SPring-8 における Mg 基 LPSO 相の弾性的性質の研究

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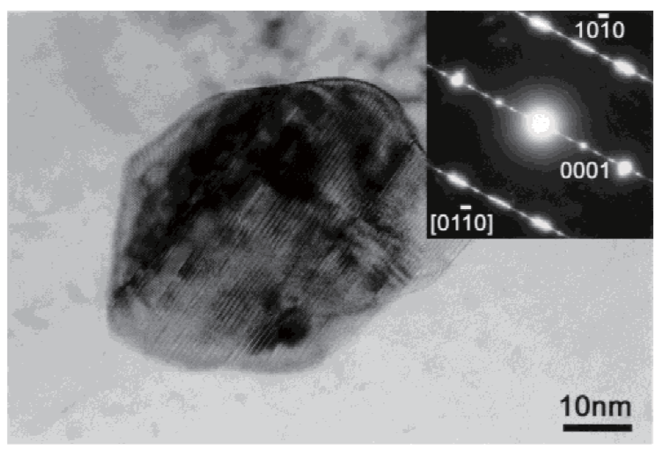
Long Period Stacking Ordered phase

has been founded in Mg-Zn-Y alloy



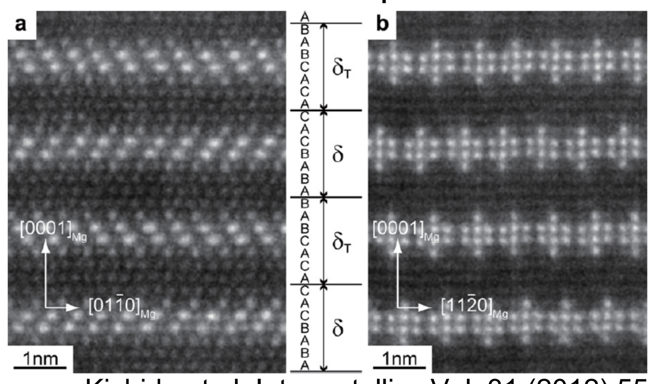
Inoue et al. J. Mater. Res. Vol. 16 (2001) 1894

This precipitate significantly improve both strength and elongation of Mg based alloys

Extensive investigations are carrying out.

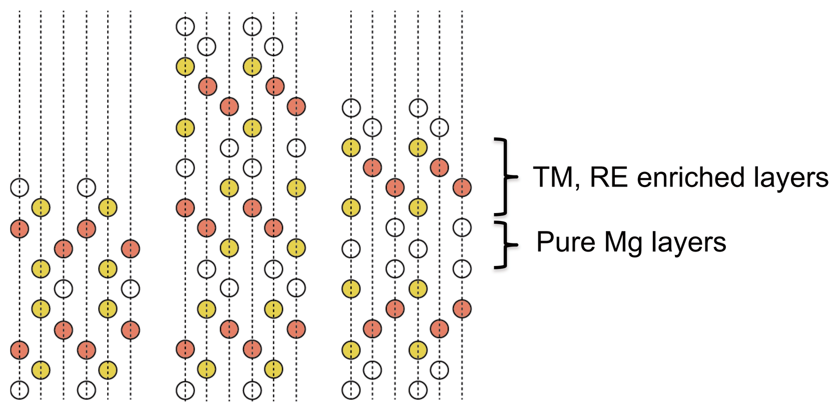
The phase is formed in Mg-TM-RE system
TM: Al, Co, Ni, Cu, Zn
RE: Y, Dy, Ho, Er, Gd, Tb, Tm

The structure of LPSO phases

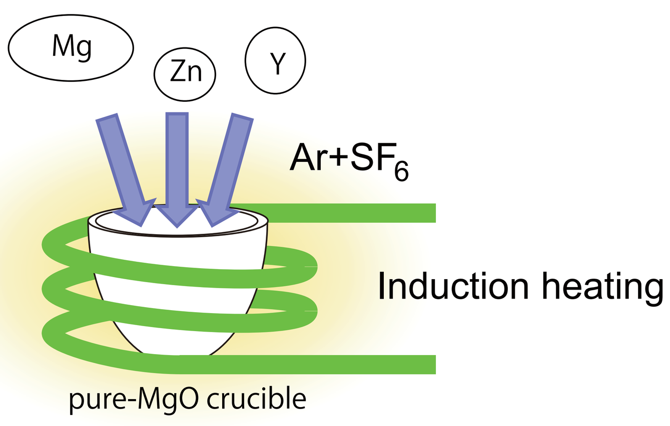


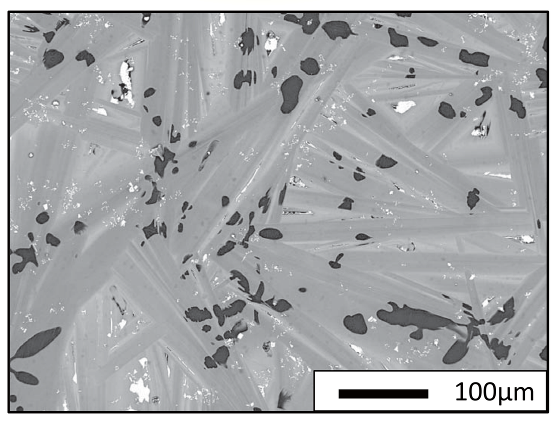
Kishida et al. Intermetallics Vol. 31 (2012) 55

Typical polytypes of LPSO phase

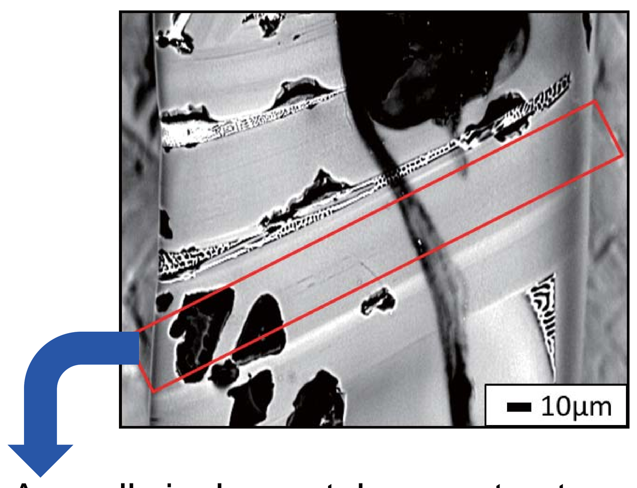


Sample preparation



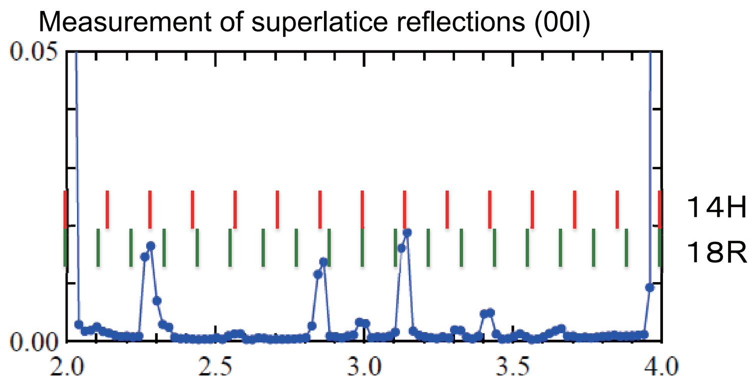


Microstructure of Mg-5at.%Zn-7at%Y alloy



A small single crystal was cut out (20 X 30 X 100 μm^3)

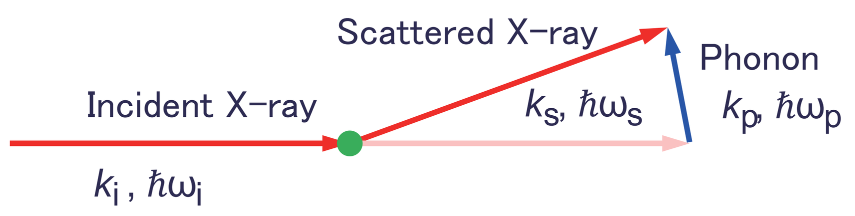
Measurement of superlatice reflections (00l)



Major phase is the 14H stacking structure

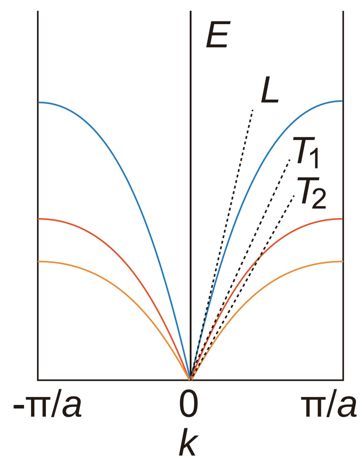
Measurement of Elastic Properties

Inelastic X-ray scattering



$k_s = k_i + k_p$ Momentum conservation principle

$\hbar\omega_s = \hbar\omega_i + \hbar\omega_p$ Energy conservation principle



Dispersion of phonons

Elastic stiffness constants of Mg-based LPSO phase with the 14H structure (Hexagonal)

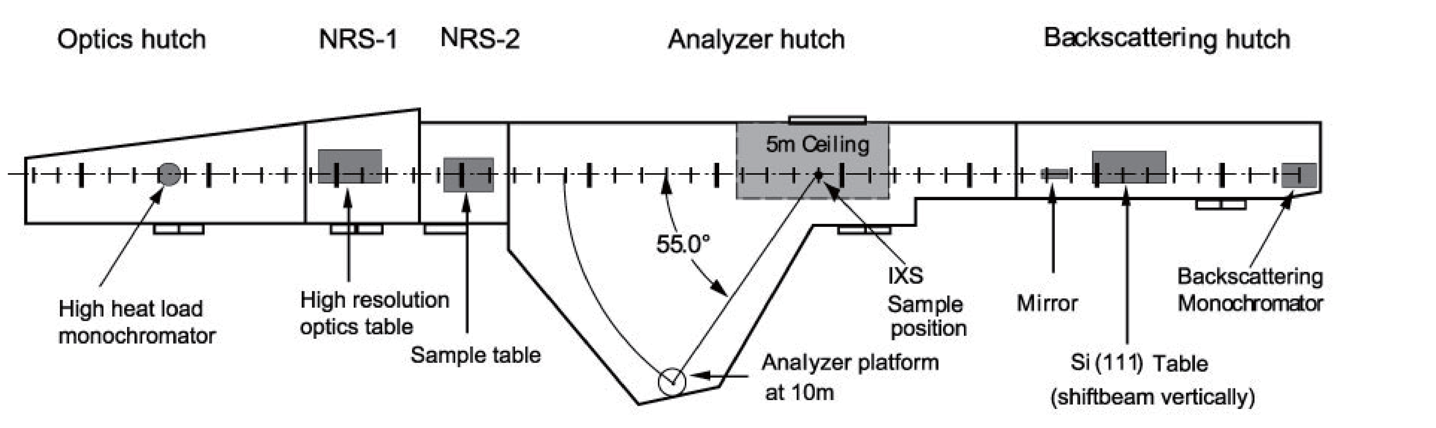
$$\begin{pmatrix} c_{11} & c_{12} & c_{13} & & 0 & \\ c_{12} & c_{22} & c_{23} & & & \\ c_{13} & c_{23} & c_{33} & & & \\ & & & c_{44} & & \\ & 0 & & & c_{55} & \\ & & & & & c_{66} \end{pmatrix} \qquad c_{66} = \frac{c_{11} - c_{12}}{2}$$

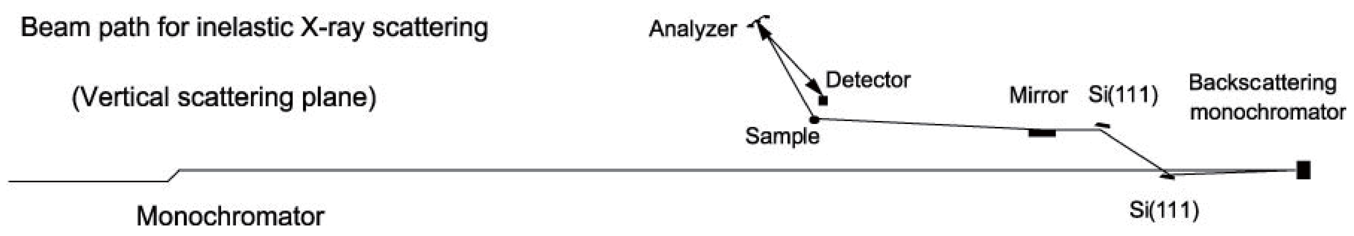
Five independent elastic constants

Relationship between energy of phonon at around the Γ point and elastic constants

$$\begin{vmatrix} k_1^2 c_{11} + k_2^2 \frac{c_{11}-c_{12}}{2} + k_3^2 c_{44} - \rho\omega^2 & k_1 k_2 \frac{c_{11}+c_{12}}{2} & k_1 k_3 (c_{13}+c_{44}) \\ k_1 k_2 \frac{c_{11}+c_{12}}{2} & k_1^2 \frac{c_{11}-c_{12}}{2} + k_2^2 c_{11} + k_3^2 c_{44} - \rho\omega^2 & k_2 k_3 (c_{13}+c_{44}) \\ k_1 k_3 (c_{13}+c_{44}) & k_2 k_3 (c_{13}+c_{44}) & (k_1^2 + k_2^2) c_{44} + k_3^2 c_{33} - \rho\omega^2 \end{vmatrix} = 0$$

BL35XU hutch layout



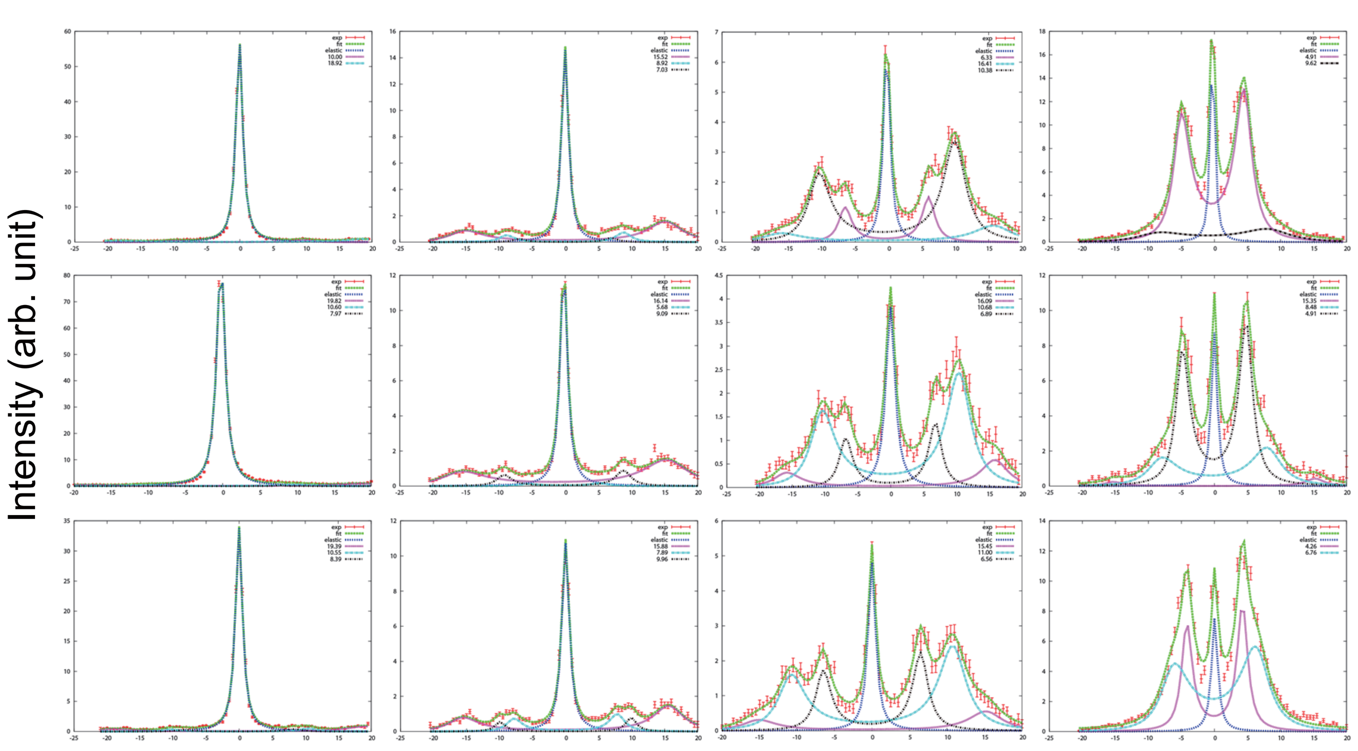


Baron et al. J. Phys. Chem. Solids Vol. 61 (2000) 461

$\hbar\omega_i \sim \hbar\omega_s \sim$ 22keV Resolution ~1.5meV

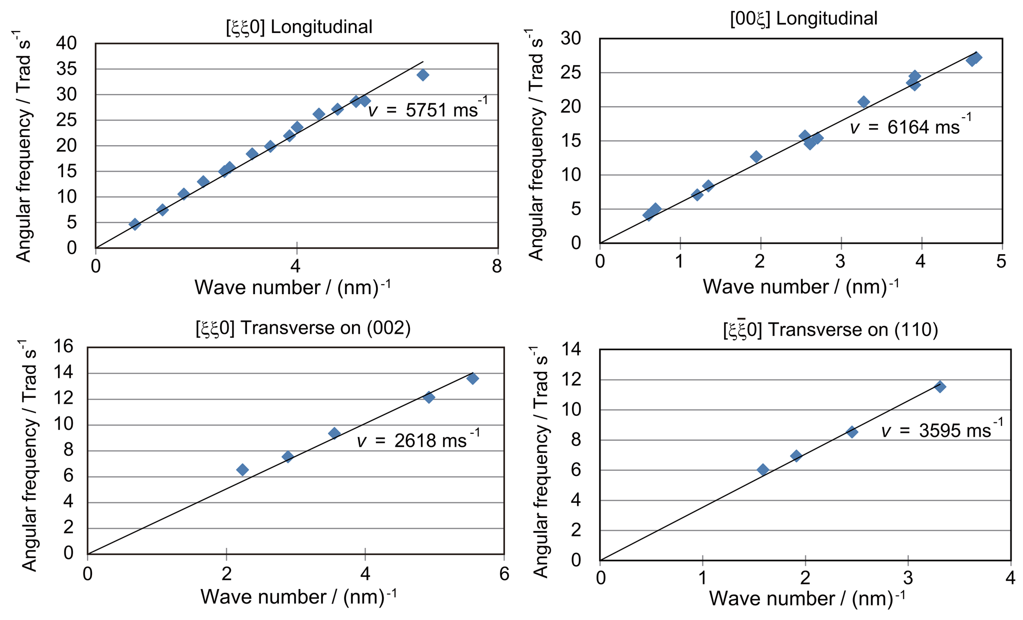
Results

Examples of measured IXS spectrums



Functions for peak fitting:
- Pseudo elastic scattering: delta function
- Phonon: Dumped harmonic oscillator

Convoluted with Lorentz function (Resolution function)



Dispersion of phonons

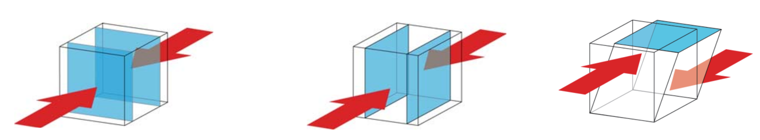
Elastic constants were roughly estimated

C_{11}	C_{33}	C_{44}	C_{66}	/ GPa
71.1	83.2	15.0	28.2	

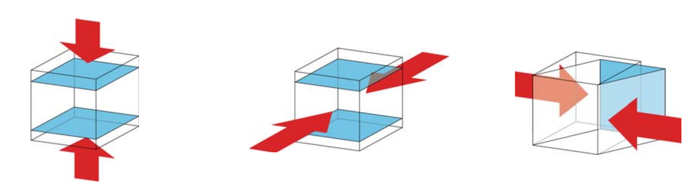
Least square fitting for all measured phonon peaks

All independent elastic constants are determined as

C_{11}	C_{12}	C_{44}	/ GPa
78.7±1.2	27.2±1.4	16.3±0.6	



C_{33}	C_{13}	C_{66}	/ GPa
93.7±2.5	26.8±1.9	25.7	



Poly-crystalline elastic constants are calculated as

Young' s modulus	Shear modulus	Bulk modulus	/ GPa
57.4	22.2	45.7	

Discussion

Elastic constants of pure-Mg

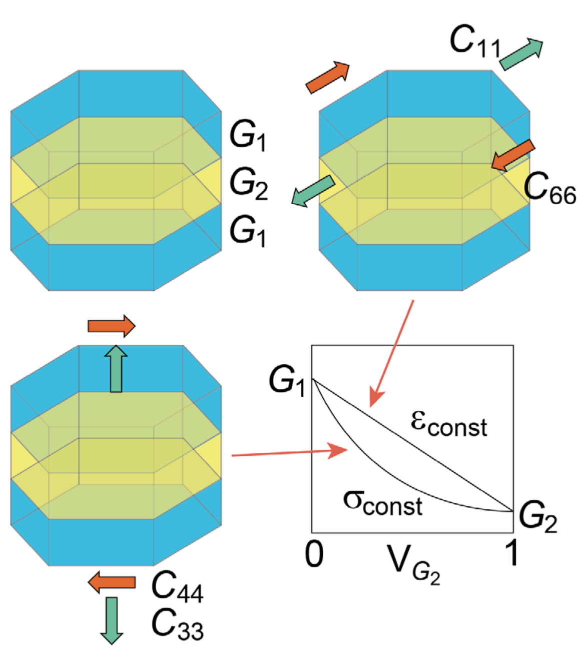
C_{11}	C_{12}	C_{44}	/ GPa
59.3	25.7	16.4	

C_{33}	C_{13}	C_{66}	/ GPa
61.5	21.4	16.8	

Most of elastic stiffness constants of LPSO phase are larger than those of pure-Mg

Inter-atomic bondings are strengthened upon alloying with Zn and Y

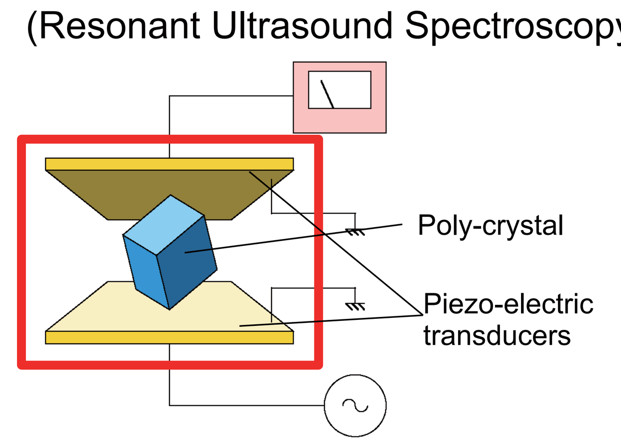
Is the LPSO phase a composite of pure-Mg and (Zn, Y) enriched layers?

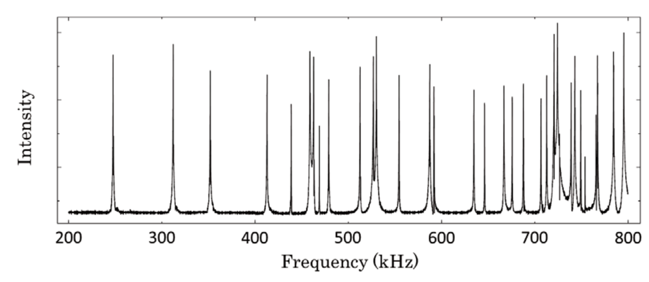


$C_{44} < C_{66}$ but $C_{11} < C_{33}$

LPSO phase is not a simple composite of pure-Mg and (Zn, Y) enriched layers

Comparing with the macroscopic measurement (Resonant Ultrasound Spectroscopy)





Young' s modulus	Shear modulus	Bulk modulus	/ GPa
53.4	20.9	40.2	

Future works

Measurements for LPSO phases with other stacking sequence

To separate the elastic properties of pure-Mg and (Zn, Y) enriched layers

Measurements for LPSO phases with other alloying elements

To understand what is the common elastic propertis of LPSO phases