MÖSSBAUER SPECTROSCOPY STUDIES OF Al-Ni-Fe DECAGONAL ALLOYS

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The results of [57]Fe Mössbauer spectroscopy studies of the Al-Ni-Fe decagonal alloys and corresponding crystalline alloys are presented. The presence of two distinct distributions of the electric quadrupole interactions is observed in the spectra of the decagonal alloys. The possible structural implications of this finding are discussed.

1 Introduction

Quasicrystals (QC's), just as amorphous alloys, lack long-range periodic order. Therefore, diffraction methods upon which the bulk of our knowledge on the structure of QC's is based, must be supplemented by local probes, such as Mössbauer spectroscopy (MS), [1] extended x-ray-absorption fine structure, nuclear quadrupole resonance, or NMR, [2] if the true atomic structure of these alloys is to be understood.

MS studies of the decagonal (*d*) alloys Al-Co-Ni and Al-Co-Cu revealed [1,3] a distinct structure of their Mössbauer spectra, which could be associated with a possible structural model for these alloys. In this paper we report results of [57]Fe MS investigations of two Al-Ni-Fe *d* alloys and two corresponding crystalline alloys which are of similar chemical composition but of different crystallographic structure.

2 Experimental

The *d* alloys of nominal compositions $Al_{70}Ni_{15}Fe_{15}$ and $Al_{71}Ni_{24}Fe_5$, and the corresponding crystalline alloys, $Al_{72}Ni_9Fe_{19}$ of the Al_5Co_2-type structure and $Al_{76}Ni_9Fe_{15}$ of the $Al_{13}Fe_4$-type structure, were prepared as described else-

where.[4,5] The X-ray diffraction, electron microscopy, and metallographic studies showed that the samples are single phase.

[57]Fe MS measurements were performed at room temperature using a standard Mössbauer spectrometer operating in a sine mode. The surface densities of the Mössbauer absorbers corresponding to these alloys were respectively 144, 25.0, 106, and 139 μg [57]Fe/cm^2. The absorbers can therefore be regarded as being thin.

3   Results and Discussion

Mössbauer spectra of nonmagnetic QC's consist of two broad lines, which indicate the presence of a distribution of quadrupole splittings, P(Δ). [1] The Mössbauer spectrum of the d Al$_{70}$Ni$_{15}$Fe$_{15}$ alloy cannot be fitted successfully with one P(Δ) component, as is clearly evidenced by the residual spectrum [Fig. 1(a)]. Nevertheless, the derived P(Δ) is of a bimodal type [Fig. 1(c)], which indicates the possibility of two different classes of Fe environments. An
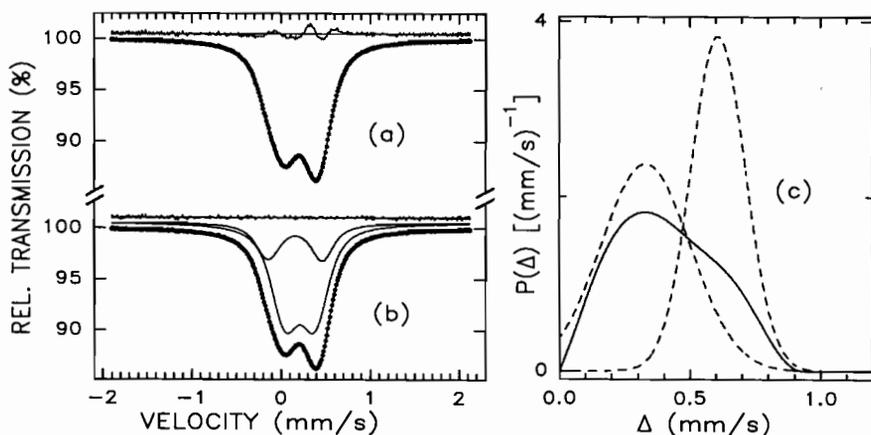
Figure 1: The room-temperature Mössbauer spectrum of d Al$_{70}$Ni$_{15}$Fe$_{15}$ fitted with (a) one P(Δ) component [the solid line in (c)] and (b) two P(Δ) components [the broken lines in (c)]. The P(Δ) component spectra are also shown in (b). The residuals, multiplied by a factor of three, are also shown above each spectrum.

excellent fit is obtained with two P(Δ) components [Fig. 1(b)], which suggests the existence of two structurally distinct classes of environments around the Fe atoms in this alloy.

A good fit of the Mössbauer spectrum of the d alloy $Al_{71}Ni_{24}Fe_5$ can be obtained only with two $P(\Delta)$ components [Fig. 2]. The parameters associated with these two $P(\Delta)$'s are very similar [Figs. 1(c) and 2(b)] for the both d alloys studied.[6] This implies that the quasicrystalline structure of these two d alloys must be very similar.
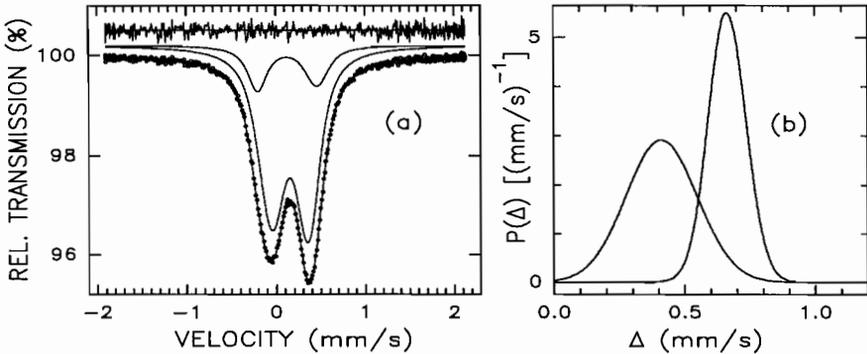
Figure 2: The room-temperature Mössbauer spectrum of d $Al_{71}Ni_{24}Fe_5$ (a) fitted with two $P(\Delta)$ components (b). The $P(\Delta)$ component spectra and the residuals, multiplied by a factor of three, are also shown in (a).

The same similarity can be noticed between the parameters of the $P(\Delta)$'s associated with the d Al-Ni-Fe alloys studied here and those characteristic for the d Al-Co-Ni and Al-Co-Cu alloys.[3] It therefore can be concluded that these three series of d alloys must have a very similar atomic structure. This is consistent with a similar observation based on the structural and positron lifetime measurements.[5,7]

The Mössbauer spectrum of the crystalline alloy $Al_{72}Ni_9Fe_{19}$ can be successfully fitted with one $P(\Delta)$ component [Fig. 3(a)]. Note that the $P(\Delta)$ distribution is very sharp, as expected for a crystalline alloy in which Fe atoms occupy one crystallographic site. Obviously, there is no relation between the structure of this alloy and that of the d Al-Ni-Fe alloys.

The Mössbauer spectrum of the crystalline alloy $Al_{76}Ni_9Fe_{15}$, in which Fe atoms occupy five inequivalent crystallographic sites,[8] can be approximated with two $P(\Delta)$ components [Fig. 3(b)]. The bimodal nature of the $P(\Delta)$ distribution in this alloy suggests that there should be some similar structural motifs in this alloy and in the Al-Ni-Fe d alloys. The recent refinement of the $Al_{13}Fe_4$ structure[8] indicates the presence of the one-dimensional channels built

of icosahedral and/or pentagonal prisms, which may be the relevant motifs for the atomic structure of the d Al-Ni-Fe alloys.
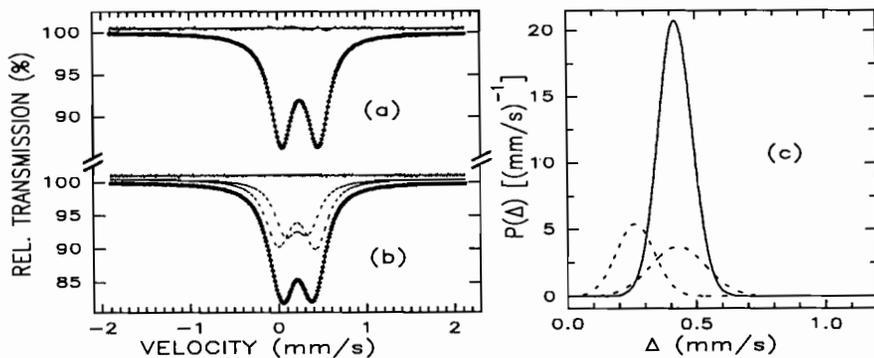
Figure 3: The room-temperature Mössbauer spectra of the crystalline alloys $Al_{72}Ni_9Fe_{19}$ (a) fitted with one $P(\Delta)$ component [the solid line in (c)] and $Al_{76}Ni_9Fe_{15}$ (b) fitted with two $P(\Delta)$ components [the broken lines in (c)]. The $P(\Delta)$ component spectra are also shown in (b). The residuals, multiplied by a factor of three, are shown above each spectrum.

Acknowledgments

References

1. Z M Stadnik in *Mössbauer Spectroscopy Applied to Magnetism and Materials Science*, ed. G J Long and F Grandjean (Plenum, New York, 1996), p. 125, and references therein.
2. A. Shastri *et al.*, *Phys. Rev.* B **50**, 15651 (1994).
3. Z M Stadnik *et al.* in *Aperiodic '94, Proceedings of the International Conference on Aperiodic Crystals*, ed. G Chapuis and W. Paciorek (World Scientific, Singapore, 1995), p. 259.
4. A.-P. Tsai *et al.*, *Jpn. J. Appl. Phys.* **29**, L1696 (1990).
5. R. Würschum *et al.*, *Phys. Rev.* B **52**, 6411 (1995).
6. Z.M. Stadnik *et al.*, to be published.
7. B. Grushko and K. Urban, *Philos. Mag.* B **70**, 1063 (1994).
8. J. Grin *et al.*, *Z. Kristallogr.* **209**, 479 (1994).