Critical currents and vortex-glass behavior in $Ba(Fe,Ni)_2As_2$ single crystals.

[1,3]K. Pervakov, [1]V. Vlasenko, [1]S. Gavrilkin,
[2,3]E. Khlybov, [1]V. Pudalov and [1]Yu. Eltsev

[1]P. N. Lebedev Physical Institute, Russian Academy of Sciences,
[2]Institute for High Pressure Physics, Russian Academy of Sciences,
[3]International Laboratory of High Magnetic Fields and Low Temperatures.

Different families of Fe-based superconductors

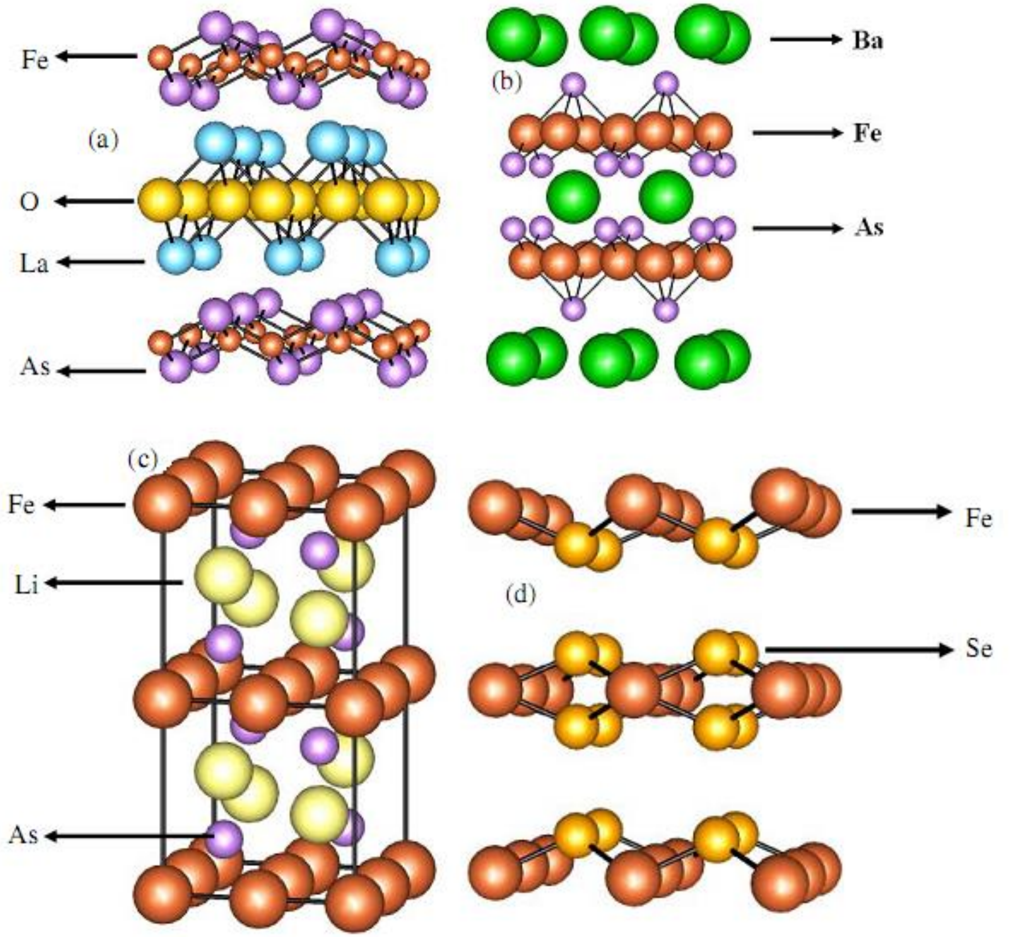
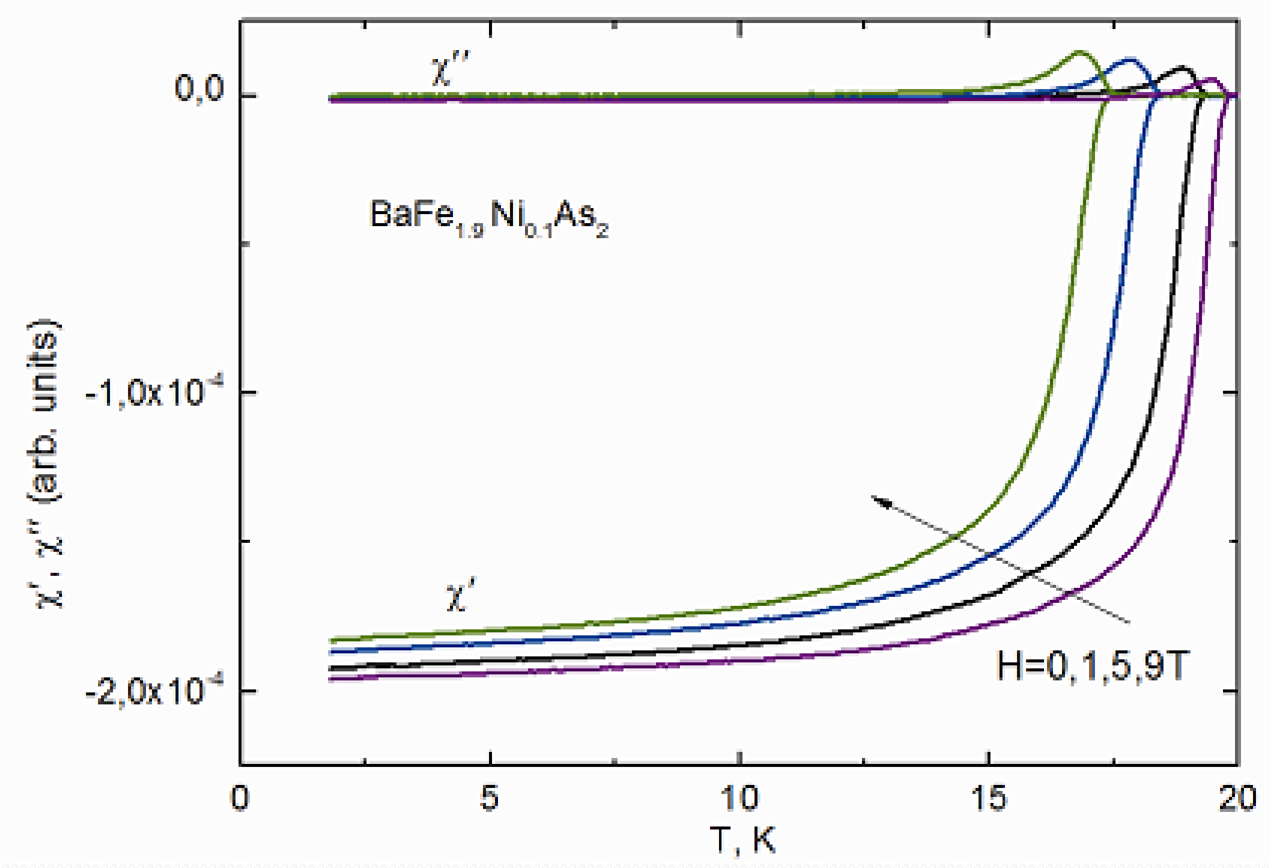
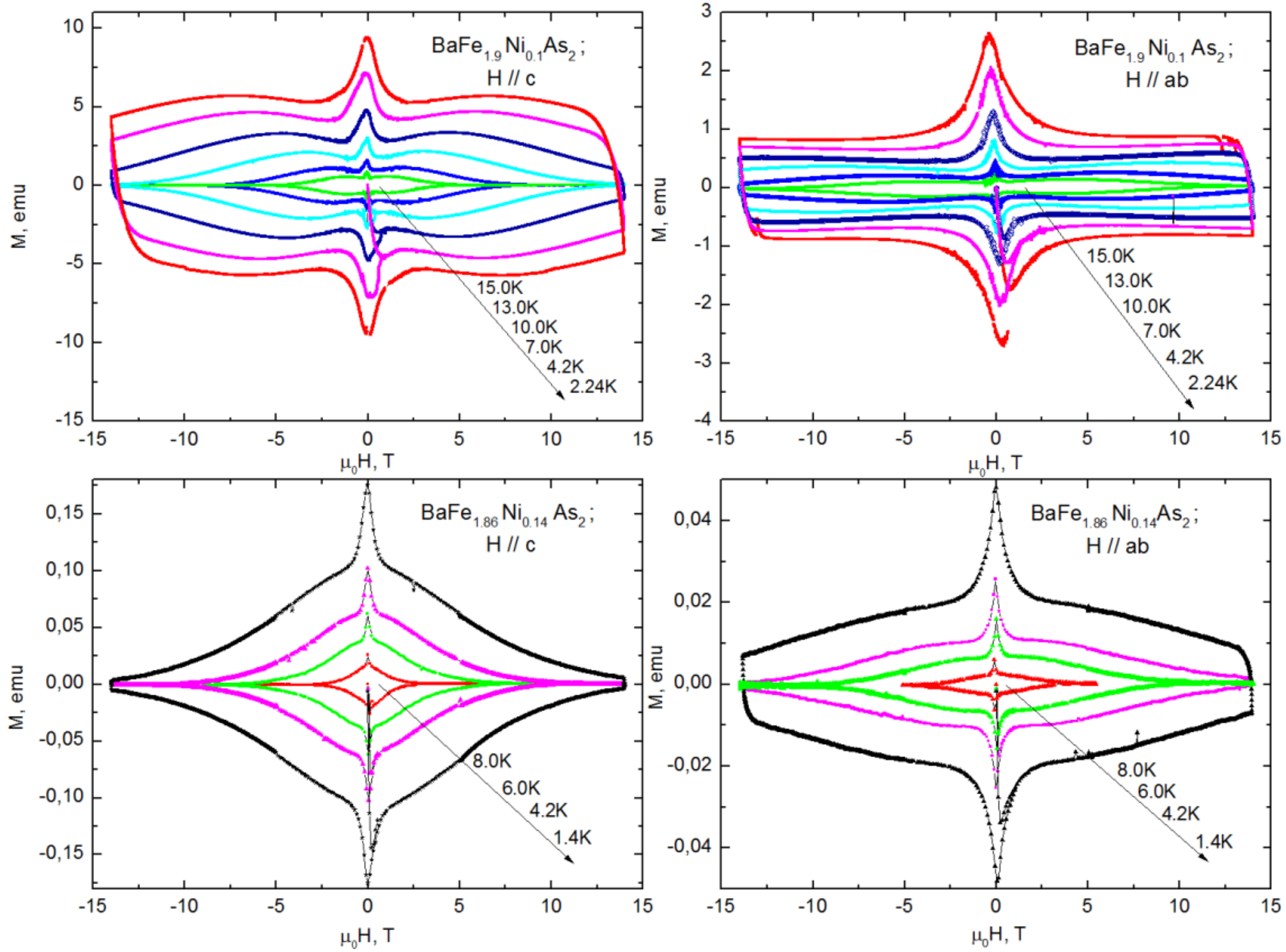


Figure 1. Crystal structure of the four categories of iron pnictides (a) '1111' type (b) '122' type (c) '111' type (d) '11' type.

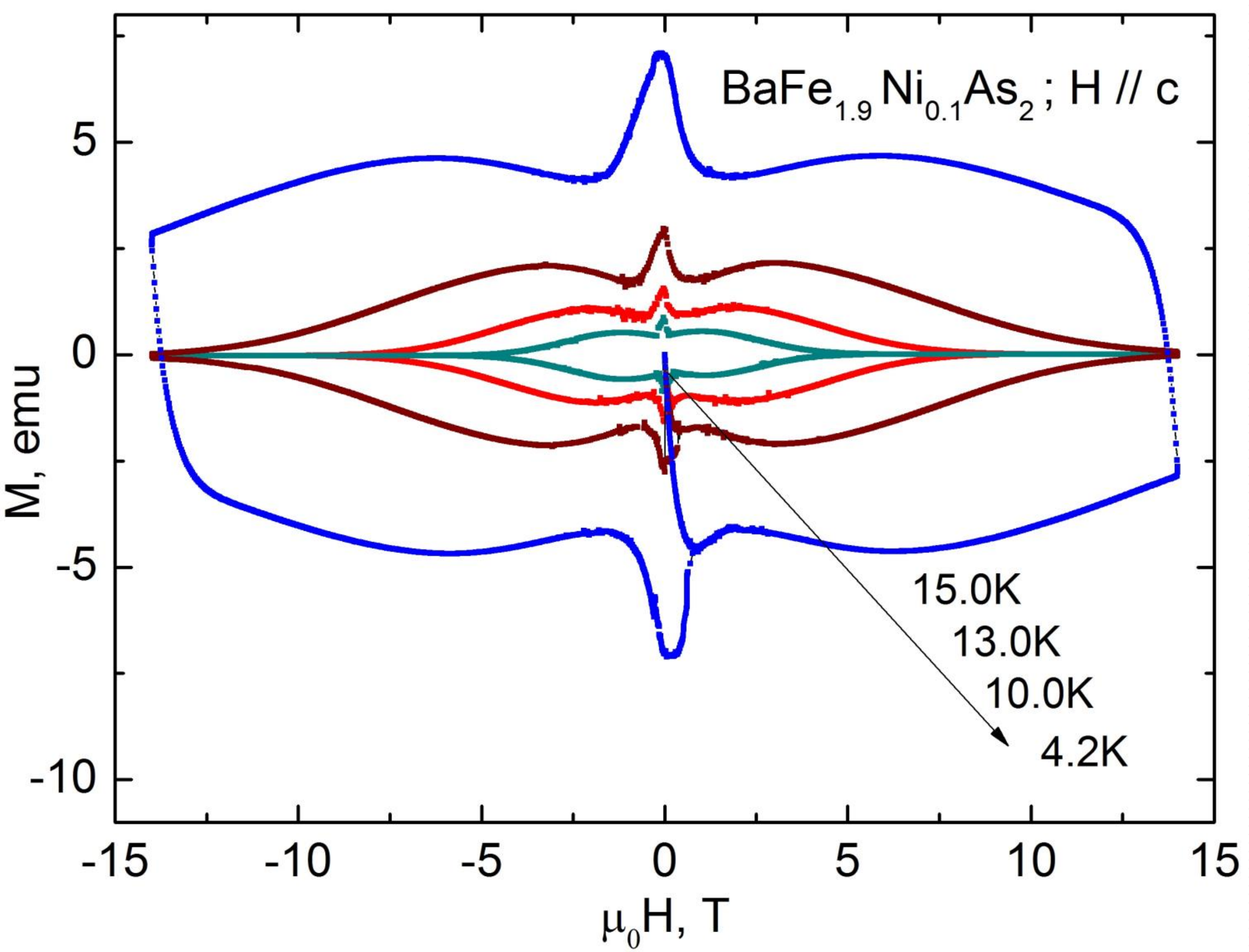
Temperature dependence of ac-susceptibility Ni-doped 122 single crystals



Bulk magnetization *vs* magnetic field Ni-doped 122 crystals



Bulk magnetization *vs* magnetic field Ni-doped 122 crystals

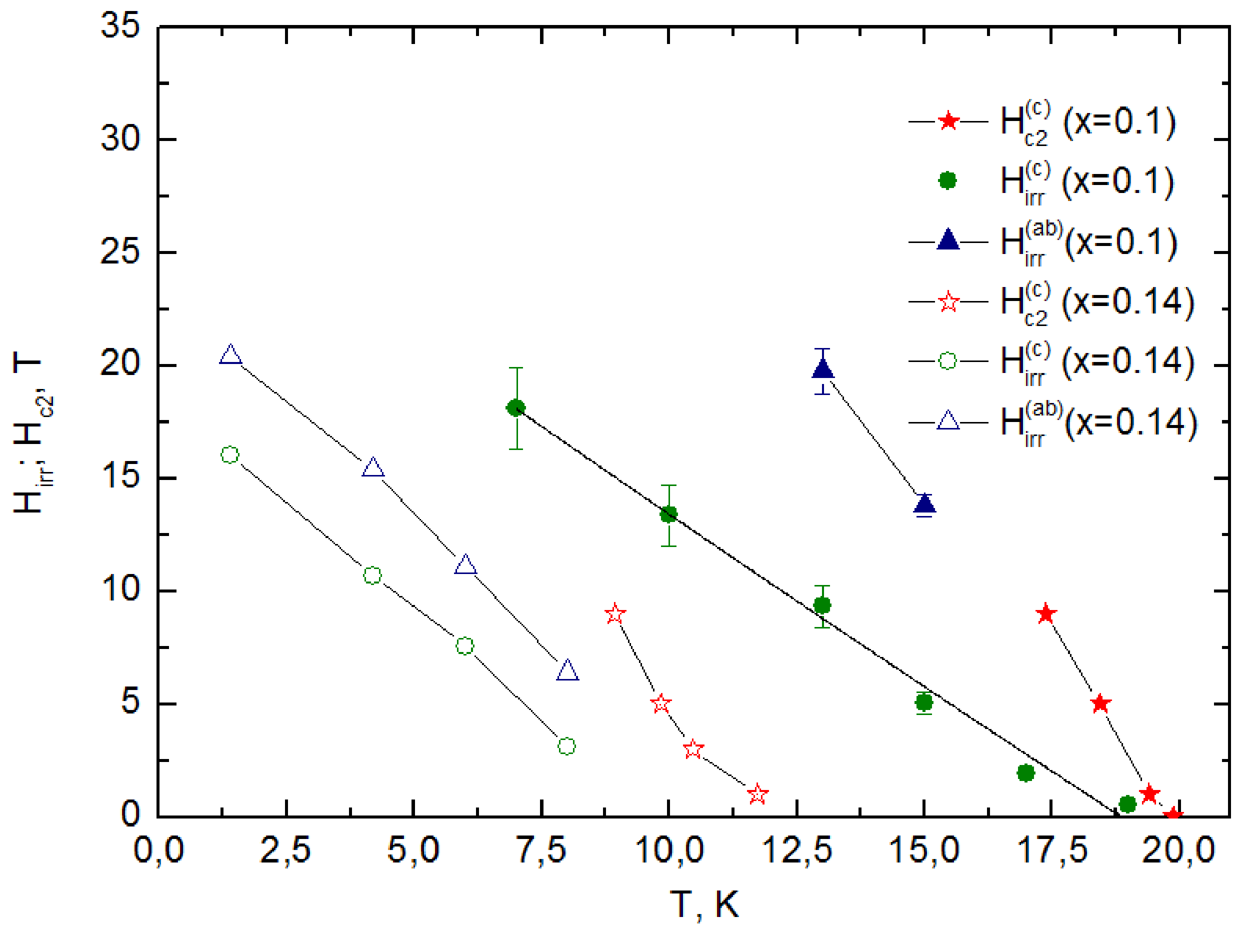


$$J_c = 20\,\Delta M/a(1 - a/3b)$$

$$\Delta M = M_{down} - M_{up},$$

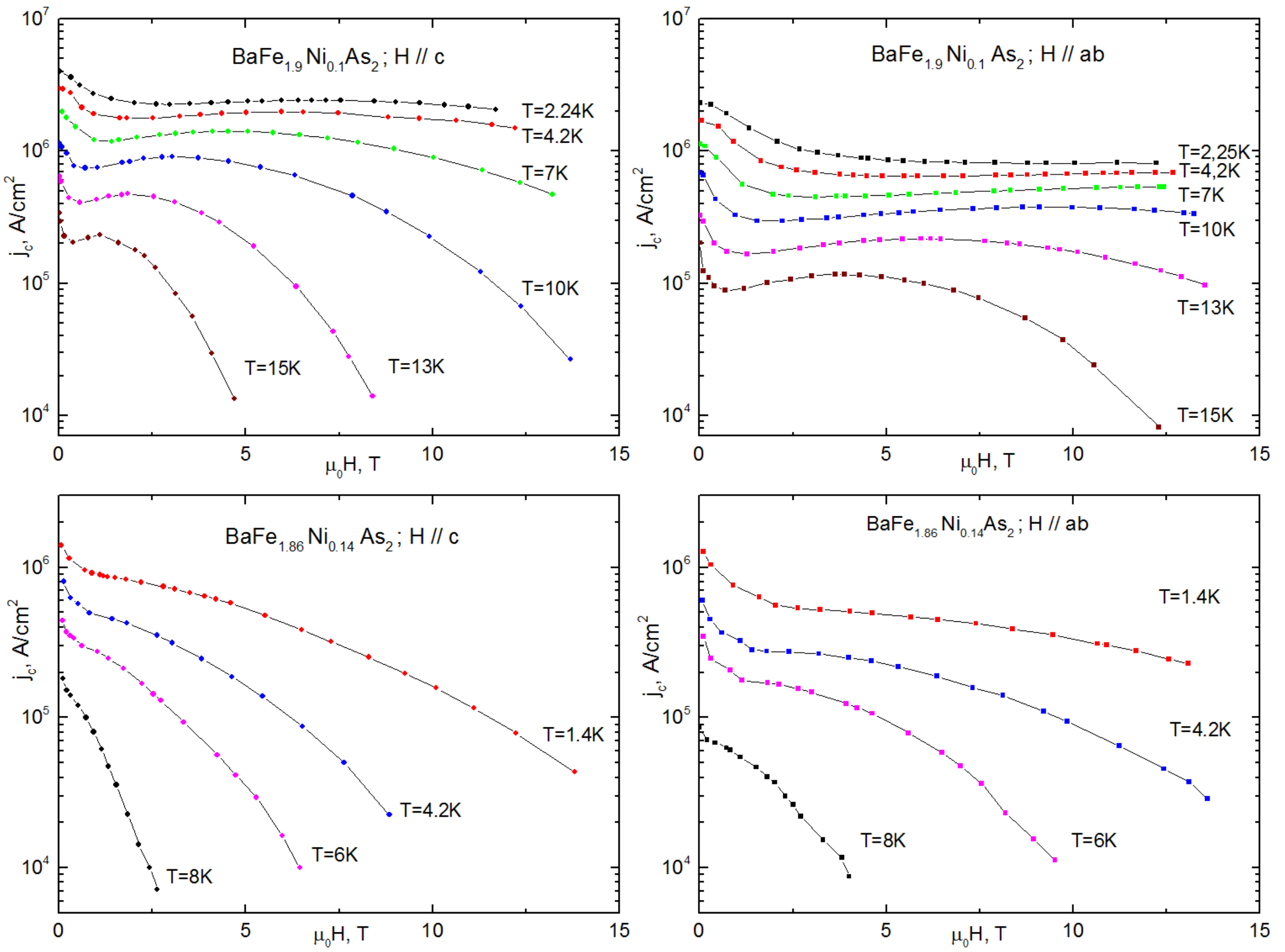
$$M = M_0 + A\exp(C \times H)$$

Magnetic phase diagram of Ni-doped 122 single crystals from M(H) measurements

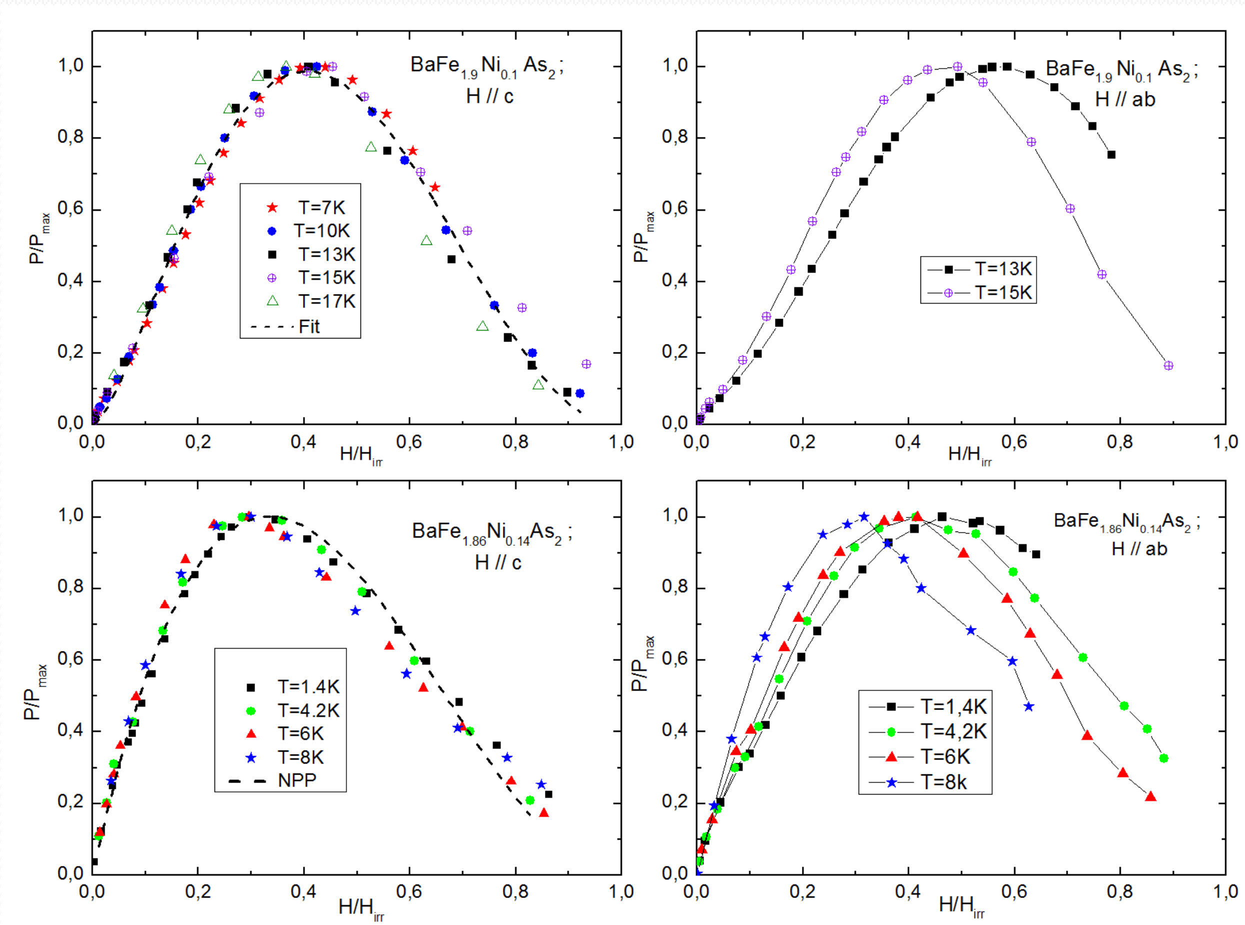


H_{c2}/dT ≈4.2T/K for $BaFe_{1.9}Ni_{0.1}As_2$ H_{c2}/dT ≈3.6T/K for $BaFe_{1.86}Ni_{0.14}As_2$

Critical current of Ni-doped 122 single crystals



Scaling of normalized pinning force vs reduced field in Ni-doped 122 single crystals



$$f_p = \frac{F_p}{F_p^{max}} = J_c(H) \times H / (J_c(H) \times H)_{max}$$

$$h = H/H_{irr}$$

$$f_p \propto h^p(1-h)^q$$

h_{max}=0.2 suggests grain-boundary pinning

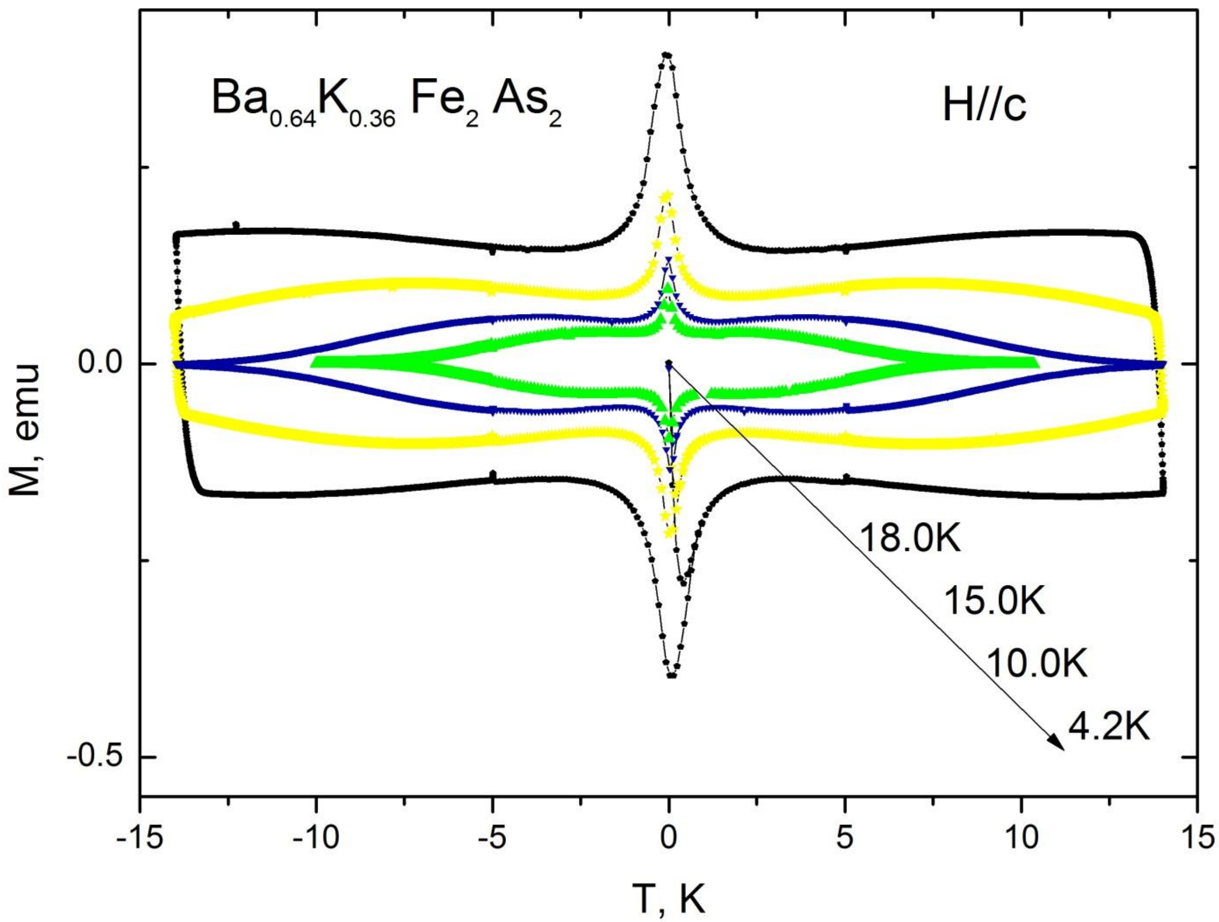
h_{max}=0.33 corresponds to NPP pinning

h_{max}=0.7 is due to pinning caused by the order parameter spatial variations

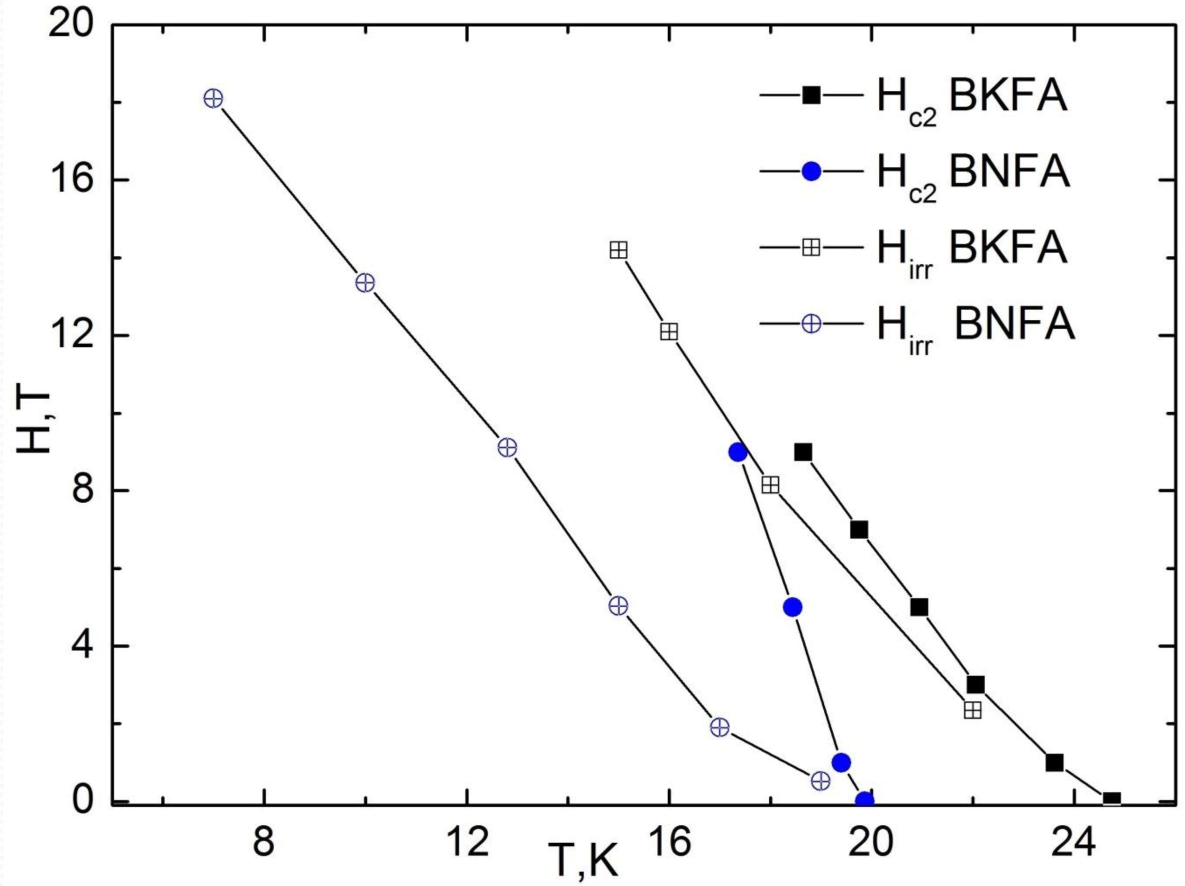
Data for single crystals of 122 family of different compositions with around optimal doping level

composition	T_c, K	dH_{c2}/dT, T/K	J_c, A/cm²	$h_{max}=H_{max}/H_{irr}$	reference
$BaFe_{1.9}Ni_{0.1}As_2$	19.5	-4.2	$3x10^6$ (at 4.2K)	0.4	Supercond. Sci. Technol, **26**, 015008 (2013).
$BaFe_2As_{1.36}P_{0.64}$	28	-	$4x10^5$(at 15.4K)	0.7	Phys.Rev. B **84**, 140504(R) (2011).
$BaFe_{1.84}Co_{0.16}As_2$	24.1	-8	$9x10^5$ (at 4 K)	-	Phys. Rev. B **81**, 014503 (2010)
$Na_{0.75}Ca_{0.25}Fe_2As_2$	33.4	-	$1.1x10^6$ (at 5 K)	-	Phys. Rev. B **84**, 094522 (2011).
$BaFe_{1.86}Co_{0.14}As_2$	22	-	$2.6x10^5$ (at 5 K)	-	Phys. Rev. B **78**, 224506 (2008)
$BaFe_{1.8}Co_{0.2}As_2$	24	-1.7	$6x10^5$ (at 5 K)	-	J. Phys. Soc. Jpn. **78**, 023702 (2009)
$BaFe_{1.8}Co_{0.2}As_2$	22	-2.5	$4x10^5$(at 4.2 K)	0.45	Appl. Phys. Lett. **94**, 062511 (2009).
$BaFe_{1.9}Ni_{0.1}As_2$	17.6	-4.2	$4x10^5$(at 2 K)	-	J. Appl. Phys. **109**, 07E151 (2011)
$Ba_{0.72}K_{0.28}Fe_2As_2$	32	-4.4	$3x10^5$(at 7 K)	-	Phys. Rev. B **82**, 024525 (2010)
$Ba_{0.65}Na_{0.35}Fe_2As_2$	29.4	-	$1x10^6$ (at 5 K)	0.28	arXiv:1205.2210v1 (2012)
$Ba_{0.68}K_{0.32}Fe_2As_2$	38.5	-3.4	$1.1x10^6$ (at 10 K)	0.43	Phys. Rev. B 80, 144515 (2009)
$BaFe_{1.85}Co_{0.15}As_2$	24.5	-2.0	$4.2x10^5$ (at 10 K)	0.37	Phys. Rev. B 80, 144515 (2009)
$BaFe_{1.91}Ni_{0.09}As_2$	18.5	-2.2	$2.3x10^5$ (at 10 K)	0.32	Phys. Rev. B 80, 144515 (2009)

Bulk magnetization *vs* magnetic field of K-doped 122 crystals



Comparative study of magnetic phase diagram of hole- and electron doped 122 single crystals with close T_c values



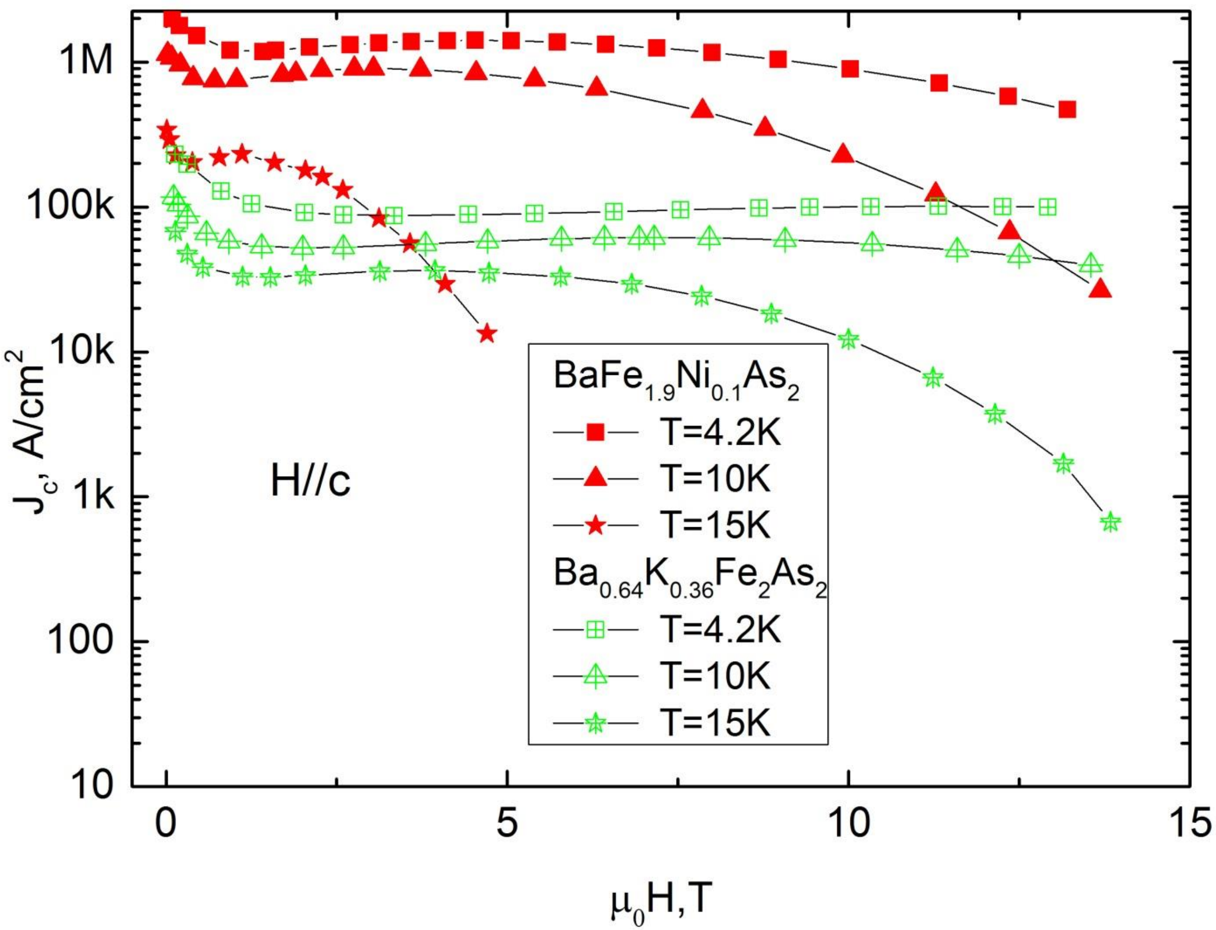
dH_{c2}/dT ≈-4.2T/K for $BaFe_{1.9}Ni_{0.1}As_2$

$H_{c2}(0) = 0.69T_c(dH_{c2}/dT)$ ≈55T

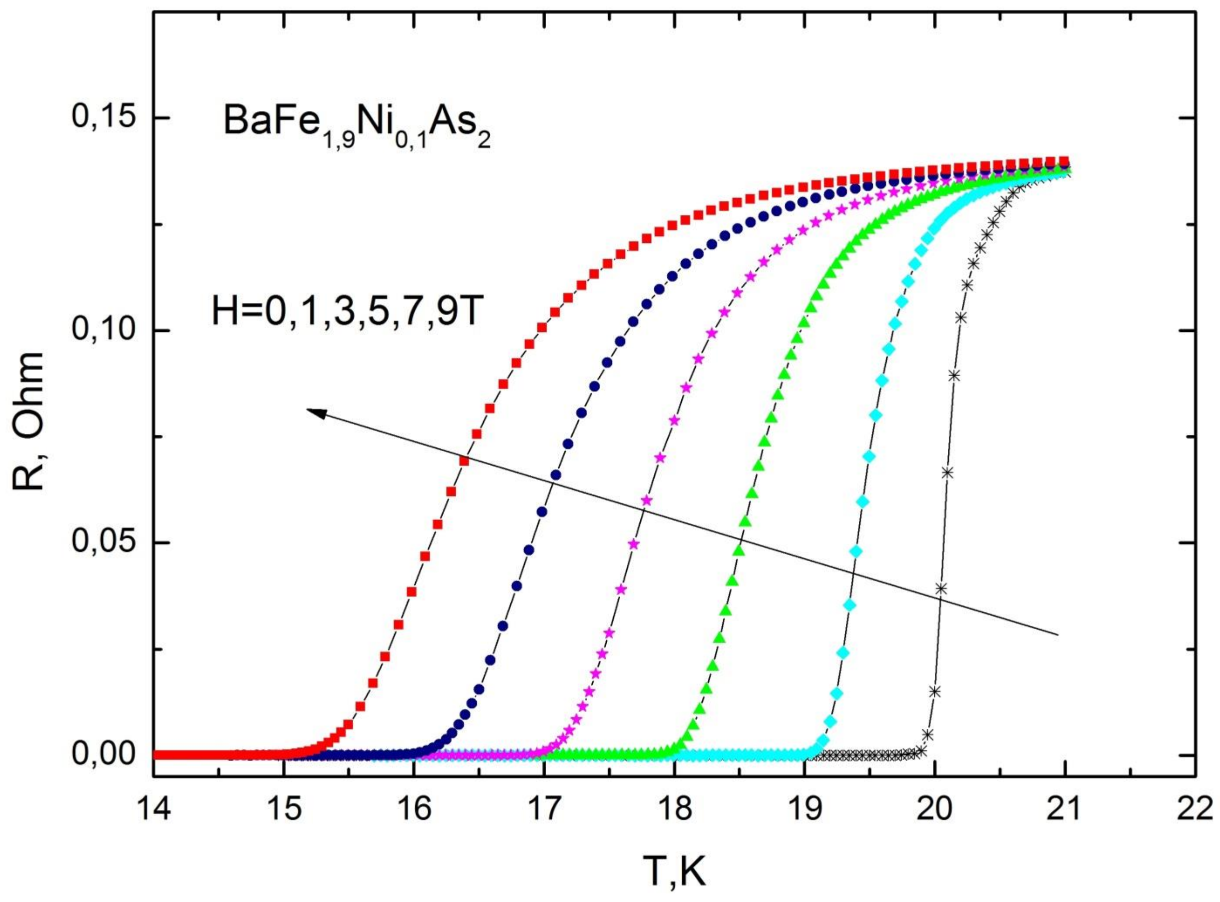
dH_{c2}/dT ≈-1.75T/K for $Ba_{0.64}K_{0.36}Fe_2As_2$

$H_{c2}(0) = 0.69T_c(dH_{c2}/dT)$ ≈31T

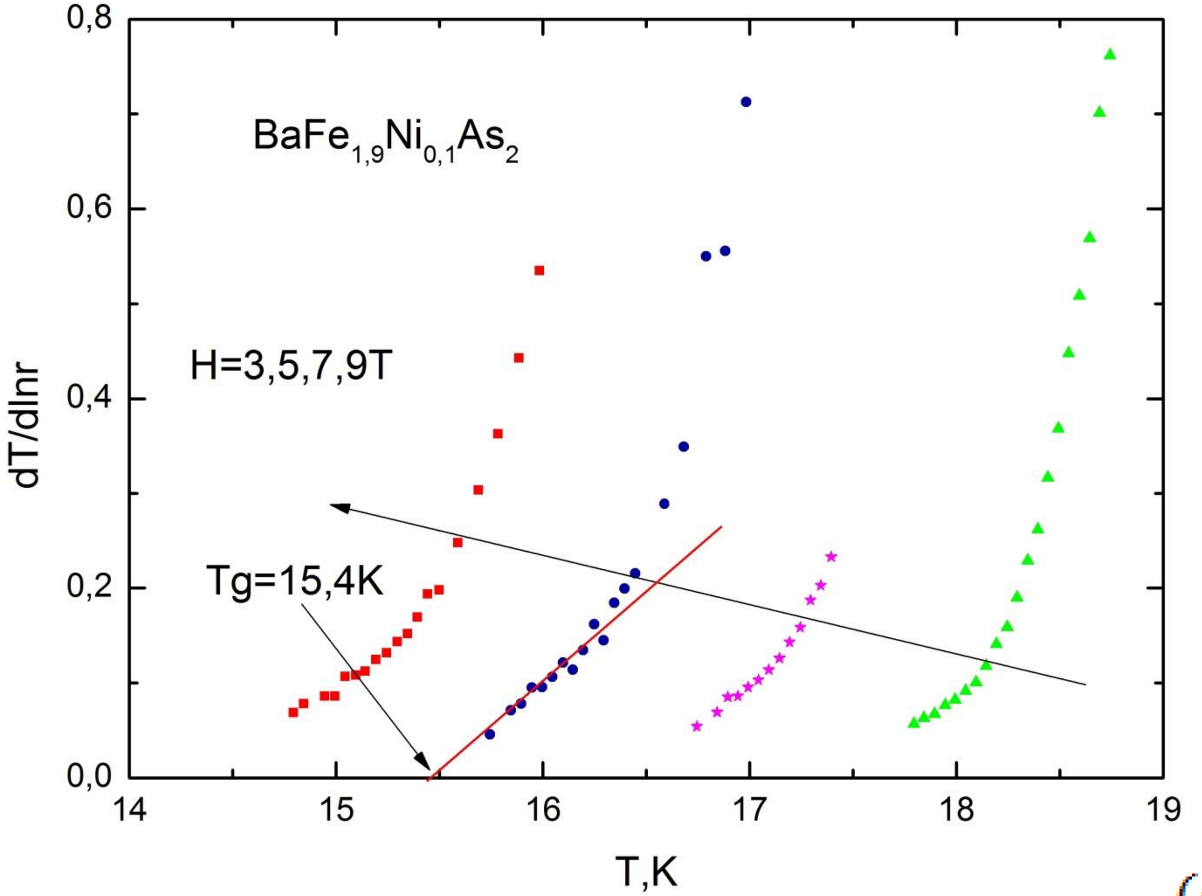
Comparative study of critical currents of hole- and electron doped 122 single crystals with close T_c values



Resistive transition of BaFe1.9Ni0.1As single crystals in magnetic field



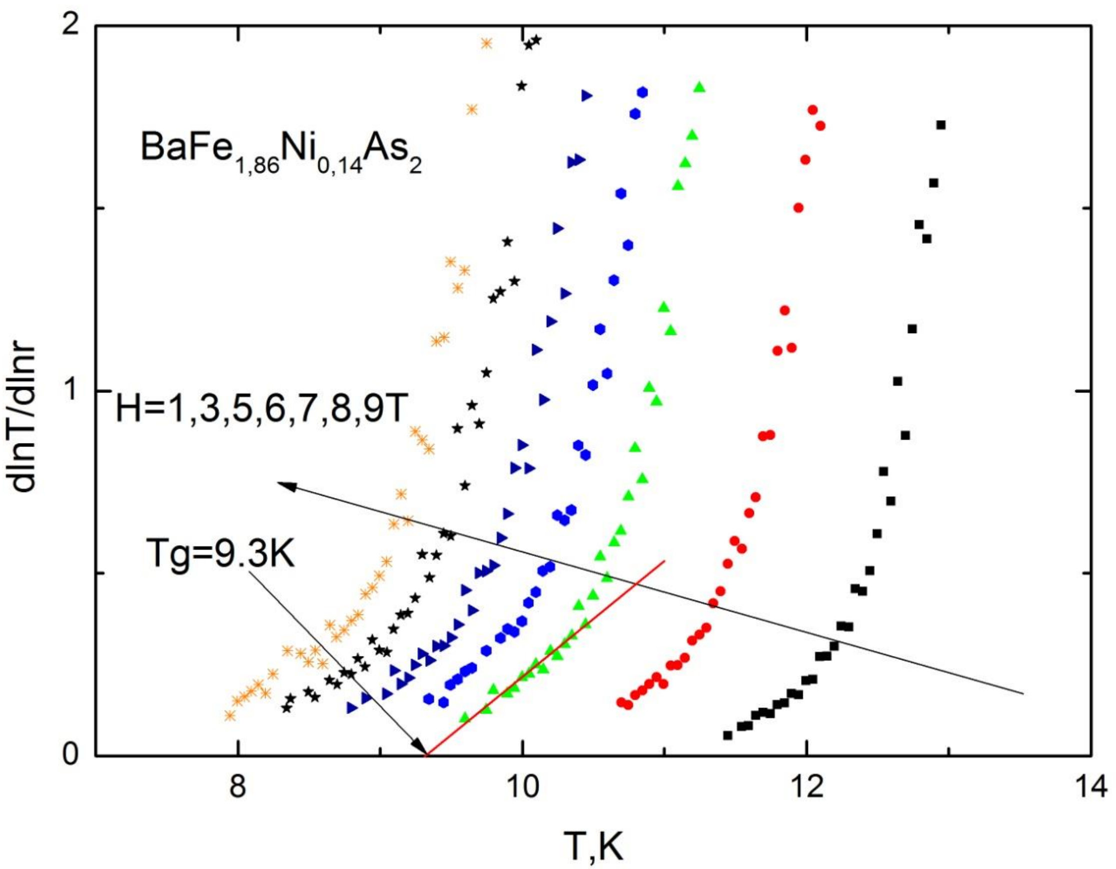
Resistive transition of BaFe1.9Ni0.1As single crystals in Vogel-Fulcher coordinates



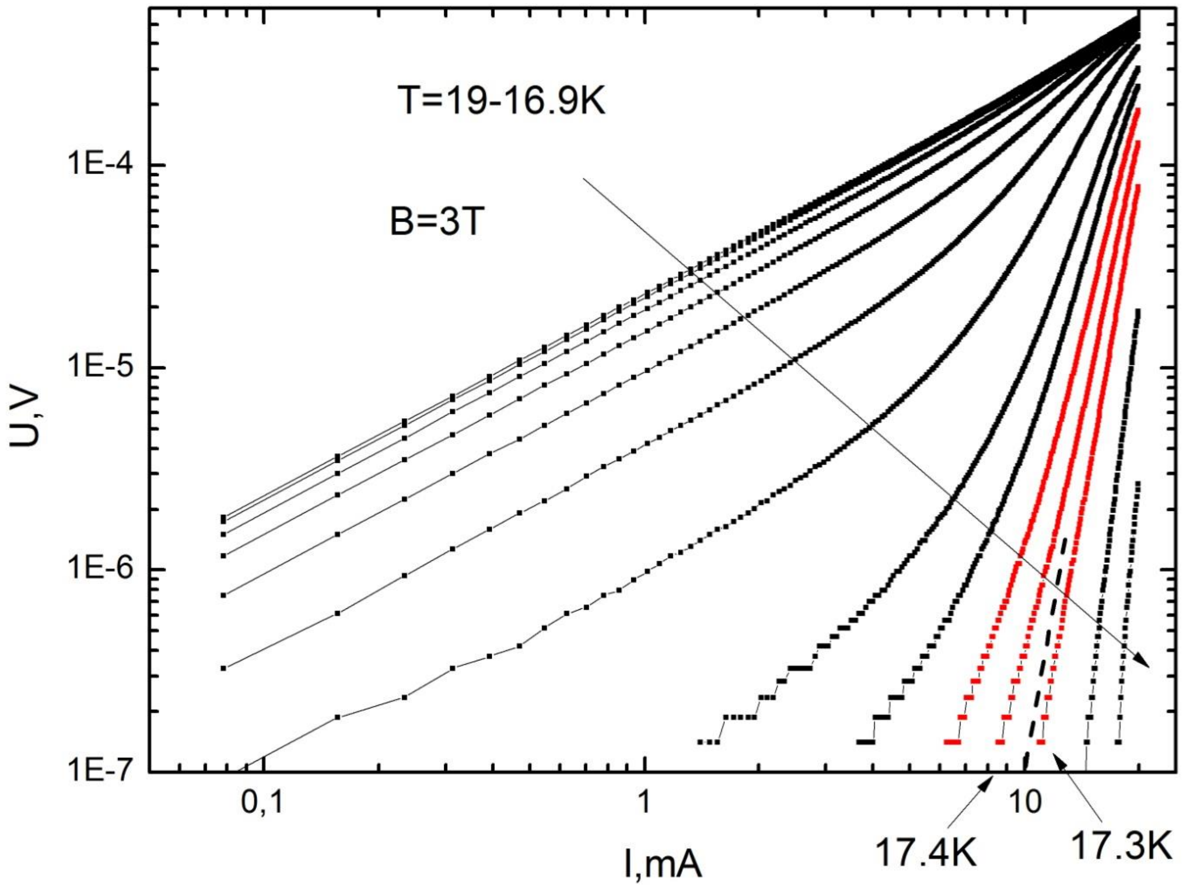
$$R \sim (T - T_g)^{\nu(z-1)}$$

$$(d\ln R/dT)^{-1} \sim (T - T_g)$$

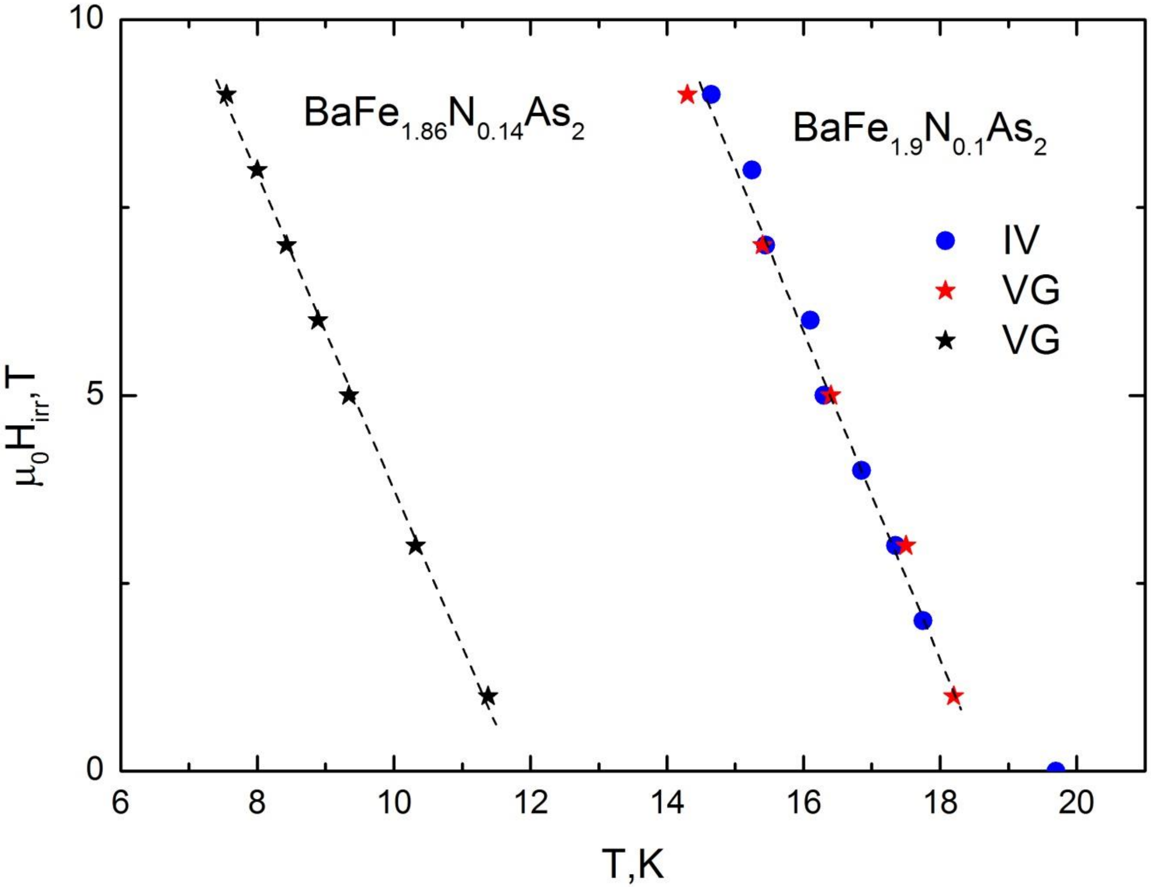
Resistive transition of BaFe1.86Ni0.14As single crystals in Vogel-Fulcher coordinates



I-V curves of $BaFe_{1.9}Ni_{0.1}As$ single crystals near vortex-glass melting temperature



Magnetic phase diagram of Ni-doped 122 single crystals from R(T) measurements



Conclusions

1. For Ni-doped samples we observed critical current density exceeding 10^6 A/cm^2 at low temperature suggesting strong intrinsic pinning in these samples.
2. For Ni-doped samples and for H//*c*-axis field orientation, the curves of normalized pinning force $f_p = F_p/F_p^{max}$ vs $h = H/H_{irr}$, measured at different temperatures fall in a single curve with peak position $h_{max} \approx 0.33$ for $BaFe_{1.86}Ni_{0.14}As_2$ crystal and $h_{max} \approx 0.4$ for $BaFe_{1.9}Ni_{0.1}As_2$ sample indicating single dominating normal point pinning mechanism.
3. In the H//*ab*-planes geometry where shielding current consists of two components parallel and perpendicular to the c-axis $f_p(h)$ curves show no scaling.
4. Critical current density of $BaFe_{1.9}Ni_{0.1}As_2$ crystal exceeds J_c for $Ba_{0.64}K_{0.36}Fe_2As_2$ at fields below ~1T. With increasing field difference between J_c values for $BaFe_{1.9}Ni_{0.1}As_2$ and $Ba_{0.64}K_{0.36}Fe_2As_2$ crystals rapidly decreases, thus, demonstrating higher critical currents in $Ba_{0.64}K_{0.36}Fe_2As_2$ samples in strong magnetic fields above ~10-15T.
5. Temperature dependence of the resistance as well as IV-characteristics may be described within vortex-glass model.

Thank you for your attention!