Density and sound velocity of liquid Fealloys under high pressure: Implication for Mercury core

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Introduction

Based on metal-silicate reaction with requirement of 1-4 wt% S in the silicate Mercury core compositions are estimated to +Core S contents <20wt% \rightarrow Core must contain Si +Core Si content >10 wt% \rightarrow Core has < 2 wt% S

\rightarrow Mercury core likely contains Si.

(Chabot et al. 2014)

 \rightarrow Elastic properties (e.g. density, compressibility) of liquid Fe-Ni-Si are important to constrain the Mercury core size and composition.



Aim of this study

Simultaneous measurement of density and sound velocity for liquid was developed to obtain elastic properties of liquid Fe-alloys

The effects of Si content and pressure on density and sound velocity of liquid Fe-Ni-Si were investigated.

Method Sound velocity: V Ultrasonic pulse echo

$$V = \frac{L}{T}$$



Density: X-ray absorption



$$\frac{I}{I_0} = \exp(-\mu\rho t)$$

 I_0 :Incident X-ray intensity I: Transmitted X-ray intensity μ : mass absorption coefficient ρ : density, *t*: sample thickness

Experimental set-up

WC anvil

Sound velocity

Cubic multi-anvil press

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Oscilloscope

Waveform

generator

SPring-8 BL22XU

35keV

Densit

Ion chamber(I₀)



X-ray absorption: Ion chamber

Diffraction: Imaging plate P marker: hBN+MgO

Effect of Si content



 V_{P} increases with Si content. This trend is opposite to the effect of S.

Si reduce the Fe-Ni density moderately.

*Fe-Ni-Si: 1573-1773K, Fe-Ni: 1800-1900K

*Calc density Fe: 1900K, Fe-Si:1600K

Density-V_P relation (Birch's plot)



Lines: calculated at Mercury core pressures (6-39 GPa)

Increasing Si content shifts toward left and increasing S content shifts left downward.

Si-rich Mercury core indicates higher density and higher sound velocity compared to S-rich core, suggesting Si-rich core should be smaller than S-rich core.

If V_P or ρ of the Mercury core is obtained, light elements in the core can be strictly constrained.

Summary

We have developed simultaneous V_P and ρ measurement system for liquid alloys using cubic multi-anvil press.

Comparing with V_P of Fe-Ni, Si raise the V_P at present conditions, which is opposite to influence of S.

The pressure effect on the density and sound velocity of Fe-Ni-Si is similar to that of Fe-Ni.

In $\rho\text{-}V_{\text{P}}$ plot, Si-rich Mercury core indicates higher density and higher sound velocity compared to S-rich core.

Elastic properties of Fe-Ni-Si liquid were obtained and core size can be updated using these properties.

Elastic parameters			
Composition	K _{s0}	K _s '	Ref
Fe70Ni10Si20	108	6.4	This study
Fe90Ni10	104	6.6	This study
Fe	105	6.7	Jing et al. 2014

