NMR Study of Quasicrystal Al_<70>Pd_<20>T_<M10> Alloy (T_M : Cr, Mn, Fe and Co)

著者	Shinohara Takeshi, Sato Takashi
journal or publication title	Science reports of the Research Institutes, Tohoku University. Ser. A, Physics, chemistry and metallurgy
volume	38
number	1
page range	34-42
year	1993-03-29
URL	http://hdl.handle.net/10097/28422

NMR Study of Quasicrystal $Al_{70}Pd_{20}T_{M10}$ Alloy (T_M:Cr,Mn,Fe and Co)*

Takeshi Shinohara and Takashi Sato
Institute for Materials Research
(Received January 15, 1993)

Synopsis

^{27}Al-, ^{55}Mn- and ^{59}Co-NMR measurements have been made on quasicrytalline phases of the $Al_{70}Pd_{20}T_{M10}$ alloy (T_M:Cr,Mn,Fe and Co) in the temperature range between 5K and room temperature. There is no marked temperature dependence on peak shift and line width of either ^{27}Al- or ^{59}Co- NMR spectra except ^{27}Al- and ^{55}Mn-spectra in the $Al_{70}Pd_{20}Mn_{10}$. However, the peak shift of these spectra depends upon the constituent transition element. For the $Al_{70}Pd_{20}Mn_{10}$, the negative ^{27}Al- Knight shift and line broadening at low temperatures indicate that there exist two classes of Mn atoms, magnetic and nonmagnetic ones.

I. Introduction

There has been intense experimental and theoretical interest in icosahedral-phase (i-phase) quasicrystals since their discovery in 1984[1~4]. Although many of work has focused on understanding the structure of these complex materials[5,6], it still remains something of an open question. On the other hand, great efforts have been devoted to finding the alloy composition at which the i-phase is formed in metastable and stable states, in addition to the clarification of fundamental properties of the new phases[7~11].

Nuclear magnetic resonance (NMR) technique has provided unique local microscopic information about the structure and the electronic properties[12]. There have been several NMR studies on the i-phase and related other phases in Al-based alloys[13~22]. It is now definitely established that two separate classes of Mn sites exist in the i-phase including Mn atoms and relate with the Curie-Weiss type magnetic susceptibility.

* The 1907th report of Institute for Materials Research.

Recently, new and stable quasicrystalline $Al_{70}Pd_{20}T_{M10}$ alloys(T_M:Cr, Mn, Fe, and Co) have been found by Tsai et al[23~29]. In a previous paper, the temperature dependence of ^{27}Al- and ^{55}Mn- NMR spectra has been observed in the $Al_{70+x}Pd_{20-x}Mn_{10}$ quasicrystalline alloys[18]), being in agreement with the magnetic data.[30])

We here present the NMR measurement of ^{27}Al, ^{55}Mn and ^{59}Co in the i-phase in the $Al_{70}Pd_{20}Mn_{10}$(T_M:Cr, Mn, Fe and Co) quasicrystalline alloys.

II. Experimental

Ternary alloys of $Al_{70}Pd_{20}T_{M10}$(T_M=Cr,Mn,Fe and Co) were melted in an argon atmosphere using an arc furnace. Rapidly solidified ribbon samples were prepared using a single-roller melt-spinning apparatus. The details of the preparation procedure have already been described in ref.20. X-ray powder diffraction patterns for those $Al_{70}Pd_{20}T_{M10}$ were shown in Fig.1.

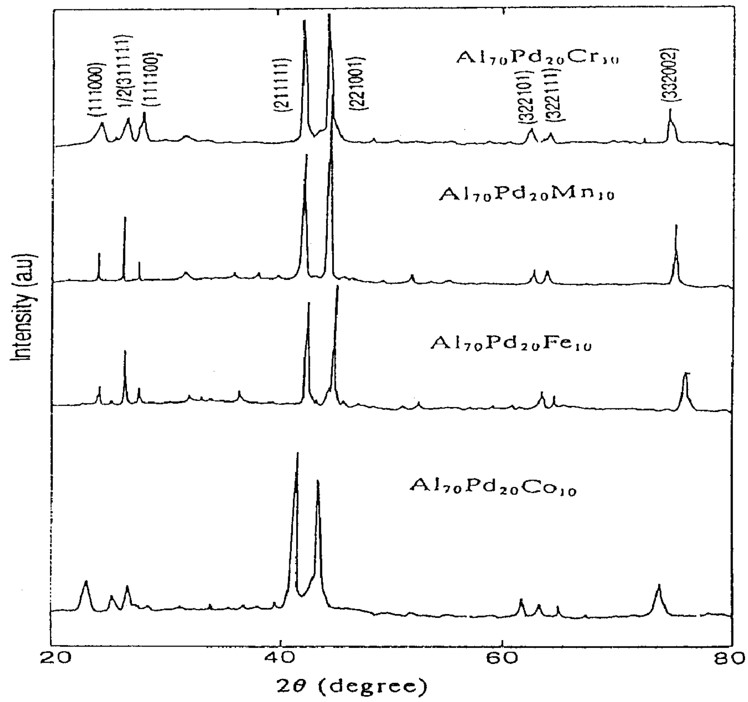

Fig. 1 X-ray diffraction patterns for rapidly solidified $Al_{70}Pd_{20}T_{M10}$ (T_M:Cr,Mn, Fe and Co)

Indexing of the peak could be made using the Elser's indices. The superstructure peak of 1/2(311111) and other lines are more intensive and sharper in the $Al_{70}Pd_{20}Mn_{10}$ and the $Al_{70}Pd_{20}Fe_{10}$ than in the others. In the $Al_{70}Pd_{20}Co_{10}$, there may coexist other phases(decagonal phase) different from the face centered six dimensional i-phase[29].

For the observation of NMR signals, a phase-coherent pulsed NMR spectrometer was utilized. Resonance spectra were obtained by plotting the spin-echo amplitude with a box-car integrator as a function of the external magnetic field. The NMR measurement was made at a constant rf pulse separation in the temperature range between 5K and room temperature.

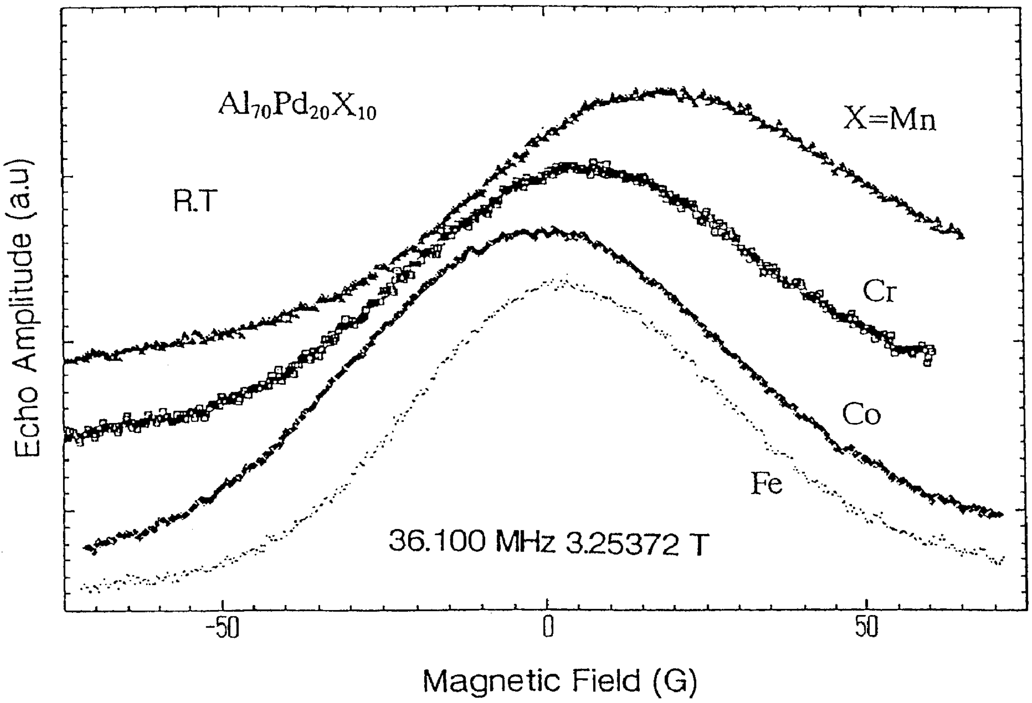

Fig. 2 ^{27}Al spin-echo spectra observed at 36.100MHz for as quenched $Al_{70}Pd_{20}Cr_{10}$(indicated as "Cr"), $Al_{70}Pd_{20}Fe_{10}$ and $Al_{70}Pd_{20}Co_{10}$, while sweeping the magnetic field. The magnetic field obtained from the superconducting magnet is 3.25372T.

Ⅲ. Results

Figure 2 shows ^{27}Al-NMR spectra observed at room temperature for the i-phases of $Al_{70}Pd_{20}T_{M10}$(T_M:Cr,Mn,Fe and Co).
The resonance signals exhibit different peak shift, that is, these ^{27}Al-Knight shifts are due to different 3d transition element (Table 1). The temperature change of the peak shift and the line width in ^{27}Al-spectra in the i-phase of $Al_{70}Pd_{20}Mn_{10}$ is remarkable, whereas those of the $Al_{70}Pd_{20}Cr_{10}$ and of the $Al_{70}Pd_{20}Fe_{10}$ are likely to be constant except the lowest temperature as shown in Figs. 3,4 and 5. In the ^{55}Mn-spectra, the peak

shift does not change with temperature but the line width does.[8)] One the other hand, the ^{27}Al-spectra in the $Al_{70}Pd_{20}Co_{10}$ are unchanged over the whole temperature range(Fig.6). The ^{59}Co-peak shift exhibits a subtle change only at the lowest temperature.(Figure 7)

Table 1 Knight shifts of $Al_{70}Pd_{20}T_{M10}$ at room temperature

	^{27}Al(%)	T_M
$Al_{70}Pd_{20}Cr_{10}$	-0.008+0.010	
$Al_{70}Pd_{20}Mn_{10}$	-0.079+0.010	+0.198+0.020[a)]
$Al_{70}Pd_{20}Fe_{10}$	-0.023+0.010	
$Al_{70}Pd_{20}Co_{10}$	+0.008+0.010	+0.465+0.020[a)]

a) at 200K

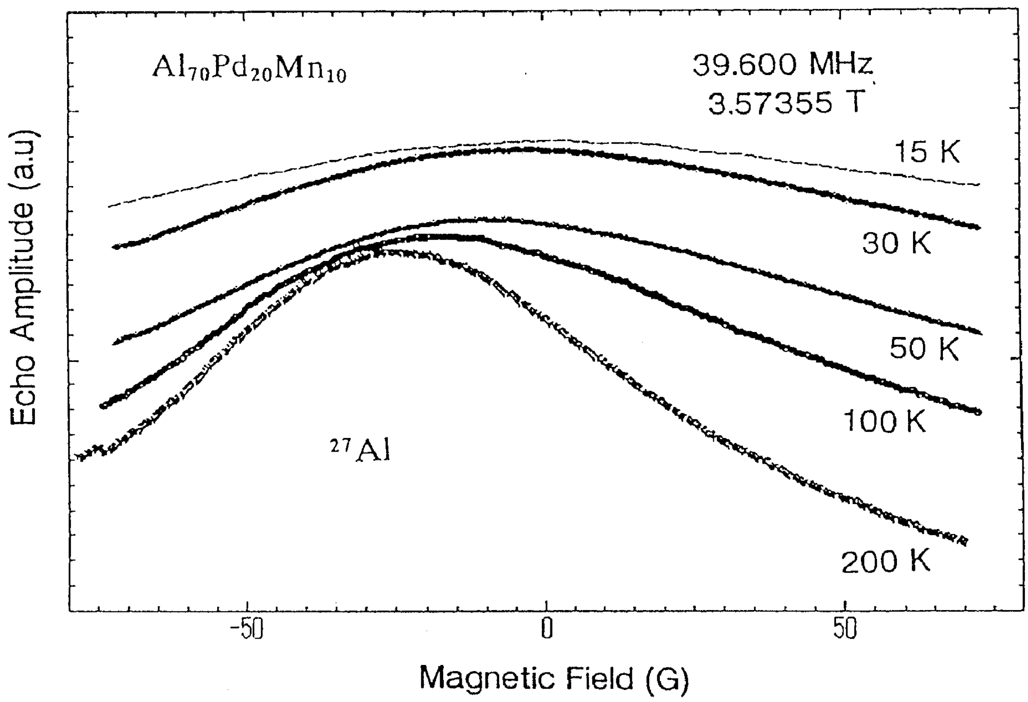

Fig. 3 Temperature dependence of ^{27}Al spin-echo spectra observed at a 39.600 MHz for the $Al_{70}Pd_{20}Mn_{10}$

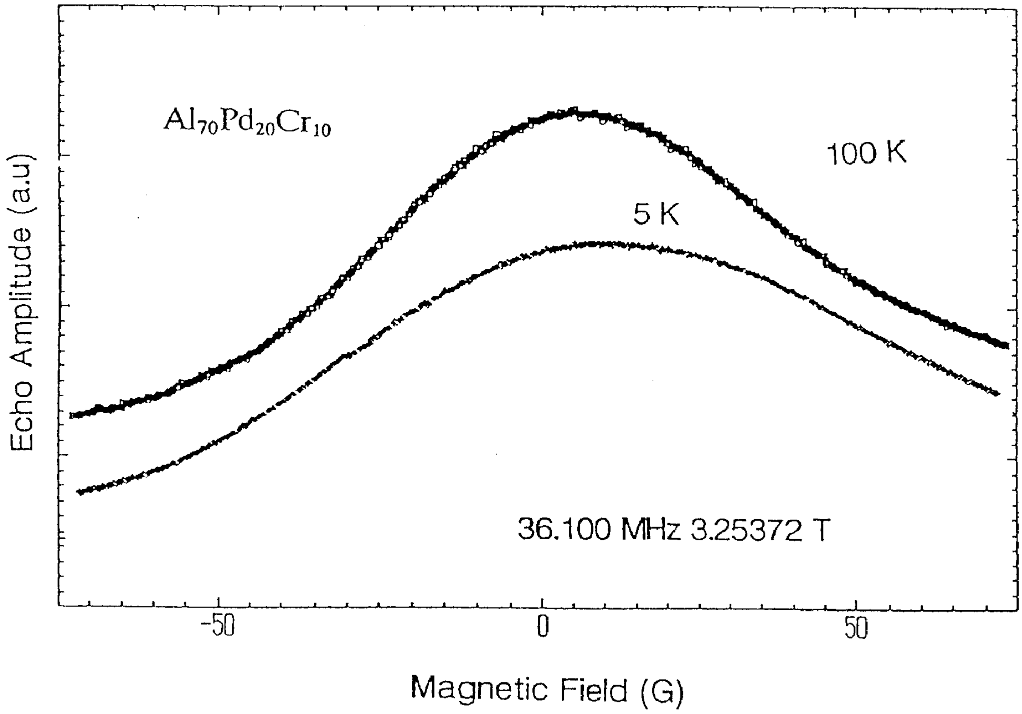

Fig. 4 Temperature dependence of ^{27}Al spin-echo spectra observed at a 36.100 MHz for the $Al_{70}Pd_{20}Cr_{10}$

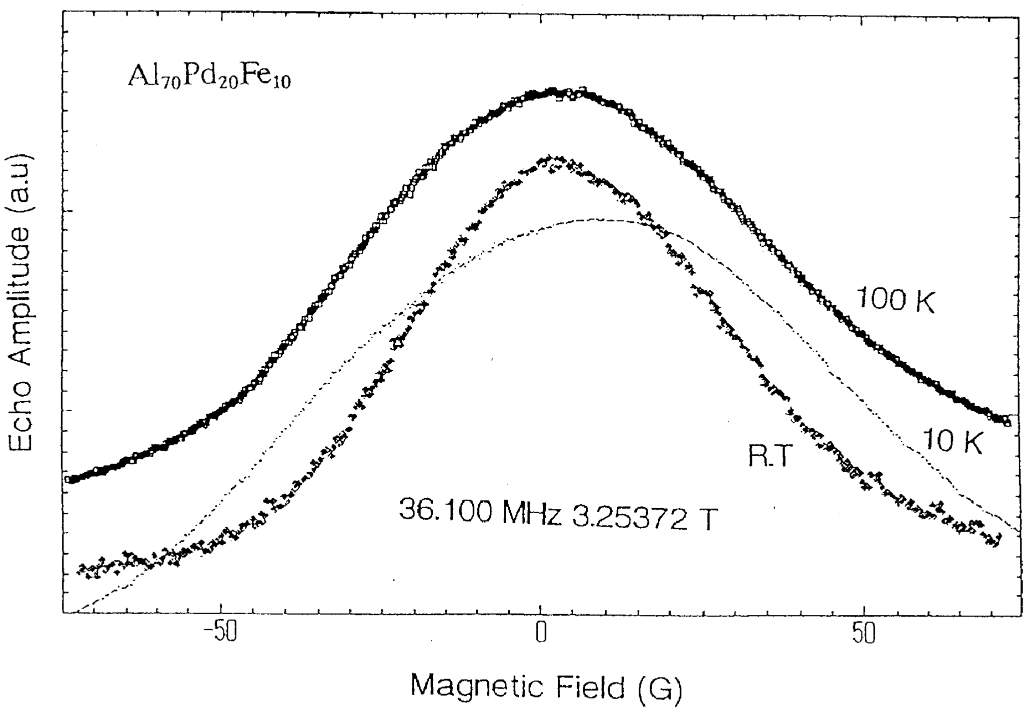

Fig. 5 Temperature dependence of ^{27}Al spin-echo spectra observed at a 36.100 MHz for the $Al_{70}Pd_{20}Fe_{10}$

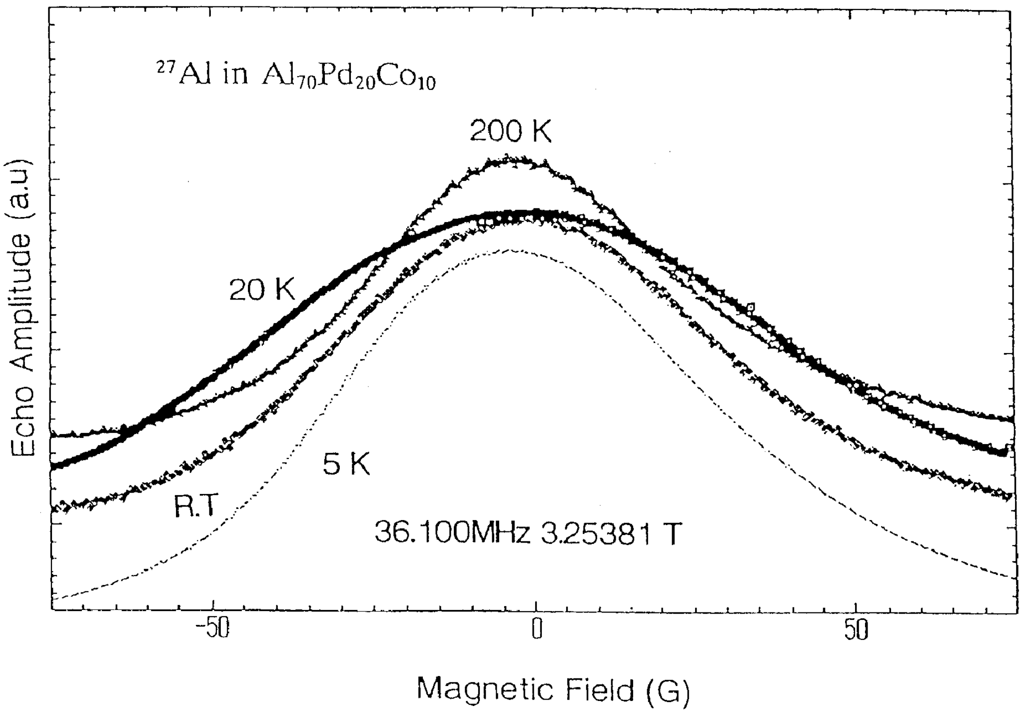

Fig. 6 Temperature dependence of ^{27}Al spin-echo spectra observed at a 36.100 MHz for the $Al_{70}Pd_{20}Co_{10}$

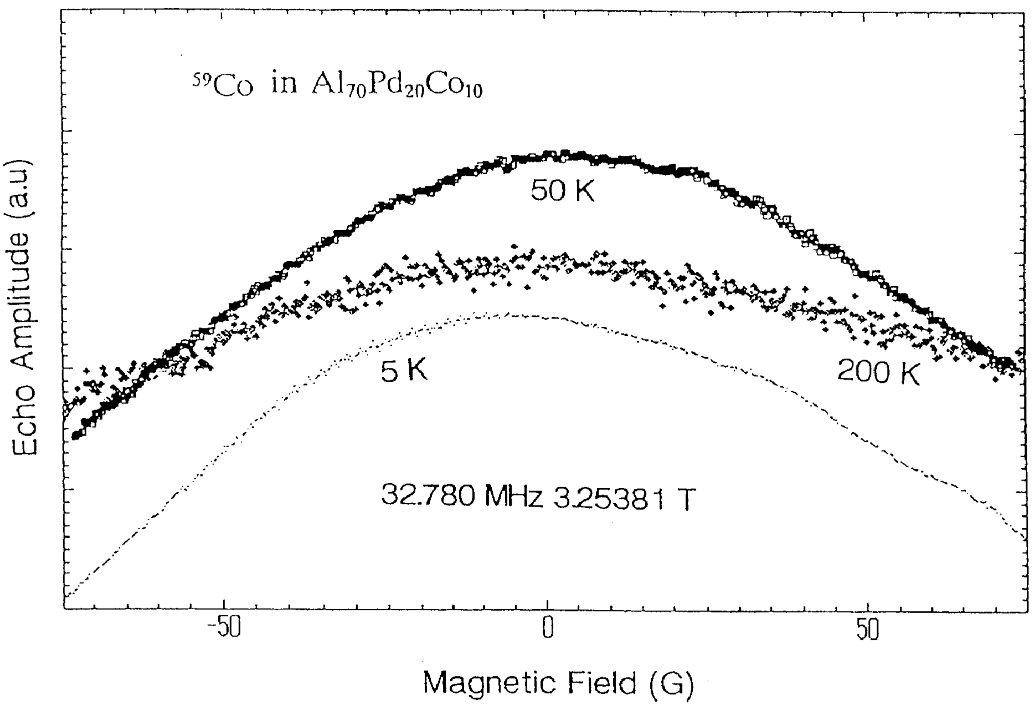

Fig. 7 Temperature dependence of ^{59}Co spin-echo spectra observed at a 32.780 MHz

IV. Discussion

For the i-phase of the $Al_{70}Pd_{20}Mn_{10}$ quasicrystal it has been reported that magnetic susceptibility shows a Curie-Weiss behavior from room temperature to 4.2K[30]. The change of the ^{27}Al- and ^{55}Mn- spectra in the $Al_{70}Pd_{20}Mn_{10}$ corresponds to the Curie-Weiss type magnetic susceptibility, indicating that there are two classes of Mn atoms, nonmagnetic and magnetic ones, like those observed in the Al-Mn and Al-Mn-Si quasicrystalline alloys[13~15]. It is considered that the NMR signals from the magnetic Mn atoms can not be observed because of short spin-spin relaxation time and/or line broadening. The present ^{55}Mn NMR signals are caused from the Mn sites which do not contribute in the essential way to the bulk paramagnetism, that is, the remaining Mn sites should be carry a local magnetic moment. Therefore, it is noted that negative value of the ^{27}Al-Knight shift comes from the contribution of the conduction electron polarization.

For the $Al_{70}Pd_{20}Cr_{10}$ and $Al_{70}Pd_{20}Fe_{10}$ quasicrystals, subtle negative value of the ^{27}Al-Knight shift suggests that these quasicrystals may be diamagnetic at room temperature. However, a definite negative value below 100K is attributable to occurrence of weak magnetic moment at the Cr and Fe atoms at low temperatures. This fact may correspond to the magnetic susceptibility data for the Al-Pd-Cr and Al-Pd-Fe quasicrystals[30] constituting almost the same concentration as the present ones.

No temperature change of the ^{27}Al-spectra for the $Al_{70}Pd_{20}Co_{10}$ alloy may be caused from the expectation that the s,p electrons of the Al atom are donated for filling the 3d-band perfectly.

Acknowledgment

The author wishes to express his thanks to Dr.A.P.Tsai and Professor T. Masumoto for providing the samples used in this work and for help in X-ray diffraction measurement.

References

1)D.Shechtman, I.Blech, D.Gratias and J.W.Cahn; Phys.Rev.Lett., 53(1984),1951.

2)G.V.S.Sastry, V.V.Rao, P.Rachardrarao and T.R.Anantharaman; Scripta Metall., 20(1986),191.

3)C.Dong, Z.K.Hei, L.B.Wang, Q.H.Song, Y.K.Wu and K.H.Kuo Scripta Metall., 20(1986),1155.

4)V.V.Molokanov and V.N.Cheboynikov; J.Non-Cryst.Solids, 117-118(1990),789.

5)J.Steinhardt and S.Ostlund; The Physics of Quasicrystals (World Scientific. Singapore, 1987)

6)A.L.Mackay; Int.J.Rapid Solid., 2(1987)51.

7)P.Stainfort, B.Dubost and A.Dubus,; C.R.Acad.Sci. Paris, 10(1985)

8)A.P.Tsai, A.Inoue and T.Masumoto; Jpn.J.Appl.Phys., 26(1987) L1505.

9)A.P.Tsai, A.Inoue and T.Masumoto; Jpn.J.Appl.Phys., 27(1988) L1587

10)L.X.He, Y.K.Wu and K.H.Kuo; J.Mater.Sci.Lett., 7(1988)1284.

11)L.X.He, Z.Zhang. Y.K.Wu and K.H.Kuo; Inst.Phys.Conf. Ser., 2 (1988)17. (Bristol:Institute of Physics)

12)A.Abragam; The Principles of Nuclear Magnetism (Clarendon Press, Oxford, 1961)

13)W.W.Warren Jr., H.S.Chen and J.J.Hauser; Phys.Rev.B, 32(1985) 7641.

14)H.Yasuoka, A.Soyama, K.Kimura and S.Takeuchi; J.Phys.Soc. Jpn.,55(1986)1058.

15)C.Lee, D.White, B.H.Suits, P.A.Bancel and P.A.Heiney; Phys. Rev., 37(1988)9053.

16)W.W.Warren, H.S.Chen and G.P.Espinosa; Phys.Rev.B,34(1986) 4902

17)T.Shinohara, A.P.Tsai and T.Masumoto; J.Mater.Res.,7(1992)62.

18)T.Shinohara, A.P.Tsai and T.Masumoto; J.Phys: Condens.Matter. 4(1992)3043.

19)T.Shinohara and T.Sato: Sci.Rep.Res.Inst.Tohoku.Univ. A, 36 (1992)316.

20)T.Shinohara, A.P.Tsai, T.Sato and T.Masumoto; J.Mater.Res., 7(1992)1970

21)T.Shinohara, A.P.Tsai, T.Masumoto and T.Sato; to be published in Mater.Trans.JIM

22)T.Shinohara, A.P.Tsai and T.Masumoto; to be published in Hyp.Ints.

23)A.P.Tsai, A.Inoue and T.Masumoto; J.Mater Sci. Lett., 6(1987) 1403

24)A.P.Tsai, A.Inoue and T.Masumoto; J.Mater Sci. Lett., 7(1988)

322
25)A.P.Tsai, A.Inoue and T.Masumoto; J.Mater Sci. Lett., 8(1989) 470
26)A.P.Tsai, A.Inoue and T.Masumoto; Jph.J.App.Phys., 26(1987) L1505
27)A.P.Tsai, A.Inoue and T.Masumoto; Jph.J.App.Phys., 27(1988) L1587
28)A.P.Tsai, A.Inoue and T.Masumoto; Jph.J.App.Phys., 26(1987) L1994
29)Y.Yokoyama, A.P.Tsai, A.Inoue and T.Masumoto; Proc.China-Japan Joint Seminar on Quasicrystals (ed.by K.K.Kuo and T.Ninomiya, World Scientific, Singapore 1991) p.2
30)K.Fukamichi, K.Kikuchi, Y.Hattori, A.P.Tsai, A.Inoue, T.Masumoto and T.Goto Proc.China-Japan Joint Seminar on Quasicrystals (ed.by K.K.Kuo and T.Ninomiya, World Scientific, Singapore 1991) p.256