Effect of Pelletization Pressure on the Structural and Superconducting Properties in Fluorine-Doped PrFeAsO

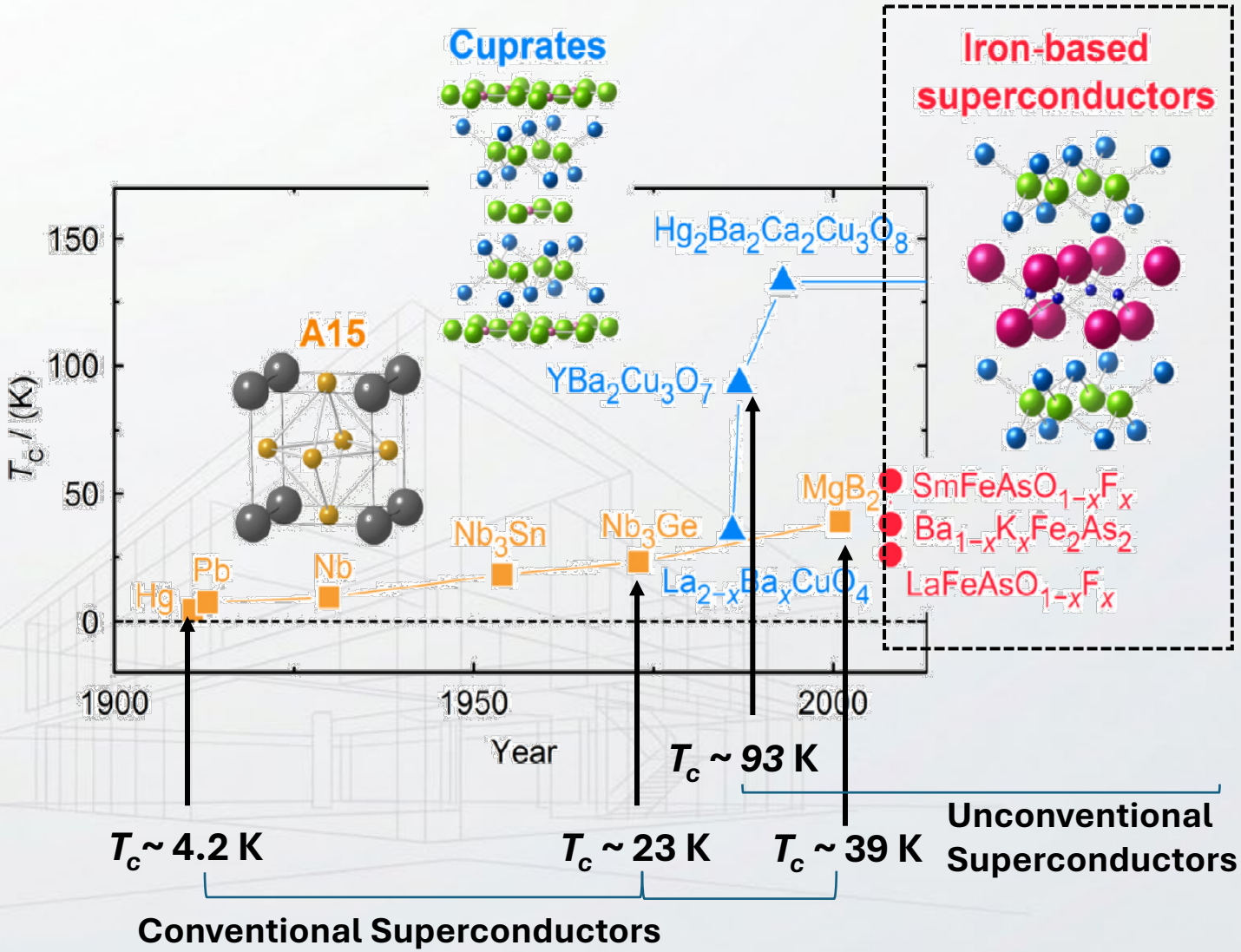
Jayant Kumar[1], Konrad Kwatek[2], Tatiana Zajarniuk[3], Taras Palasyuk[2], Yaroslaw Konopelnyk[3], Tomasz Cetner[1], Cezariusz Jastrzębski[2], Shiv J. Singh[1]

[1]*Institute of High Pressure Physics (IHPP), Polish Academy of Sciences, Warsaw, Poland*

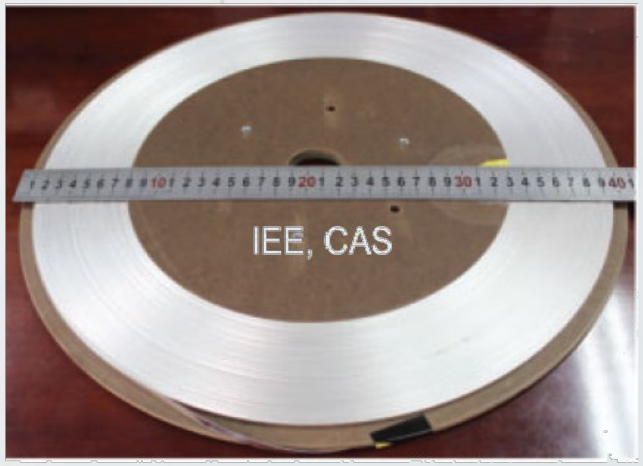
[2]*Faculty of Physics, Warsaw University of Technology, Warsaw, Poland*

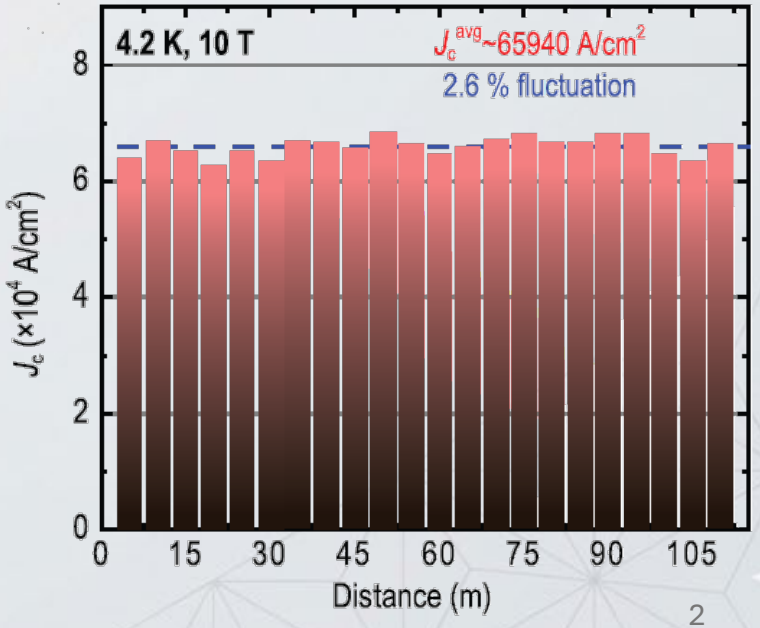
[3]*Institute of Physics, Polish Academy of Sciences, Warsaw, Poland*

Superconducting Materials & Applications



IBS Tape – 100 m

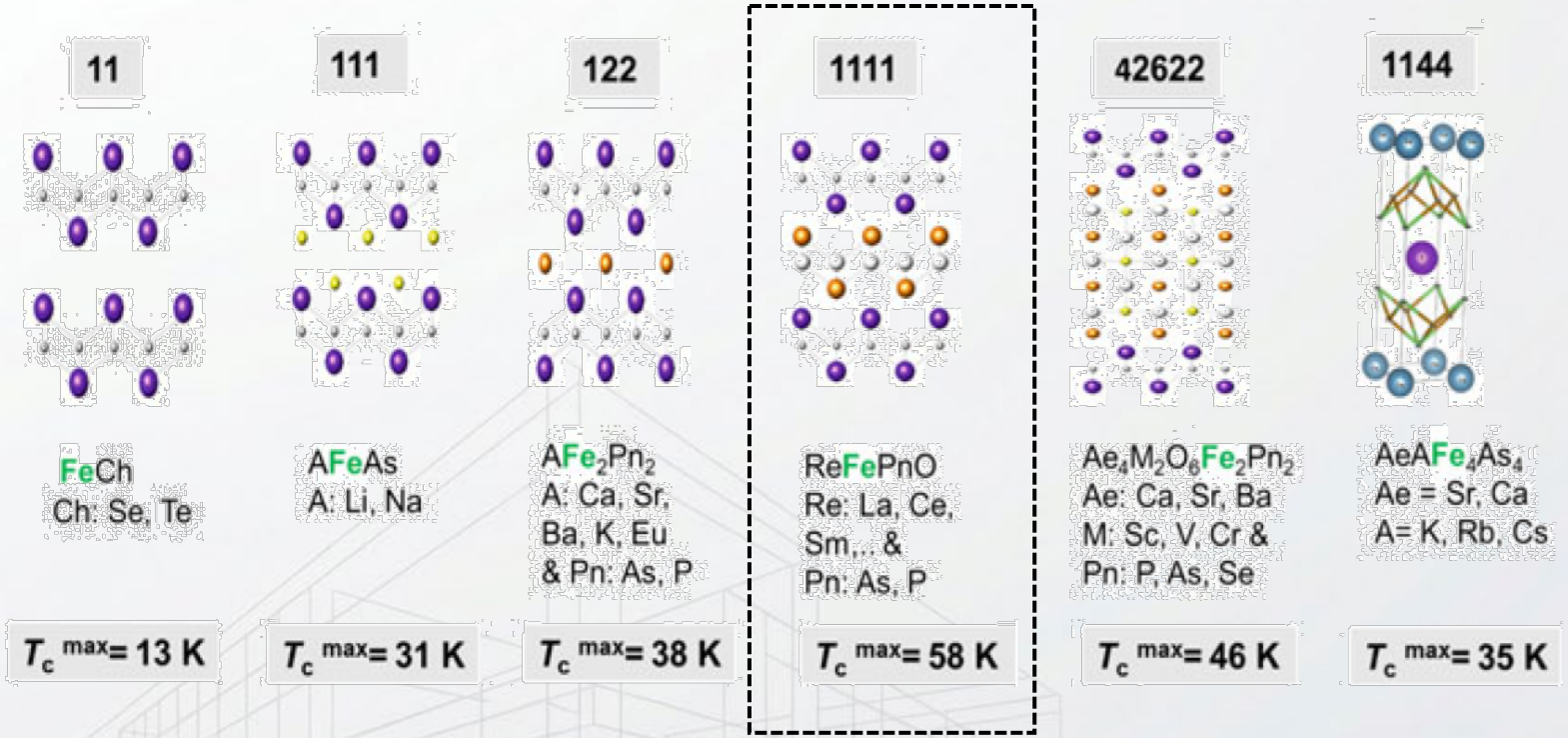


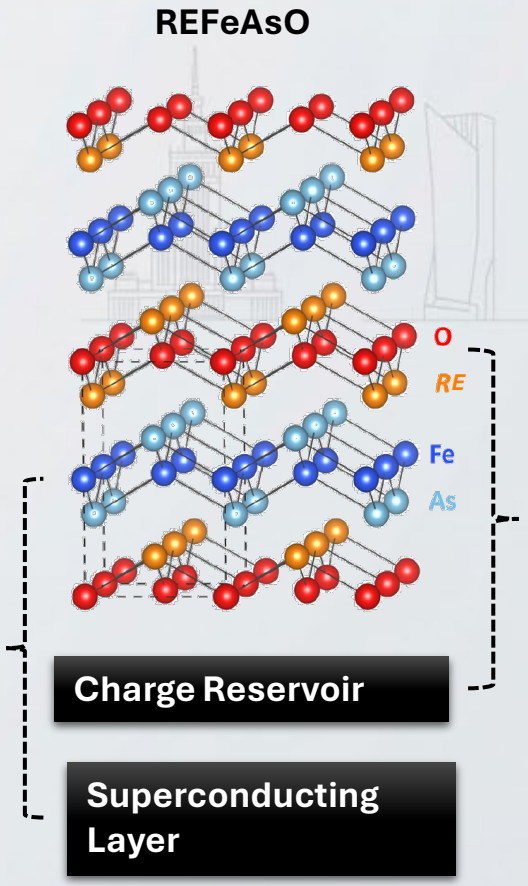


Hideo Hosono et al. *Materials Today* **21**,3 (2018)

Chiheng Dong et al. *National Science Review* **11**,122, (2024)

Iron Based Superconductor (IBS)





- Major family of IBS with maximum reported T_c.
- Different layer's & their role in the structure.

Shiv J. Singh *et. al. Crystals* **12**, 20 (2022).
S. J. Singh *et al. Phys. Rev. Mater.* **2**, 074802 (2018)
Hideo Hosono *et al. Materials Today* **21**, 3 (2018)

PrFeAsO System

Tetragonal Structure - *P4/nmm* Group
Paramagnetic State

T > 155 K

Orthrohombic Structure –
***Cmma* Group**
Paramagnetic State

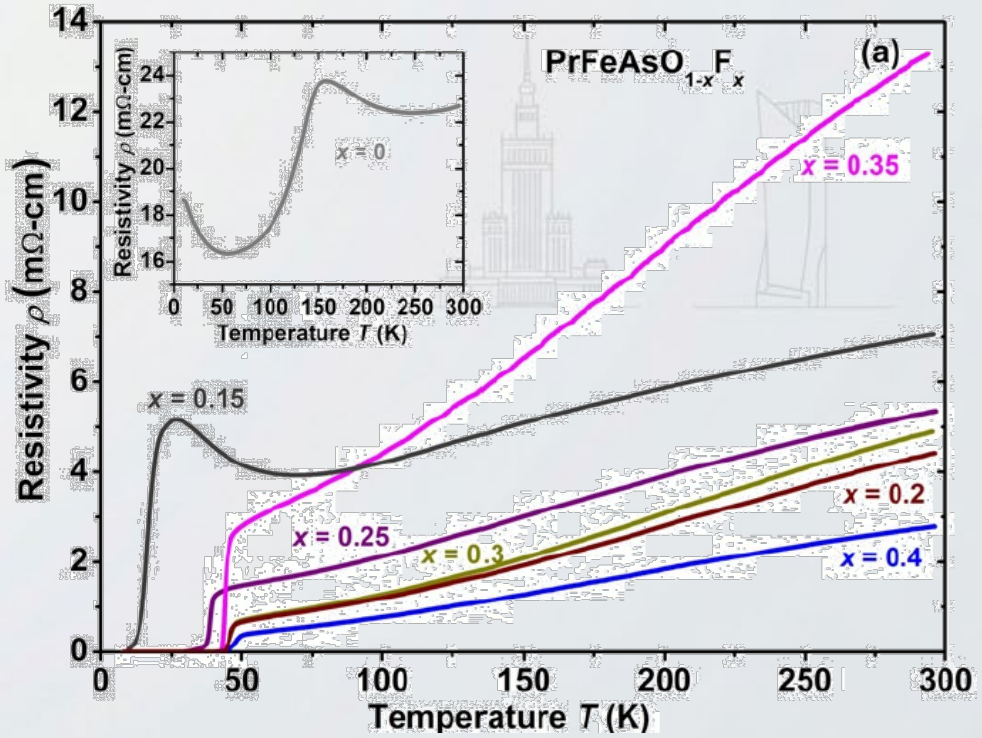
T ~ 155 K

Orthrohombic Structure
Long Range Fe AFM

T ~ 127 K

Pr Magnetic Moment align + Fe AFM

T ~ 12 -14 K

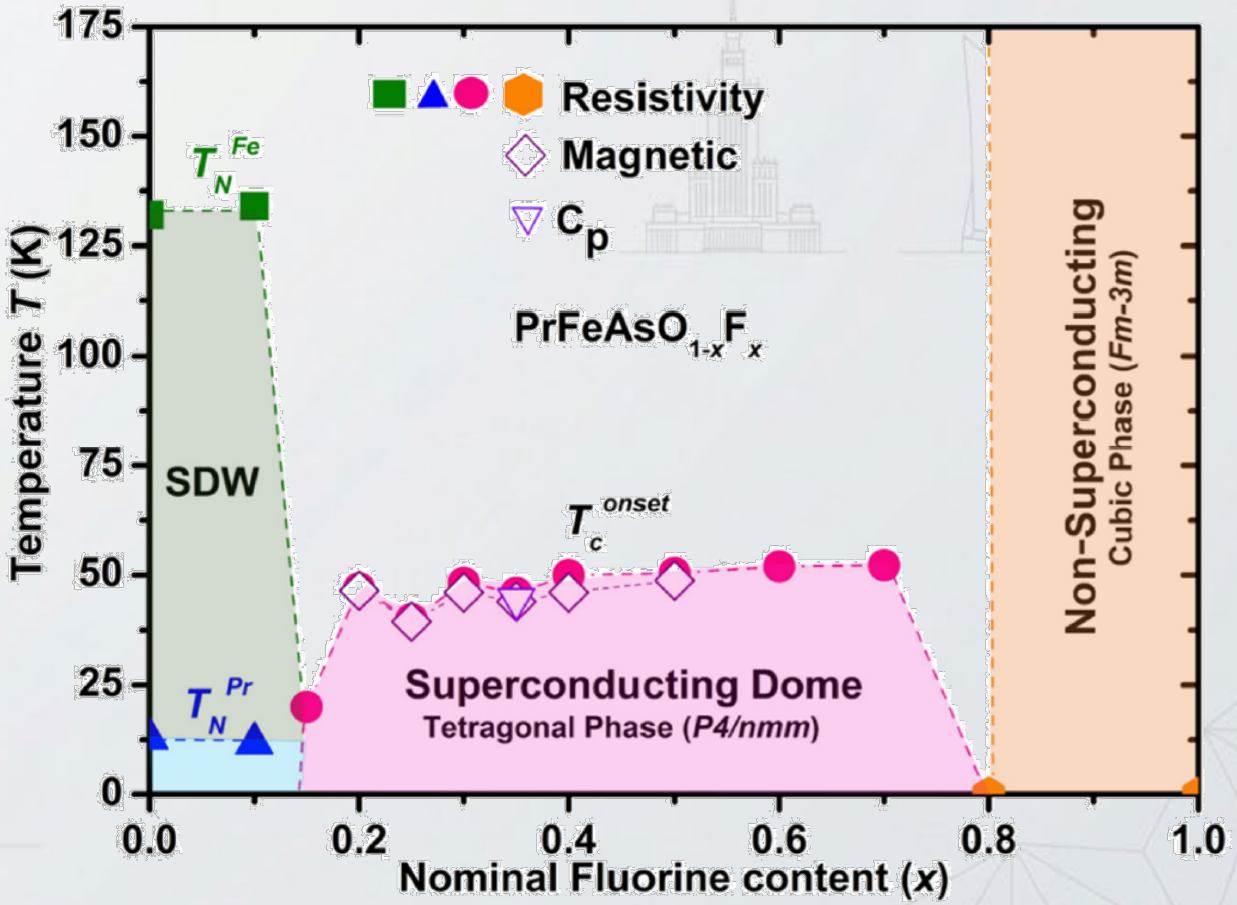


1. Doping suppresses SDW
2. Superconductivity appears.

Priya *et al. Journal of Alloys and Compounds* **1072**, 188942 (2026)

PrFeAs(O,F) System

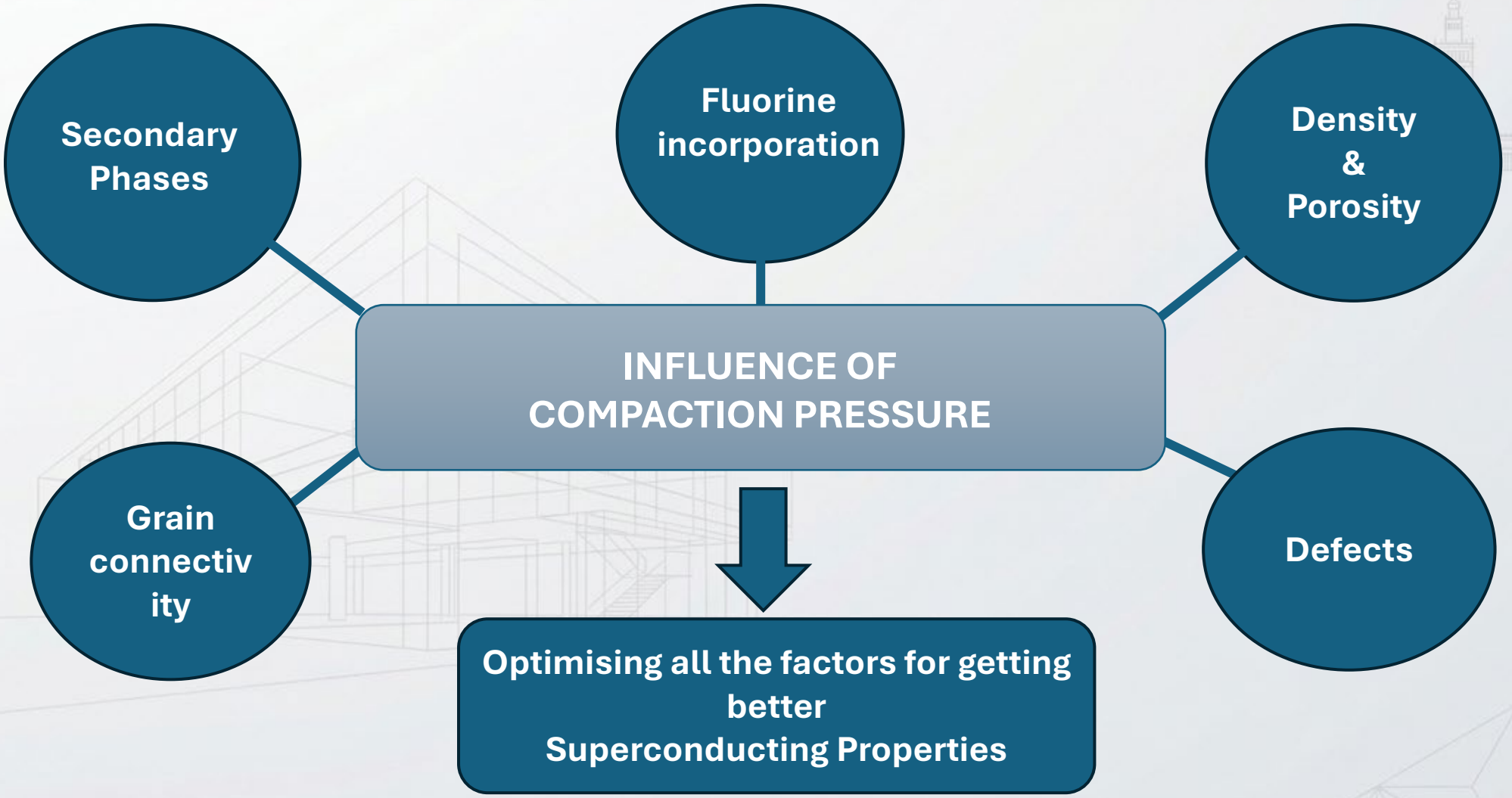
- For $PrFeAsO_{1-x}F_x$ highest reported T_c of 52 K.
- Recently reported complete electronic phase diagram by Priya *et al.*
- The optimized Fluorine content doping reported as 30% doping.
- However there is no report on the pressure study on CSP – AP synthesis and its effect.

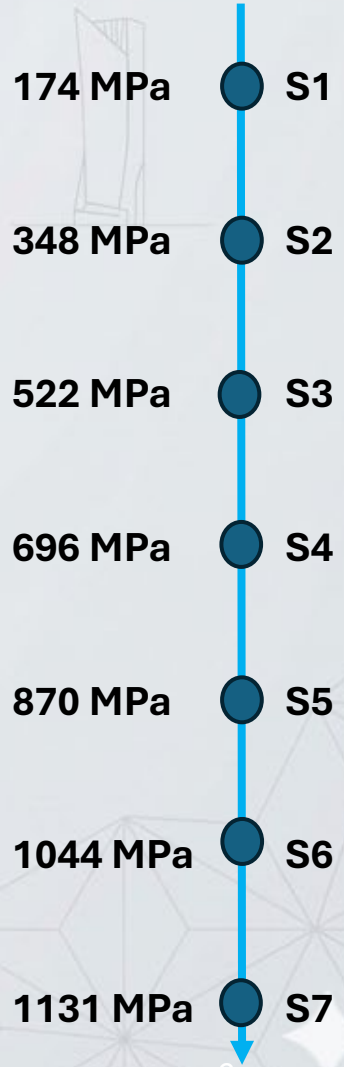


Priya *et al. Journal of Alloys and Compounds* **1072,** 188942 (2026)

Motivation

- Question: Is there an optimum compaction pressure for $PrFeAsO_{0.7}F_{0.3}$ doped samples?





Synthesis Process

1

Mix + grind

Pr, PrF_3, Fe_2O_3, Fe, As
~45 min in Ar glovebox

2

Pelletize

Steel die (10.4 mm Dia)

3

Sealing

Kept Inside Tantalum tube &
Sealed in Quartz Ampoule

4

Sintering

Two-step solid-state route;
950 °C final heat treatment

5

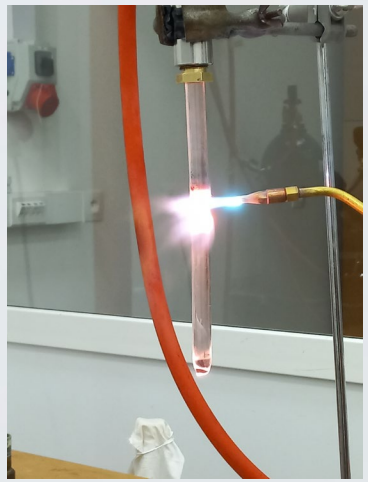
Characterization

Structure
Microstructure
Raman shift
Electrical transport
Magneto-Transport



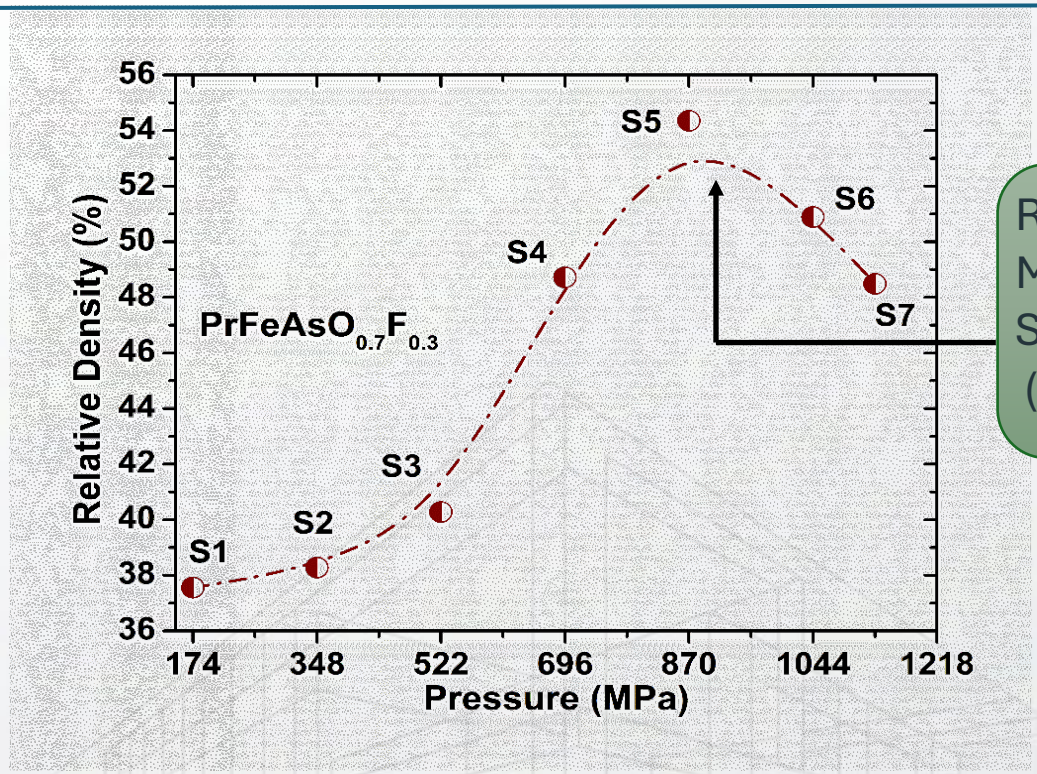




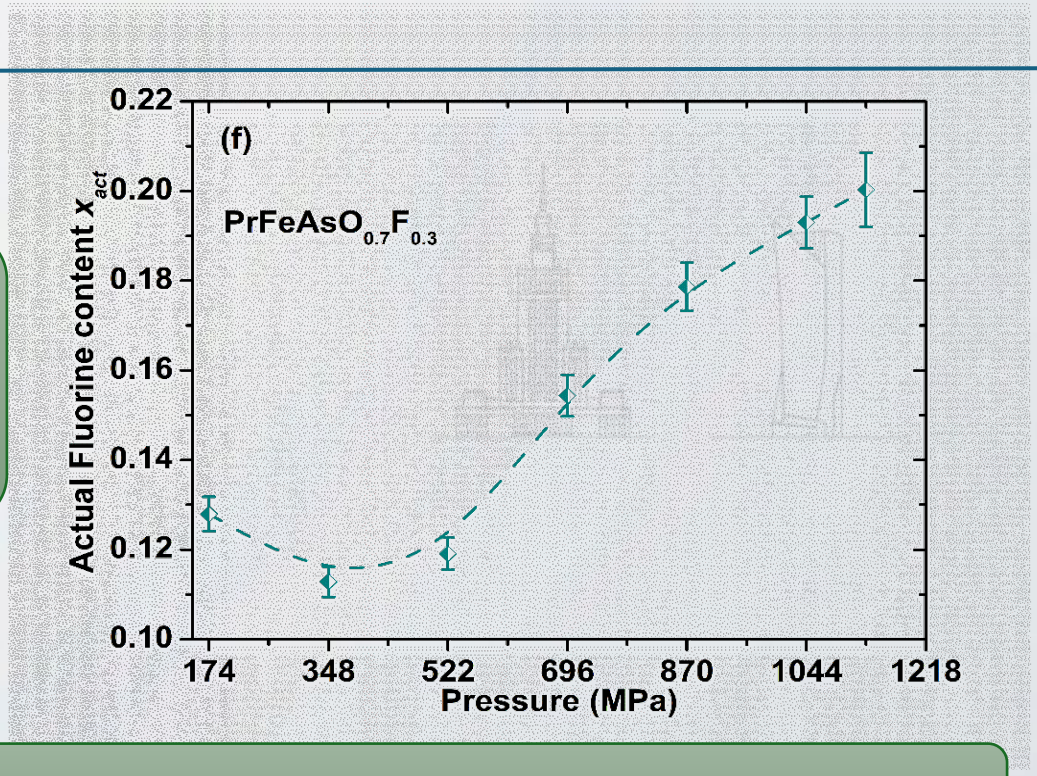




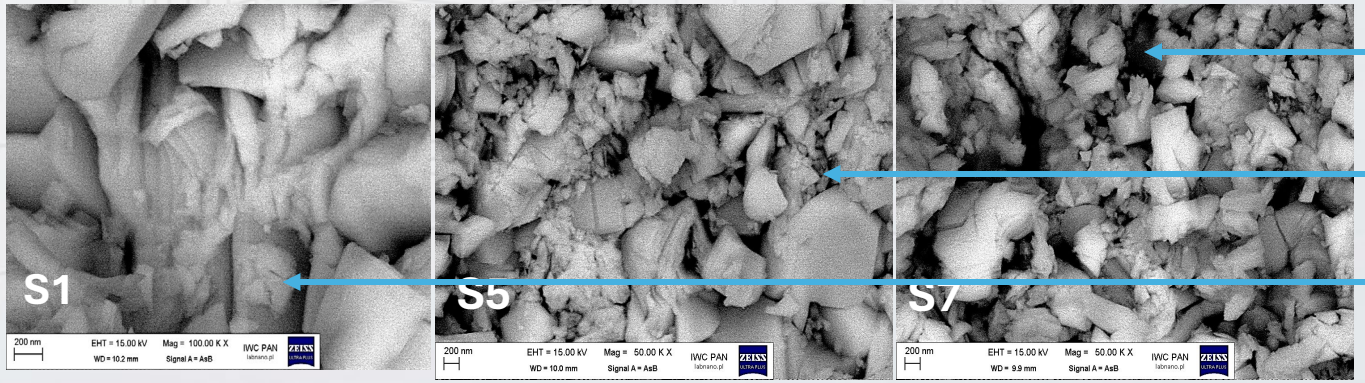
Fluorine Incorporation



Relative Density Maximum for Sample S5 (870 Mpa)



EDX-derived F signal increases from ~ 0.13 to 0.20



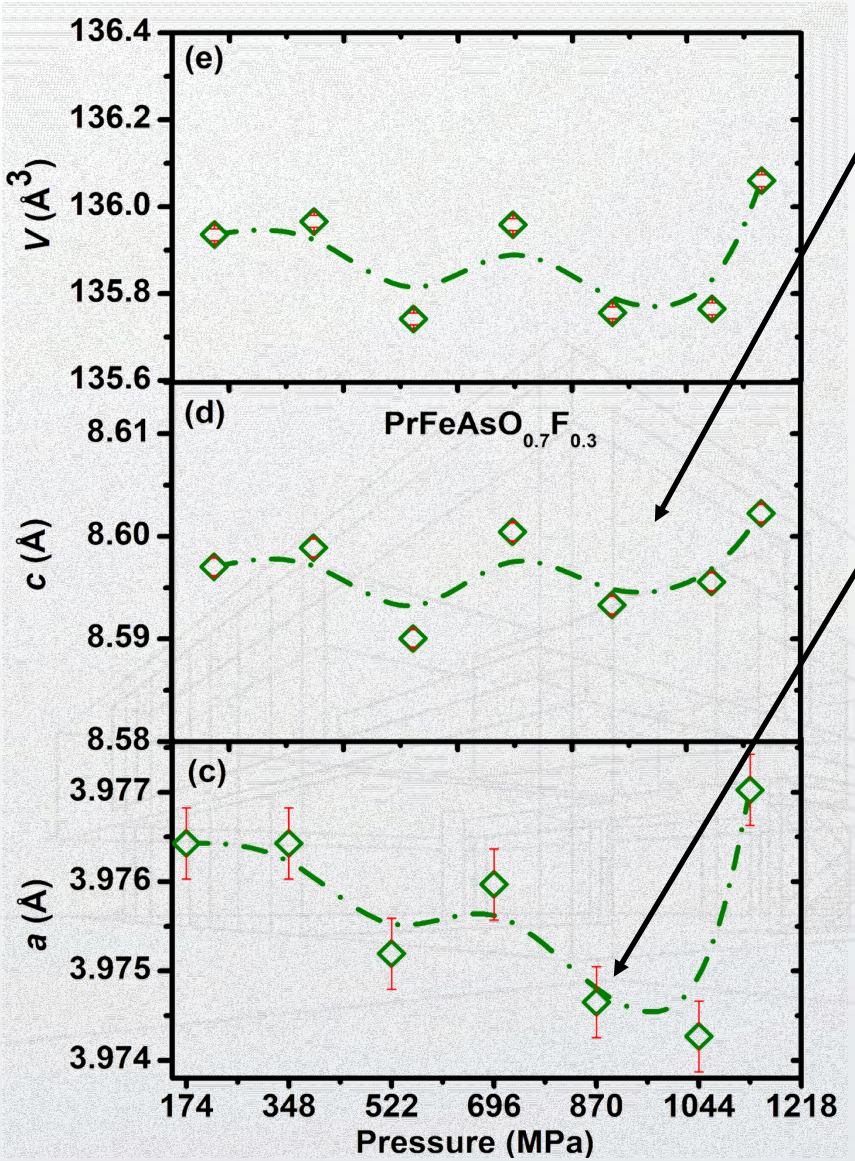
Porosity Increased For S7 (1131 Mpa)

Better grain connectivity S5 (870 Mpa)

Less Dense Sample (174 Mpa

Jayant *et al.* Submitted to *Journal of Alloys and Compounds* (2026)

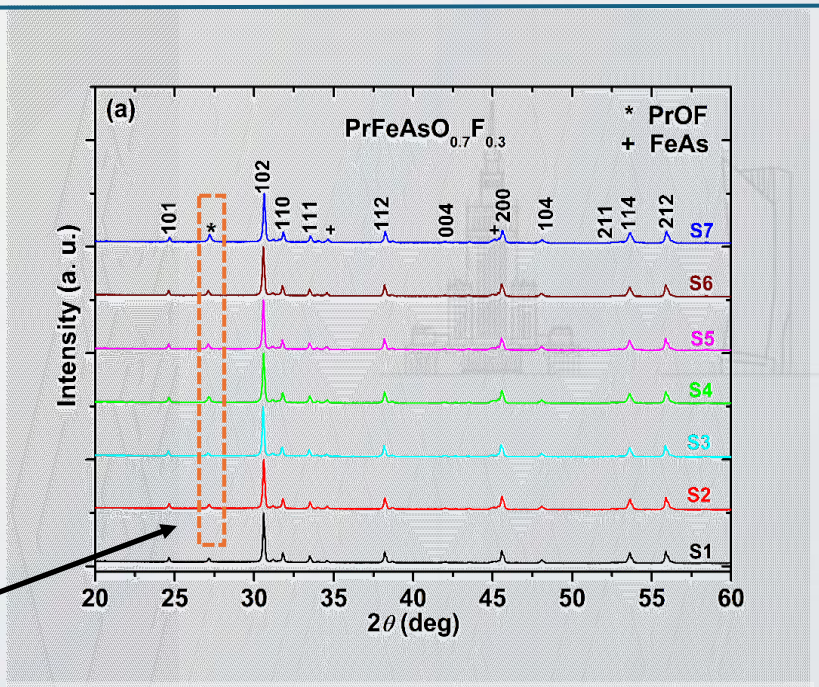
Structural Analysis

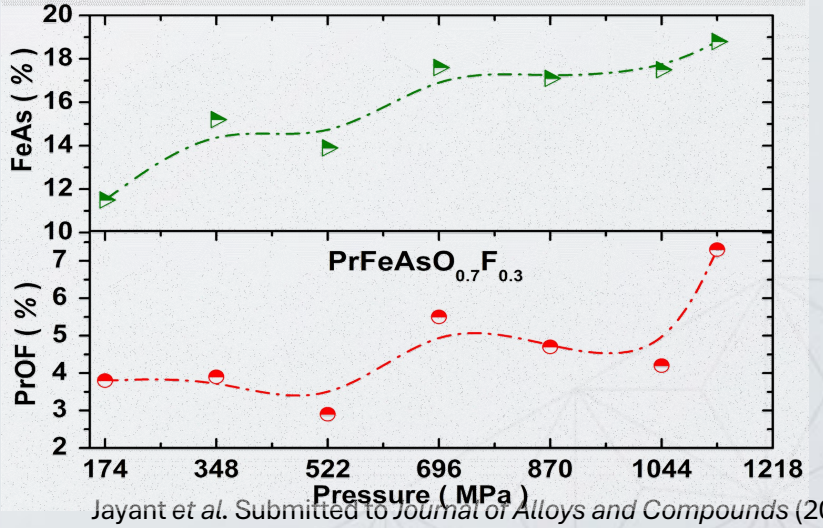


Not much significant change in “c”

Lattice “*a*” Decrease Suggest F incorporation

S1 to S7 Impurity Phase

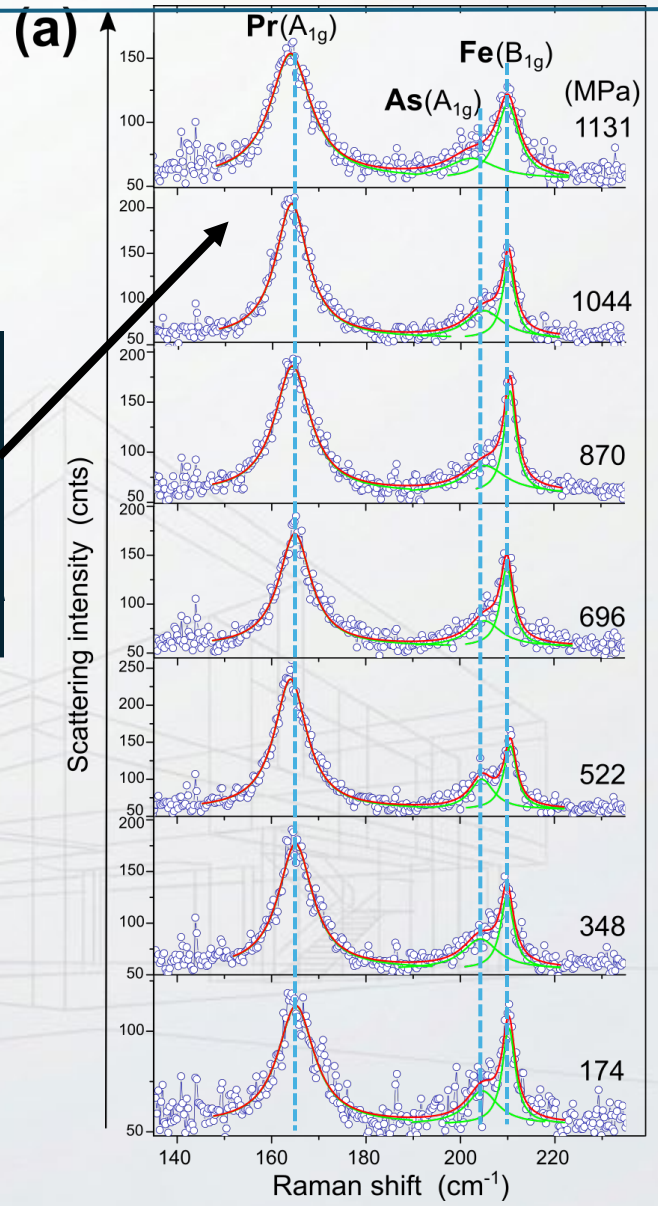


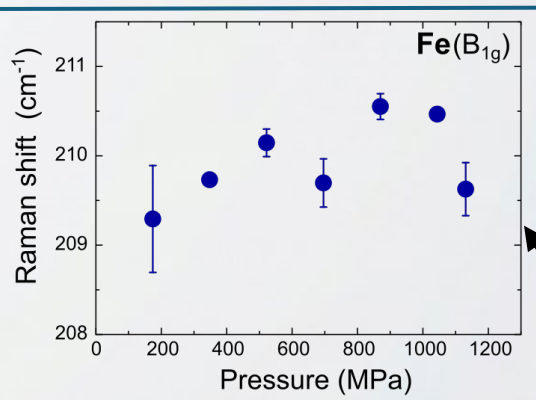


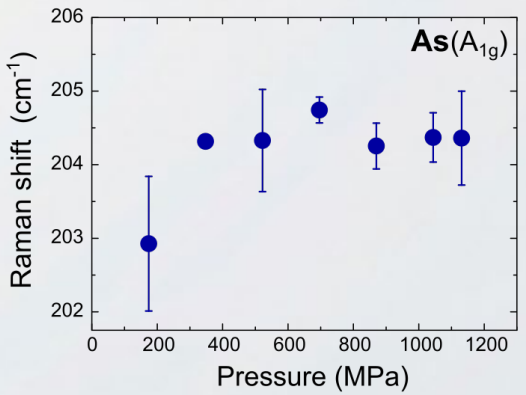
Jayant *et al.* Submitted to *Journal of Alloys and Compounds* (2026)

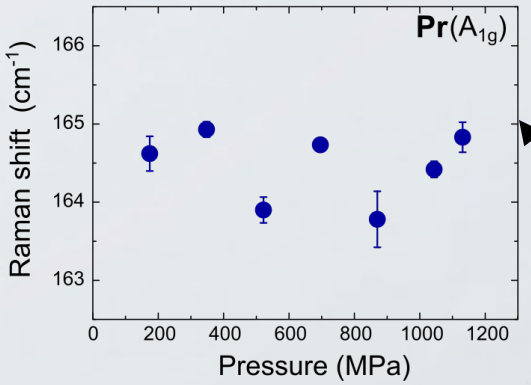
Raman Spectroscopy

Local environment remains unchanged for the atoms







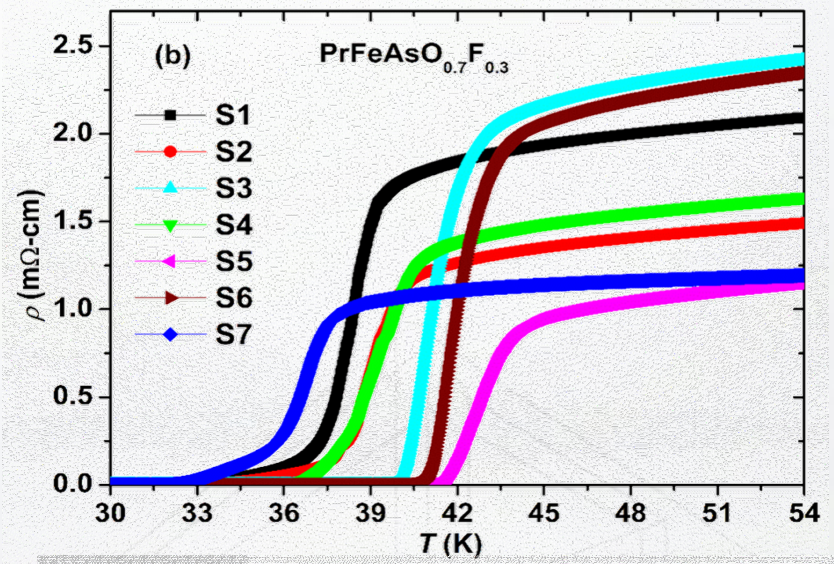


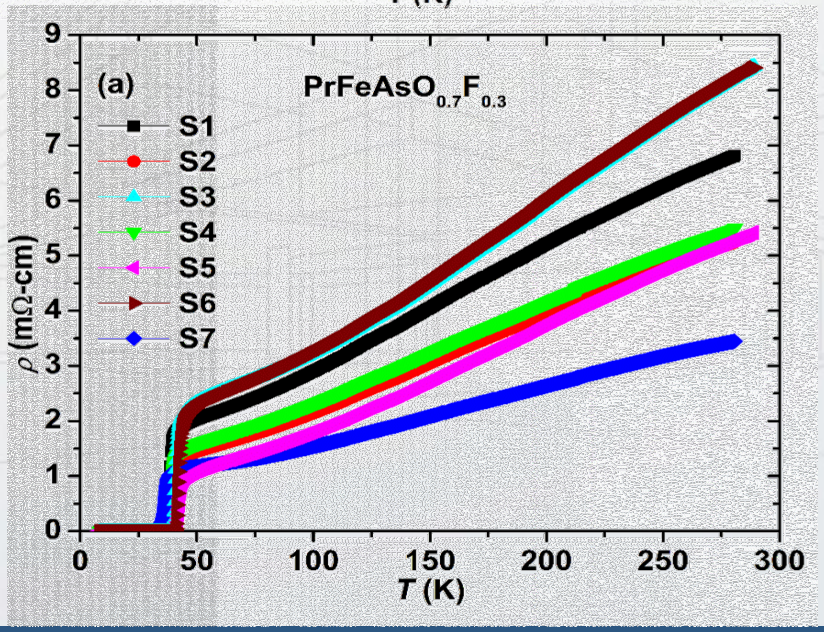
Fe and As shows monotonic change

Non monotonic & No systematic trend

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Electrical Transport Measurement



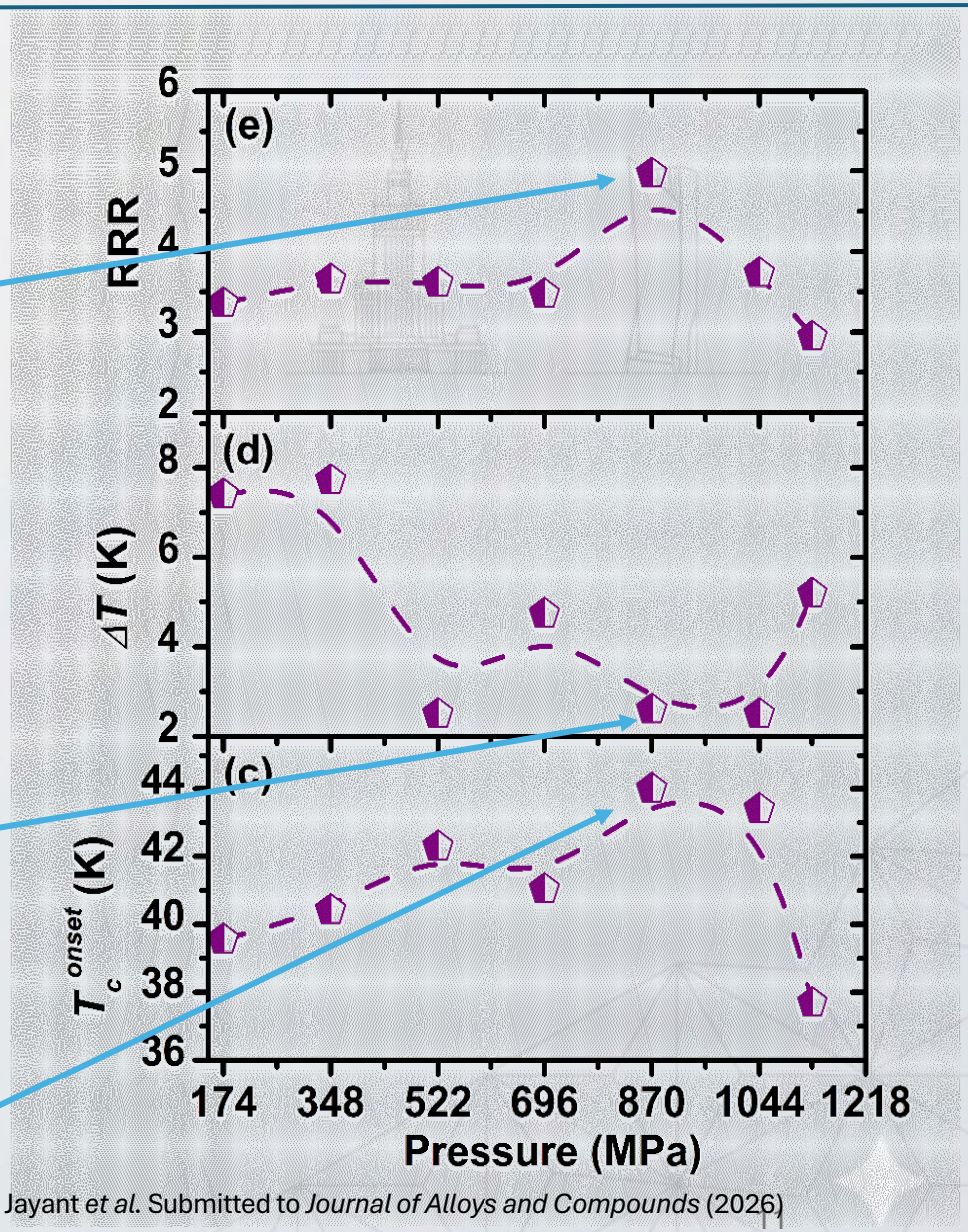


$RRR = \rho_{280K}/\rho_{55K}$

Indication of good quality samples.

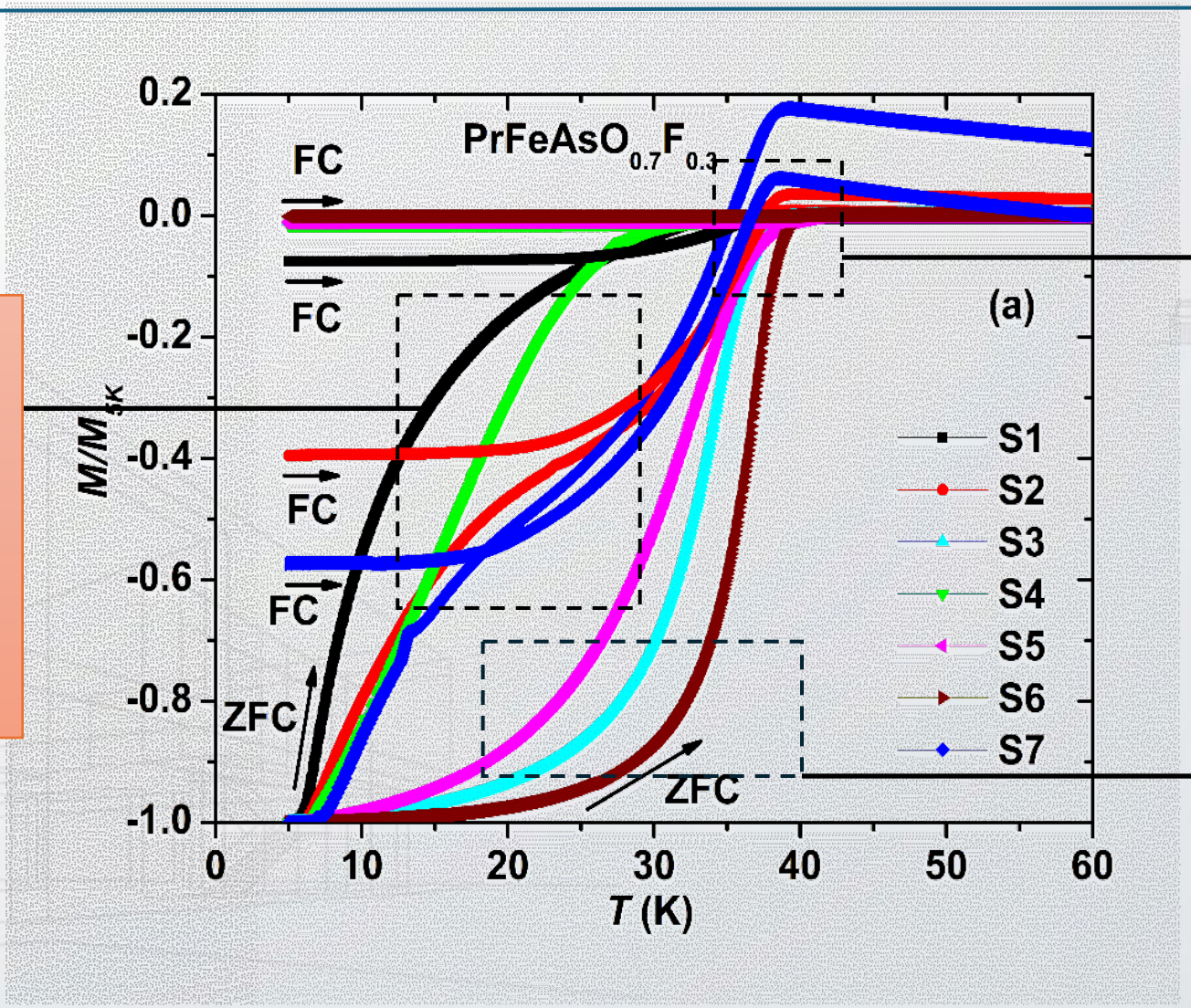
Transition width of ~ 2.6 K for S5 and S6 samples

Max T_c for sample S5 (870 MPa)



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Magnetic Properties



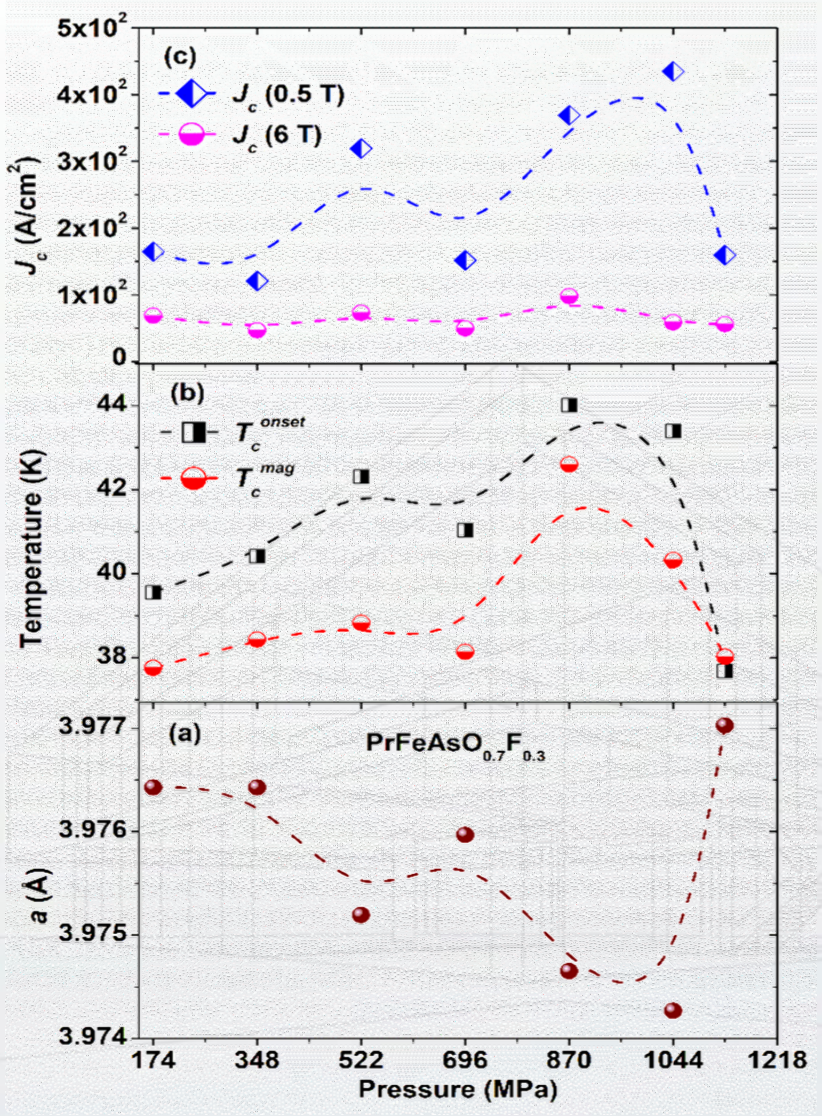
Low-pressure samples show broader two-step magnetic behavior,
May be consistent with weak intergranular coupling.

Magnetic Tc increase toward the intermediate-pressure region

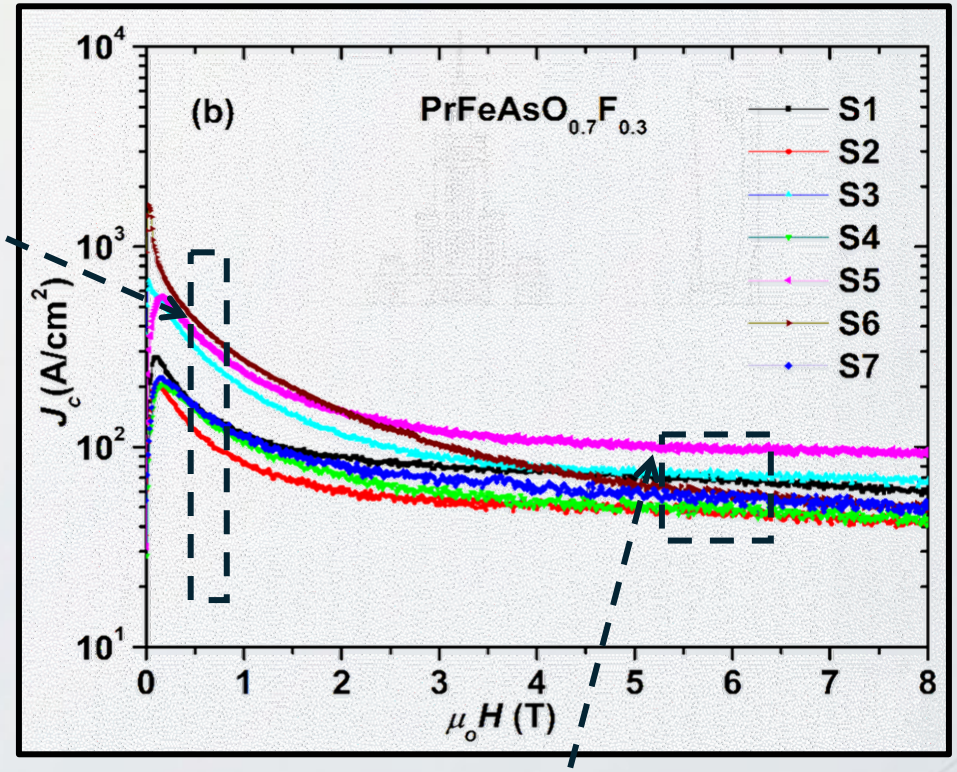
Two-step feature is suppressed as density and intergrain connectivity improve

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Current Density (Bean Model)



Max J_c for S6 at Lower Field



Max J_c for S5 at Higher Field

For J_c

Bean Critical State Model

$$Jc = \frac{20\,\Delta M}{aV(1-\frac{a}{3b})}$$

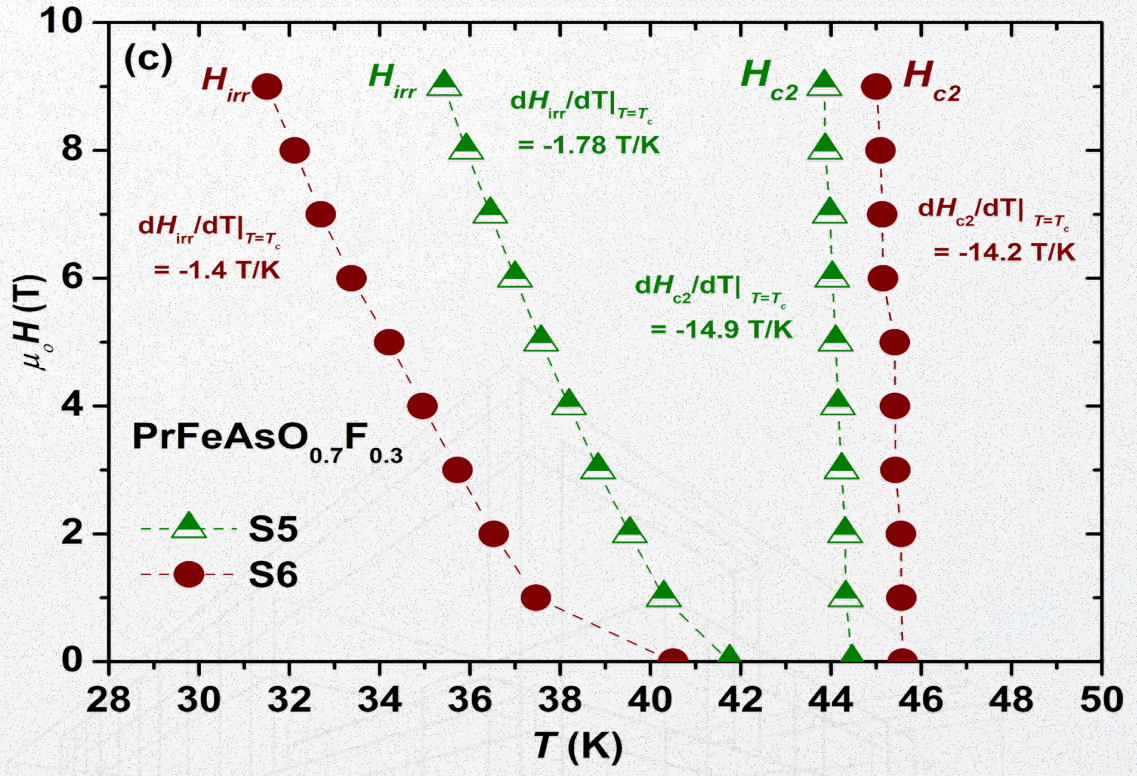
ΔM – Width of Magnetic Hysteresis

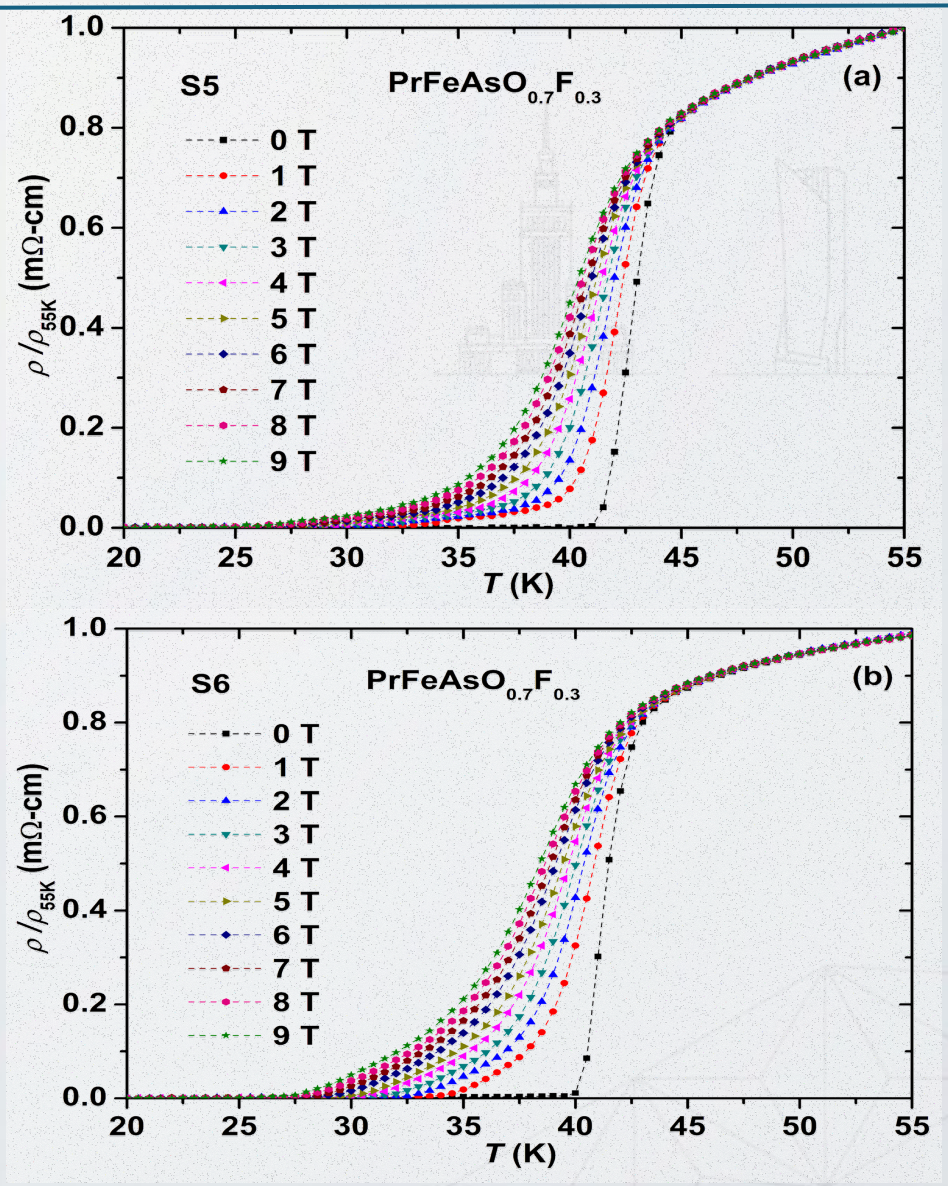
V – Volume

a,b – Dimension of Sample with a<b

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Magneto-Resistance Measurement





- H_{c2} extracted using 90% Normal state resistivity criterion ρ_n.
- H_{irr} extracted using 10% Normal state resistivity criterion ρ_n.
- Using WHH approximation the extrapolated limiting orbital field $\boldsymbol{H_{c2} > 100\ T}$ for S5 and S6.

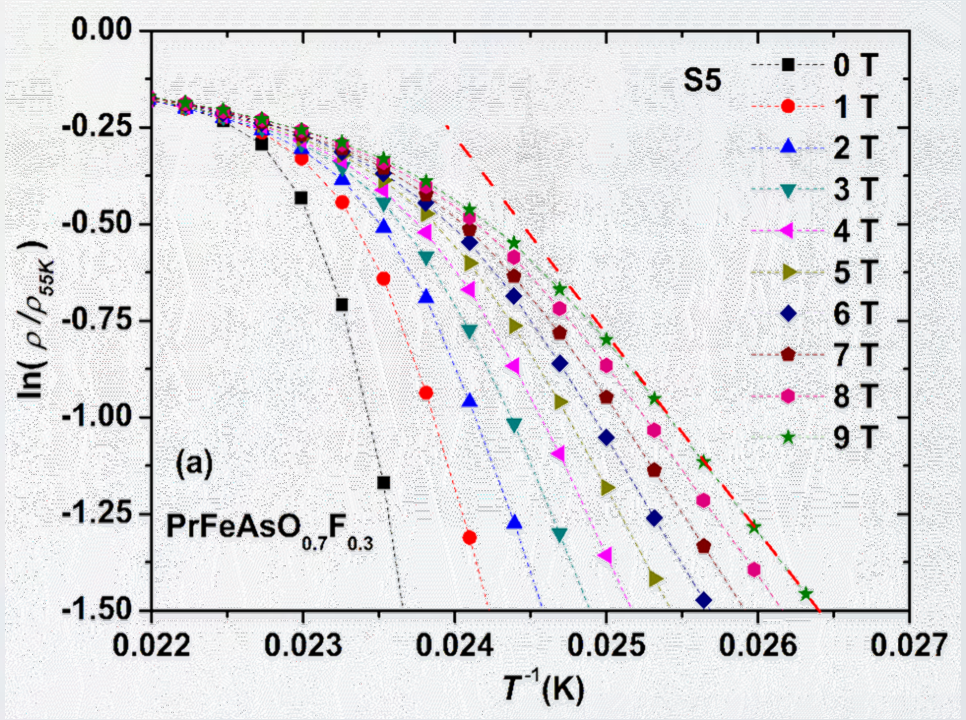
Jayant *et al.* Submitted to *Journal of Alloys and Compounds* (2026)

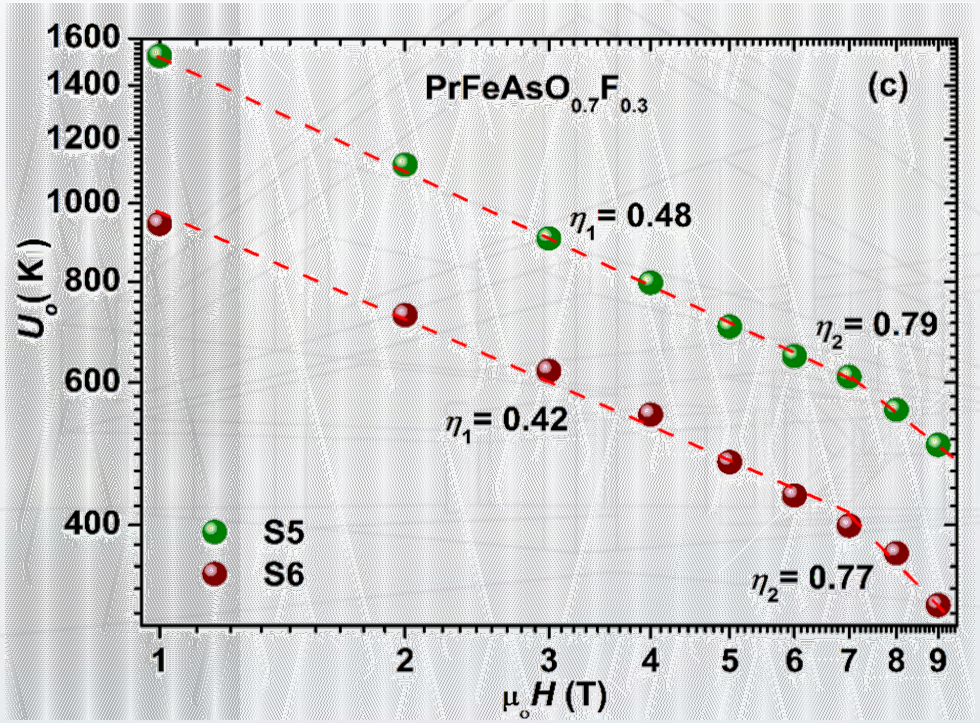
Magneto-Resistance Measurement

TAFF Analysis

Arrhenius plot is used to calculate the Activation energy

$$\ln\left(\frac{\rho}{\rho_o}\right) = -\left(\frac{Uo}{K_B T}\right)$$





- S5 retains the larger U_0 over the measured field range.
- The effective activation energy U_0 decreases with increasing field for both S5 and S6.

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Conclusion

~ 900 MPa

Optimum nominal pelletization pressure

T_c^{onset} ~ 44.2 K
Maximum Density ~ 54%
Higher J_c + larger U_o

01 Above ~ 1 GPa, secondary phases increase and density / transport performance decline.

02 T_c rises, the transition narrows, and intergrain weak-link behavior is suppressed.

03 S5 retains the larger U_o and Orbital limiting field of greater than 100 T

04 Lattice parameter a decreases up to S5, while c shows no significant change.

05 For J_c S6 performs best at low field, while S5 performs best at high field.

Jayant *et al.* Submitted to *Journal of Alloys and Compounds* (2026)

Acknowledgment

- Dr. Hab Shiv J Singh for the guidance and supervision.
  Institute of High-Pressure Physics, Polish Academy of Sciences, Warsaw, Poland
- Dr. Tatiana, Dr. Yaroslaw Konopelnyk for Magnetic measurements
  Institute of Physics, Polish Academy of Sciences, Warsaw, Poland
- Dr. Konrad Kwatek for XRD measurements
  Faculty of Physics, Warsaw University of Technology, Warsaw, Poland
- Tomasz Cetner for the help of High-pressure experiments
  Institute of High-Pressure Physics, Polish Academy of Sciences, Warsaw, Poland
- Dr. Cezariusz Jastrzebski, Taras Palasyuk for Raman spectroscopy measurements and DFT calculations
  Faculty of Physics, Warsaw University of Technology, Warsaw, Poland

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Thank you very much for your attention