1.

Table 1. Numerical values of weighting factors used in data evaluation of eqs. (2) and (3). Cond(W) is a quantitative measure for the accuracy of partial structure functions (for definition see e.g. [10])

sample	weighting factors			sample	weighting factors		
	w_{NN}^{BT}	w_{NC}^{BT}	w_{CC}^{BT}		w_{NN}^{BT}	w_{NC}^{BT}	w_{CC}^{BT}
$^{58}\text{Ni}_{44}\text{Nb}_{56}$	0.889	1.266	0.450	$^{58}\text{Ni}_{62}\text{Nb}_{38}$	0.915	1.152	0.363
$^{60}\text{Ni}_{44}\text{Nb}_{56}$	0.848	-1.438	0.610	$^{60}\text{Ni}_{62}\text{Nb}_{38}$	0.819	-1.585	0.767
$^0\text{Ni}_{44}\text{Nb}_{56}$	0.575	-2.000	1.739	$^0\text{Ni}_{62}\text{Nb}_{38}$	0.383	-2.003	2.618
cond(W)	5.4			cond(W)	4.2		
				$^Z\text{Ni}_{62}\text{Nb}_{38}$	0.003	-0.231	4.231

Results and discussion

The total structure factors for $\text{Ni}_{44}\text{Nb}_{56}$ and $\text{Ni}_{62}\text{Nb}_{38}$ are shown in Fig.1. A strong increase is observable below $0.04 \text{ \AA}^{-1}$ whereas above $0.06 \text{ \AA}^{-1}$ the structure factors smoothly become constant. Although the SANS measurements were performed up to $0.45 \text{ \AA}^{-1}$ the $S(q)$ curves are not drawn in the figures as long as they are constant. The total structure factors are very similar to each other; this is especially true for amorphous $\text{Ni}_{44}\text{Nb}_{56}$ suggesting that there are no large differences in the partial structure factors.

The Bhatia-Thornton partial structure functions are shown in Fig.2. In the case of $\text{Ni}_{62}\text{Nb}_{38}$ four different isotopic samples were measured. This gives the unique possibility to compare $S_{CC}(q)$

Figure 1: Total structure factors of amorphous $\text{Ni}_{44}\text{Nb}_{56}$ (a) and $\text{Ni}_{62}\text{Nb}_{38}$ (b) for different isotopic samples. The inserts show the curves in log-log representation. The SANS intensity is constant up to $0.45 \text{ \AA}^{-1}$, thus it is not drawn in the figure.

Figure 2: Bhatia-Thornton partial structure factors for amorphous $\text{Ni}_{44}\text{Nb}_{56}$ (a) and $\text{Ni}_{62}\text{Nb}_{38}$ (b). The inserts show the curves in log-log representation.

determined from the three independent measurements on ^{58}Ni , ^{60}Ni and ^0Ni by solving equation system (3) with that obtained directly from a single measurement on the zero alloy sample. The two curves are practically identical.

For both concentrations the $S_{NN}(q)$ and $S_{CC}(q)$ curves behave in nearly the same way. However, in both cases the level of $S_{CC}(q)$ is higher than that of $S_{NN}(q)$ and the difference between the two partial structure factors is slightly larger for $\text{Ni}_{62}\text{Nb}_{38}$. This may be seen to be even more pronounced in double logarithmic scale drawn in the inserts to the figures. In spite of the difference in level, one can conclude that inhomogeneities revealed by small-angle scattering are of both topological and chemical nature.

In order to obtain information on the dimension of the inhomogeneities, various SANS fitting procedures were used for data evaluation. The first part of the curves in log-log plot - see the insert - gives a straight region in the scattering vector range from 0.007 up to about $0.03 \text{ \AA}^{-1}$, which can be characterized by a slope of about -3.5 independently of the chemical and isotopic compositions. This is in good agreement with the finding in ref. [3] where a slope of -3.6 was given for amorphous $\text{Ni}_{63}\text{Nb}_{37}$. Attempts have also been made to use the Guinier formalism to fit the experimental total and partial functions without reasonable results. The Guinier curves showed continuous curvature without any distinct straight region. This means that in the Ni-Nb amorphous system there are no inhomogeneities of well defined dimensions as was established for some metal-metalloid type amorphous materials, e.g. Ni-P [1], Fe-B [2].

The total and partial structure factors were successfully fitted to a random two-phase model described in ref. [13]. The best fit provided a correlation length between 150 and $200 \text{ \AA}$ for the various curves. Thus, it may be concluded that in the investigated amorphous Ni-Nb system, inhomogeneities originating from both density and chemical fluctuations with a characteristic correlation length of about $180 \text{ \AA}$ are present.

References

- [1] STEEB S., LAMPARTER P., *J. Phys. France* **C8 46** (1985) 247-253
- [2] SVÁB E., FAIGEL Gy., MÉSZÁROS Gy., ISHMAEV S.N., SADIKOV I.P., CHERNYSHOV A.A., *J. Phys. France* **C8 46** (1985) 267-271
- [3] SCHAAL M., LAMPARTER P., STEEB S., *Z. Naturforschung* **43a** (1988) 1061-1064
- [4] LAMPARTER P., STEEB S., KROEGER D.M., SPOONER S., *Materials Science and Engineering* **97** (1988) 227-230
- [5] SCHAAL M., LAMPARTER P., STEEB S., *Z. Naturforschung* **44a** (1989) 4-6
- [6] TRAUBLE H., LAMPARTER P., STEEB S., *J. Phys. I France* **2** (1992) 1029-1041
- [7] BHATIA A., THORNTON D.E., *Phys. Rev.* **B2** (1970) 3004
- [8] In the present SANS experiment the same samples were measured as those investigated in refs.[9-10]
- [9] SVÁB E., MÉSZÁROS Gy., J. Takács, ISHMAEV S.N., ISAKOV S.L., SADIKOV I.P., *J. Non-Cryst. Solids* **144** (1992) 99-106
- [10] SVÁB E., MÉSZÁROS Gy., KONCZOS G., ISHMAEV S.N., ISAKOV S.L., CHERNYSHOV A.A., *J. Non-Cryst. Solids* **104** (1988) 291-299
- [11] TEIXEIRA J., in: *Equipments Experimentaux*, Laboratoire Leon Brillouin (1987)
- [12] TEIXEIRA J., in: *Structure and dynamics of strongly interacting colloids and supermolecular aggregates in solution*, (ed. S.H. Chen, Kluwer, Amsterdam 1992) pp. 635-658
- [13] DEBYE P., ANDERSON H.R., BRUMBERGER H., *J. Appl. Phys.* **28** (1957) 679