Selected for a Viewpoint in *Physics*
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Relation between Self-Diffusion and Viscosity in Dense Liquids: New Experimental Results from Electrostatic Levitation

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By using the technique of electrostatic levitation, the Ni self-diffusion, density, and viscosity of liquid $Zr_{64}Ni_{36}$ have been measured *in situ* with high precision and accuracy. The inverse of the viscosity, η, measured via the oscillating drop technique, and the self-diffusion coefficient D, obtained from quasielastic neutron scattering experiments, exhibit the same temperature dependence over 1.5 orders of magnitude and in a broad temperature range spanning more than 800 K. It was found that $D\eta = \text{const}$ for the entire temperature range, contradicting the Stokes-Einstein relation.

Seoncheol Cha
2011.11.9.

Fluid Dynamics

- Viscosity
- Atomic Diffusion

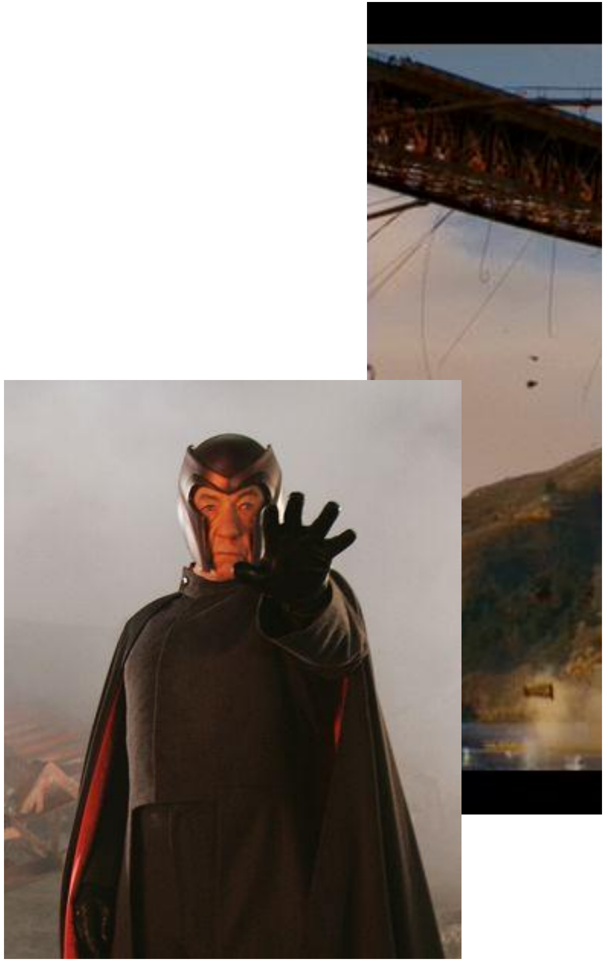
$$D_{trans} = \frac{k_B T}{6\pi\eta_0 R}$$

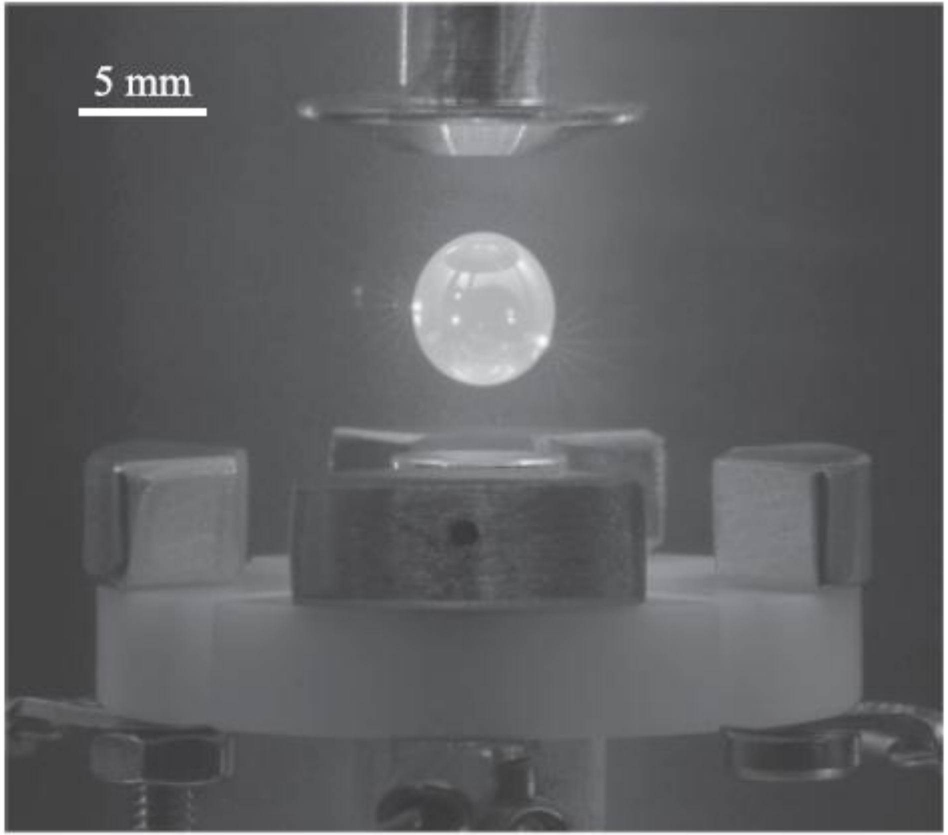
The diffusing objects are of atomistic size, deviations of D and η from the Stokes-Einstein behavior can be observed

Experimental challenging

- **Additional transport of mass by buoyancy-driven flow effect**
- **Pollution of the sample from chemical reactions (High T)**

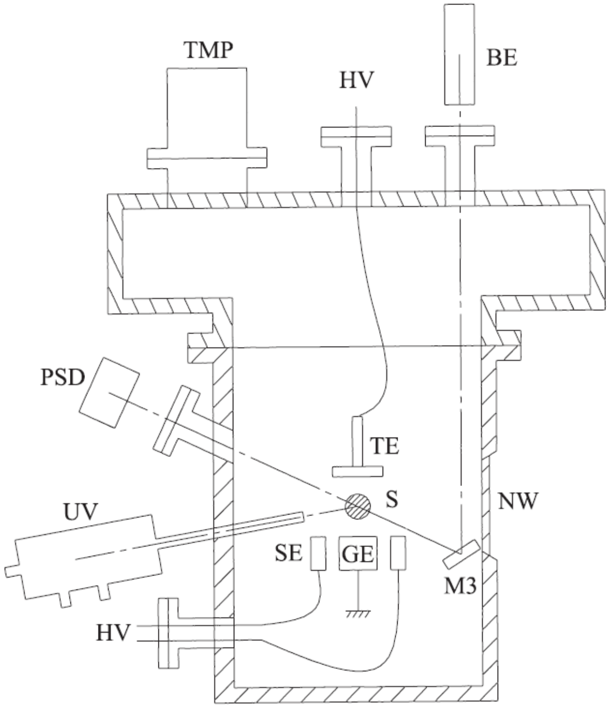
T.Kordel *et al*, PRB (2011)



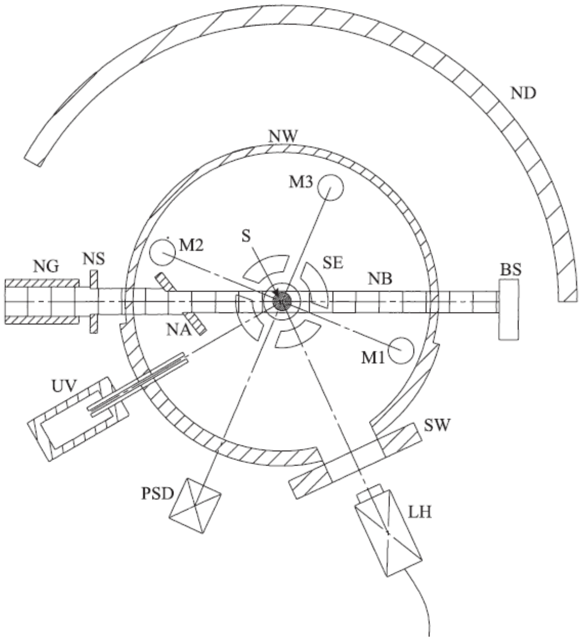


Electrostatic Levitation

T.Kordel *et al*, PRB (2011)



Vertical cut



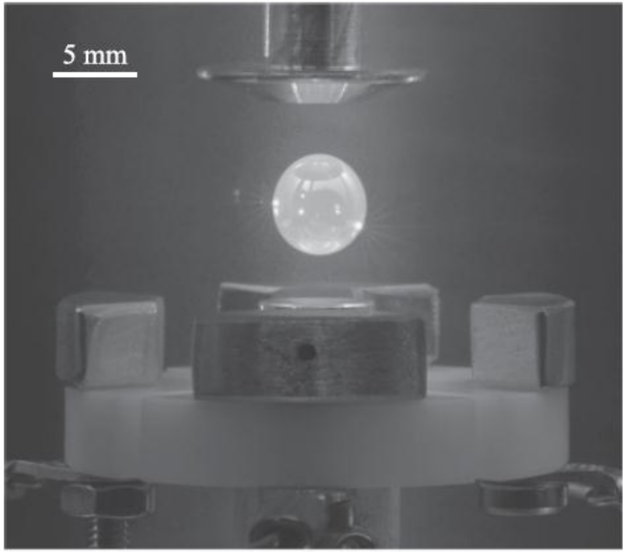
Horizontal cut

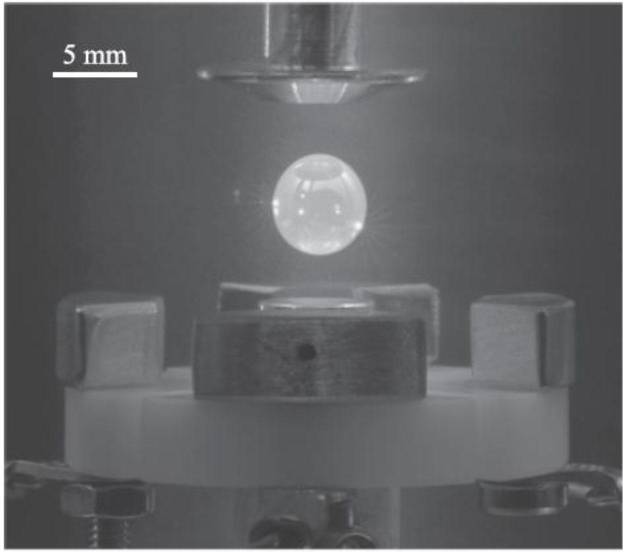
10^{-8} mbar
1.5 – 3 mm diameters
20 – 90 mg masses

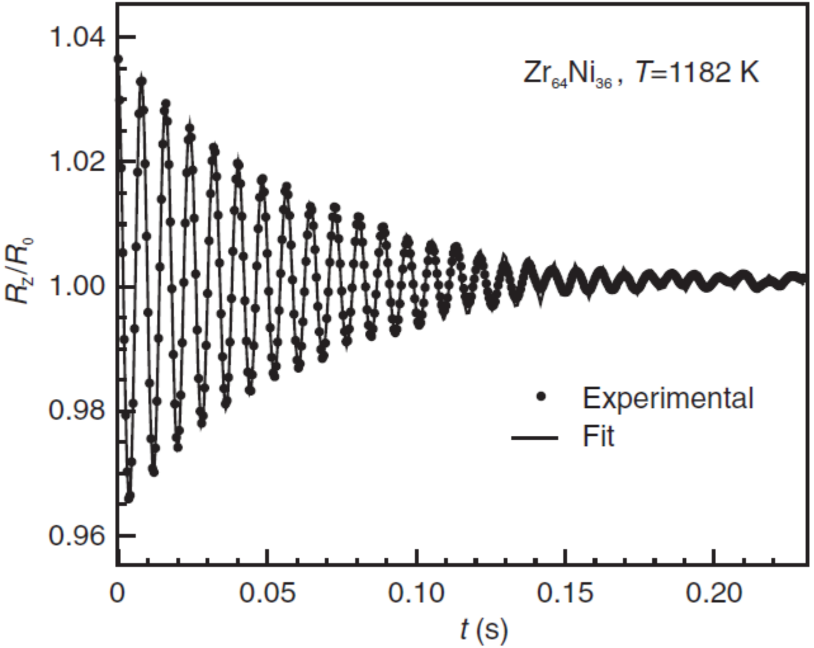
Static electric field
Feedback loop system
(HeNe laser & PSD)

Heating & Melting : two
25W IR lasers

480 x 500 pixel 2000Hz
CCD Camera



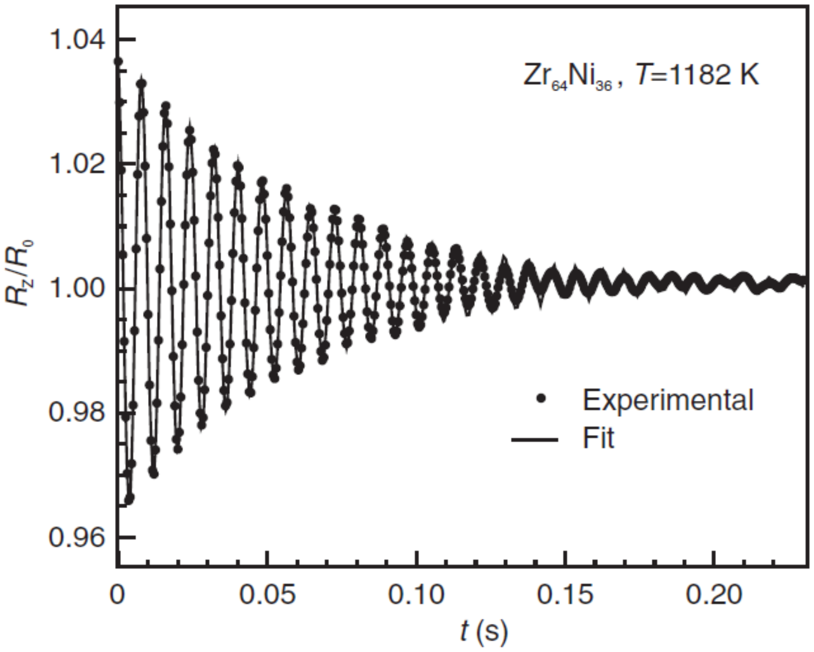

5 mm


Zr64Ni36, T=1182 K
Experimental
Fit
1.04
1.02
1.00
0.98
0.96
Rz/R0
0
0.05
0.10
0.15
0.20
t (s)

$$R_z(t) = R_0 + A\exp(-t/\tau)\sin(wt + \delta_0)$$

Lamb's law

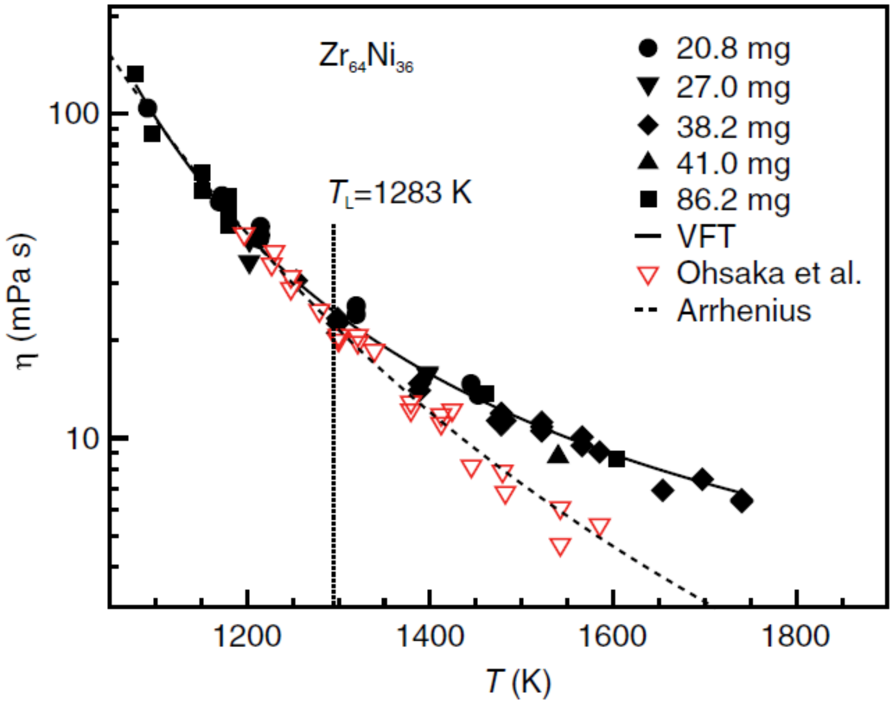
$$\eta = \frac{\rho R_0^2}{5\tau_0}$$

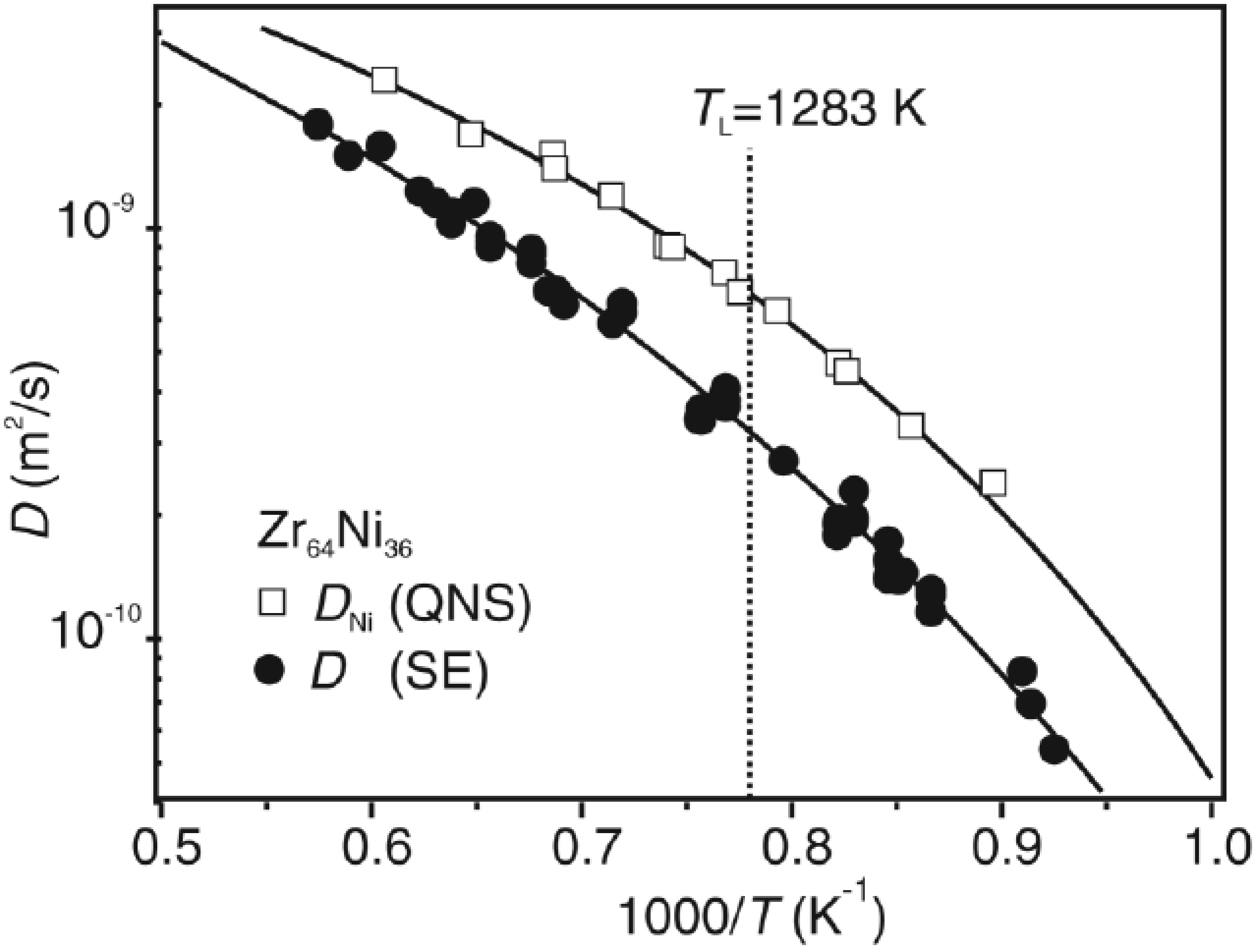


Vogel-Fulcher-Tammann (VFT)

- Typical for glass-forming systems

$$\eta = \eta_0 \exp(\frac{E_\eta}{k_B(T - T_0)})$$



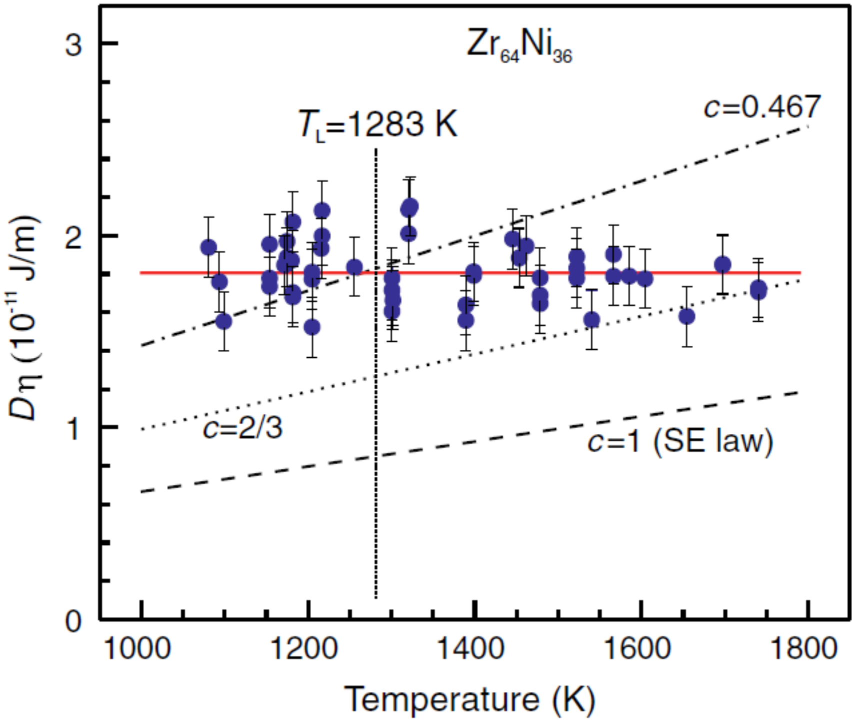


T_L=1283 K
10^{-9}
10^{-10}
D (m^2/s)
$Zr_{64}Ni_{36}$
D_{Ni} (QNS)
D (SE)
0.5
0.6
0.7
0.8
0.9
1.0
1000/T (K^{-1})

$$D_{trans} = \frac{k_B T}{6\pi\eta_0 R}$$

$$R = c r_{Ni}$$

$$r_{Ni} = 1.15\dot{A}$$



$$D_{trans} = \frac{k_B T}{6\pi\eta_0 R}$$

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$$r_{Ni} = 1.15\dot{A}$$

Mode-coupling theory

- **Strongly coupled dynamics**

$$D_{trans}\eta_0 = const$$