

Fe(Se,Te) epitaxial thin films deposited on flexible metallic substrates

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Coworkers

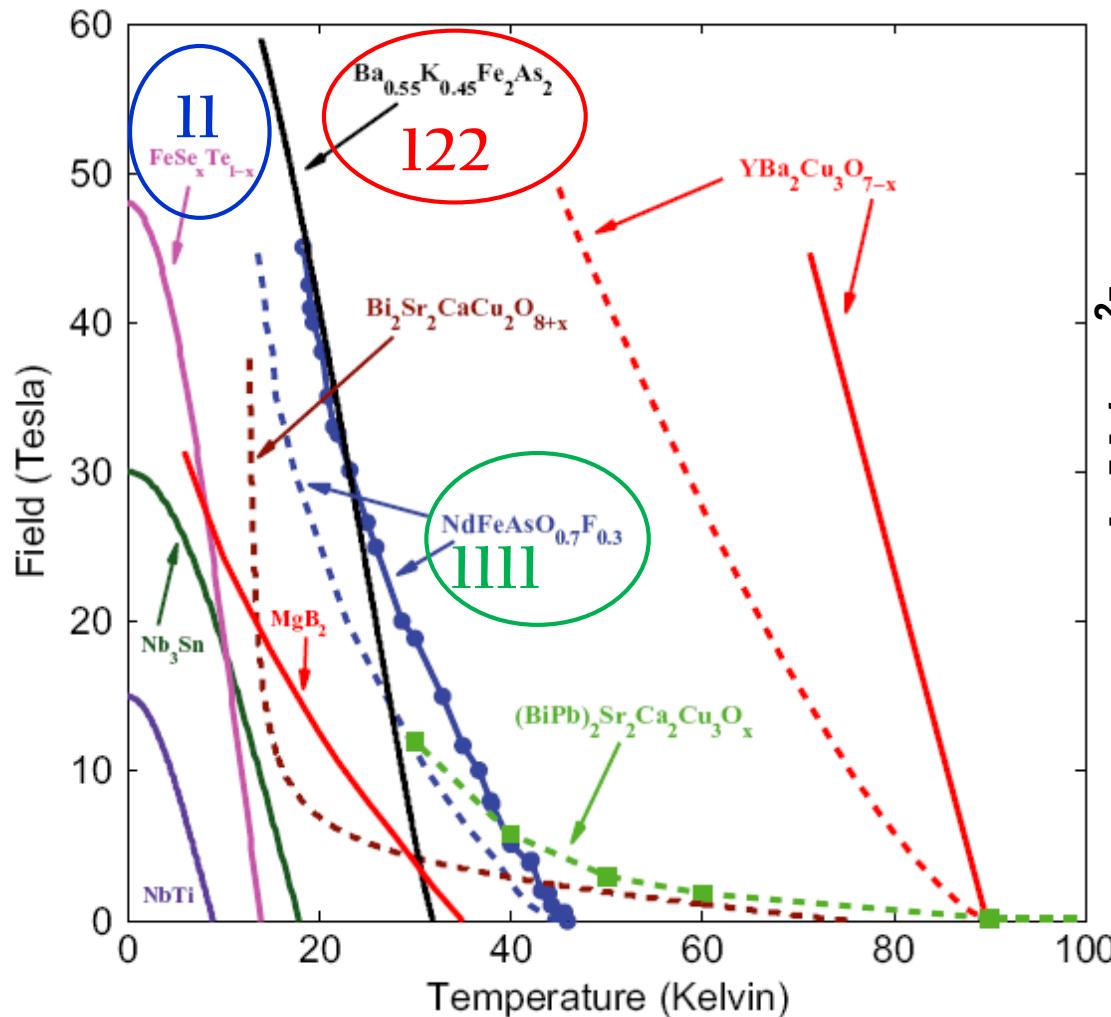
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CNR-SPIN Genova, Italy

Andrea Augieri, Giuseppe Celentano, Antonella Mancini, Angelo Vannozzi
ENEA Frascati, Italy

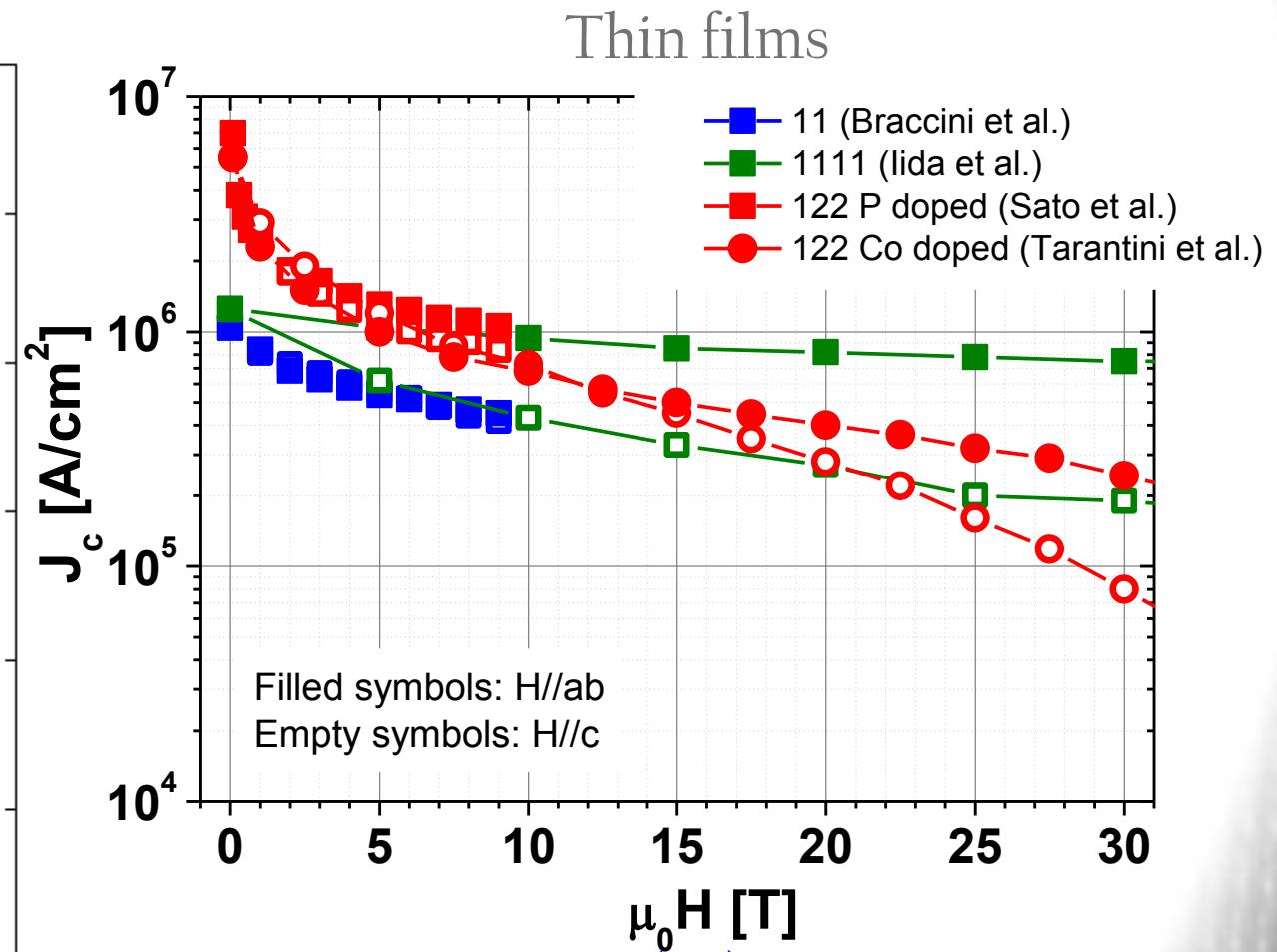
Acknowledgements

Amalia Ballarino and Simon Hopkins, CERN:
collaboration within the Addendum FCC-GOV-CC-0086
of the Memorandum of Understanding FCC-GOV-CC-0004 for the FCC study

H_{c2} and J_c of technical conductors: comparison



C. Tarantini et al., PRB 84, 184522 (2011)



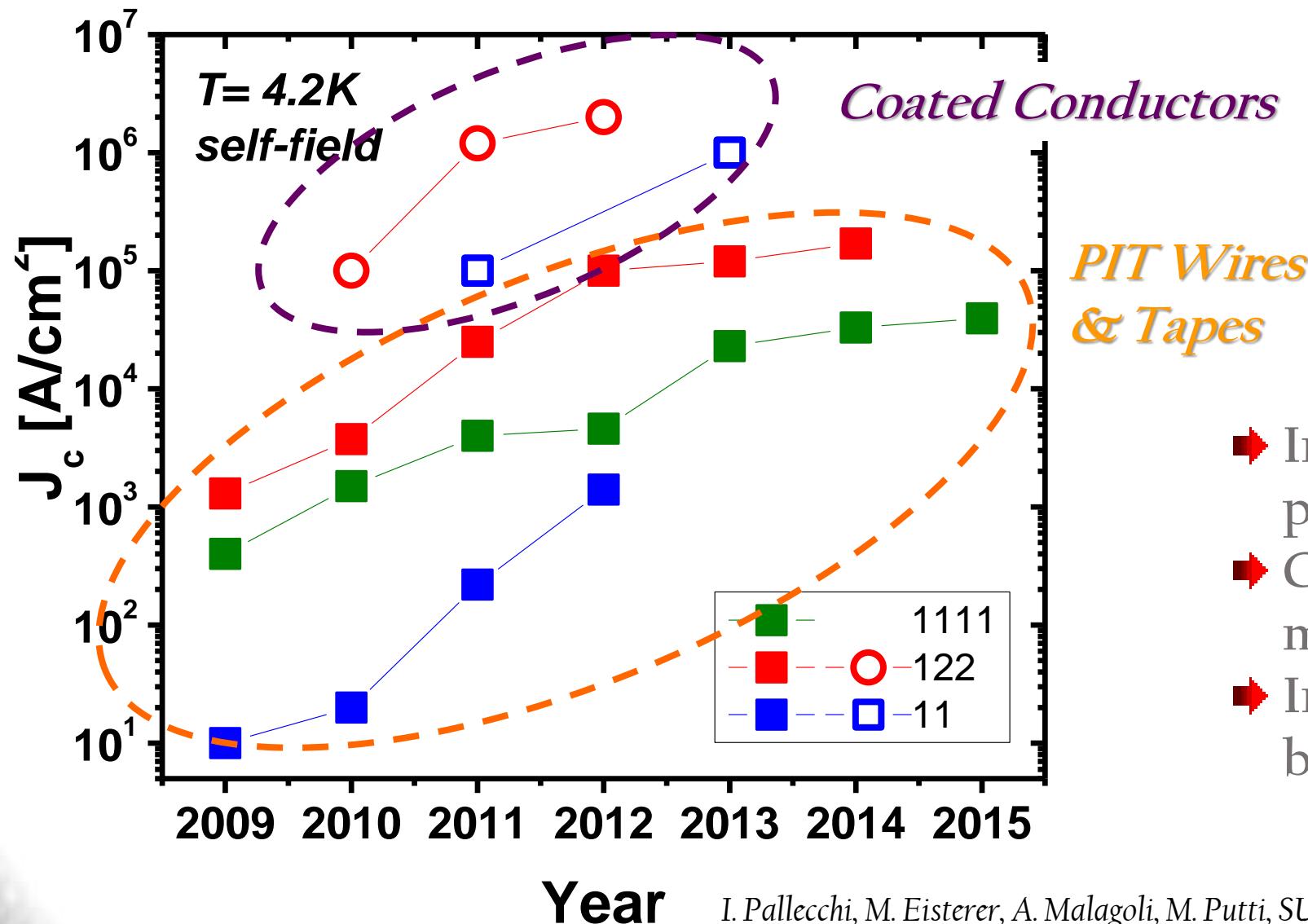
V. Braccini, APL 103, 172601 (2013)

Iida, Sci. Rep. 3:2139 (2013)

Tarantini et al., Sci. Rep. 4, (2014)

Sato et al., Applied Physics Letters 104, 182603 (2014)

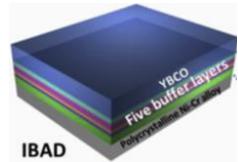
J_c of technical conductors: comparison



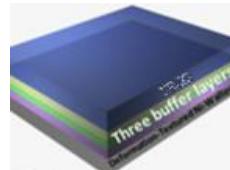
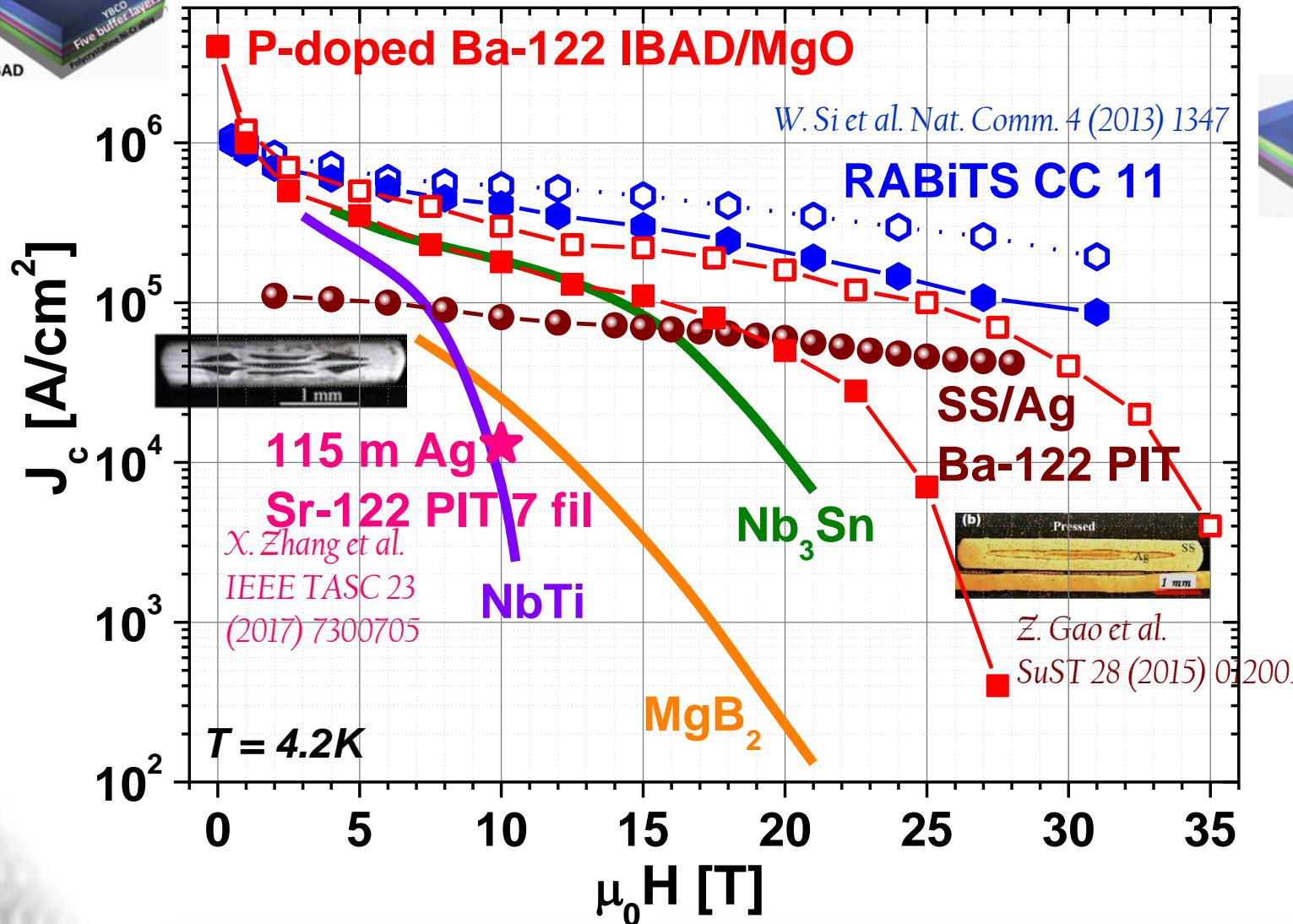
- Improving the phase purity
- Controlling the mechanical processes
- Increasing the density by HP

I. Pallecchi, M. Eisterer, A. Malagoli, M. Putti, SUST (2015) 28

J_c of technical conductors: comparison

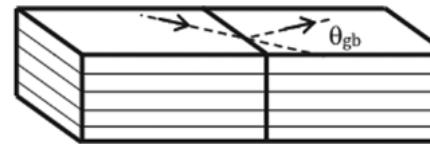
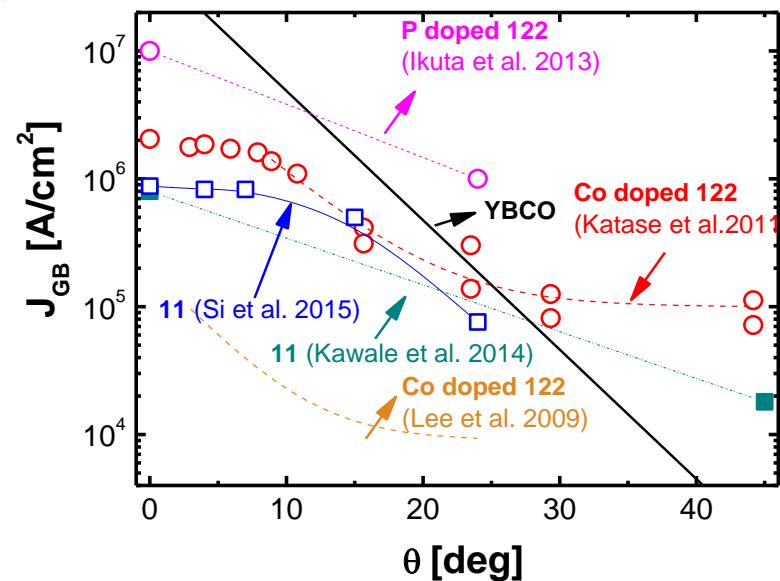


K. Iida et al. Sci. Rep. 7 (2017) 39951



Outstanding J_c reached
in short samples,
feasibility of long
conductors proven

Dependence of J_c on the misorientation angle

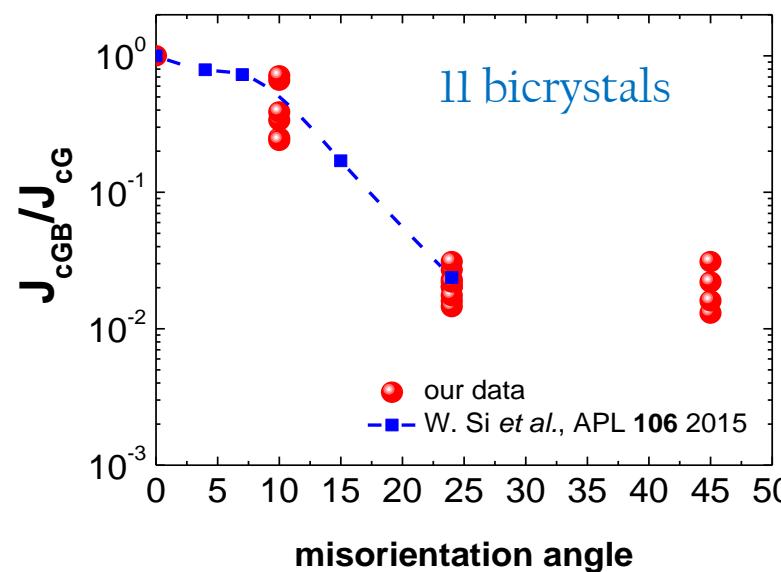


122 bicrystals

Lee et al., *Appl. Phys. Lett.* 95, 212505 (2009).
Katase et al., *Nat. Commun.* 2, 409 (2011)
Sagakami et al., *Physica C* 494 (2013) 181–184

11 bicrystals

Kawale et al., ASC 2014
Si et al., *Appl. Phys. Lett.* **106** 032602 (2015)



In HTS J_c decreases exponentially with GB angle.

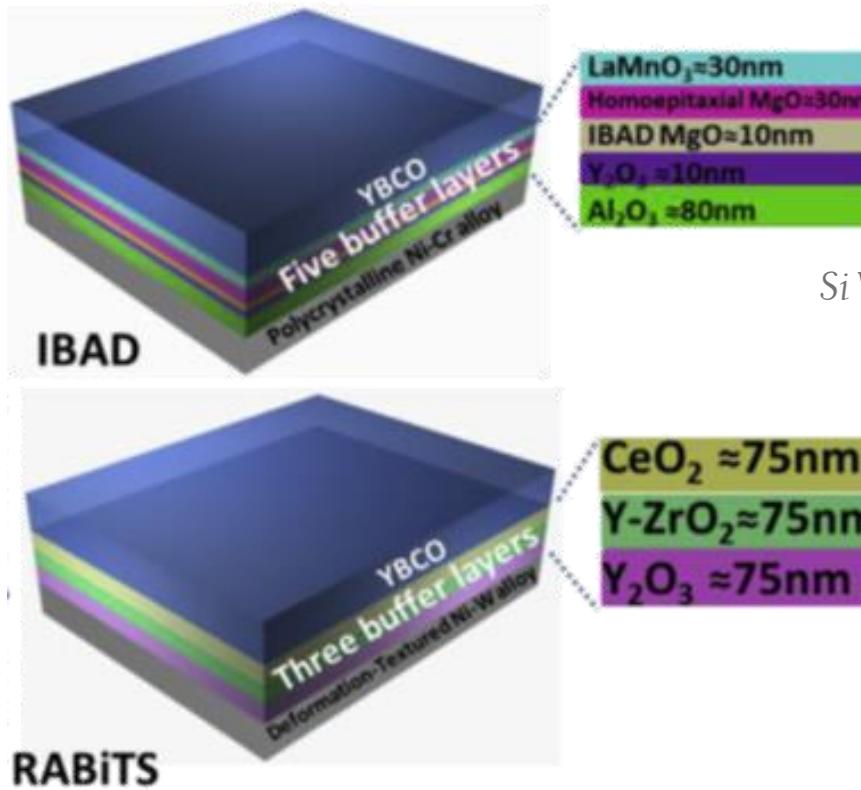
In IBS, GBs are weak link but critical misorientation angle is $>10^\circ$, higher than the 4° of YBCO.

IBS has Advantageous GBs over HTS

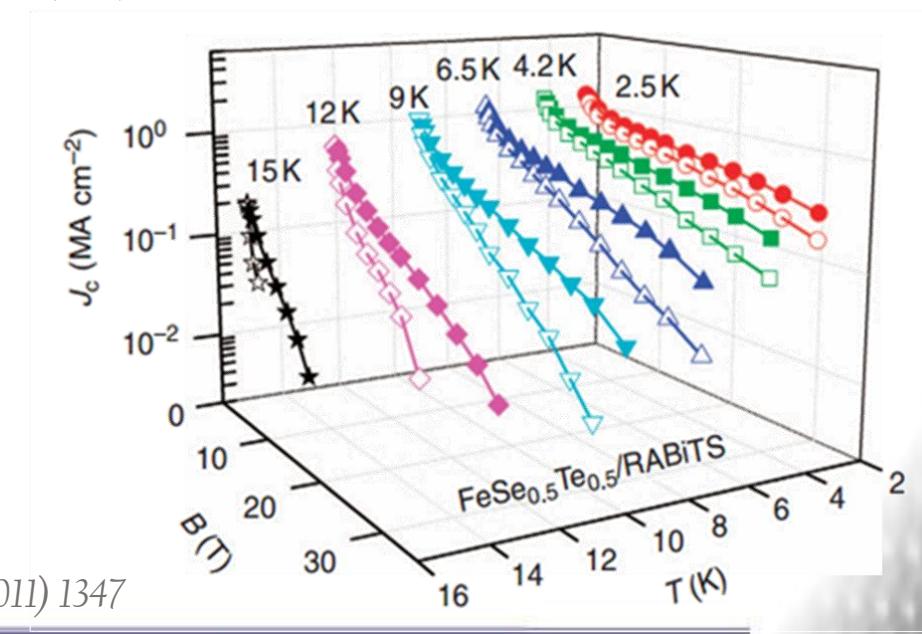
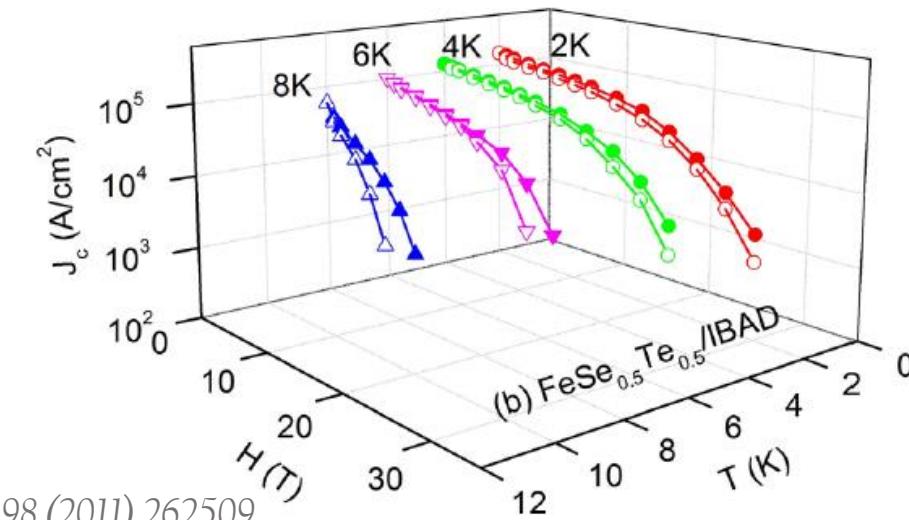
Fe(Se,Te) conductors: state-of-the-art



11 thin films were successfully grown on textured metallic templates used for YBCO



Si W. et al, *Appl. Phys Lett.* 98 (2011) 262509



Si W. et al, *Nat. Comm* 4 (2011) 1347

Given that in IBS the misorientation angle is about 10° and therefore the weak link behaviour is much less critical than in YBCO, it is possible to deposit on biaxially textured metallic substrate with a simpler structure than commercial ones.

Furthermore, oxidation of the metallic template is not an issue for IBS.

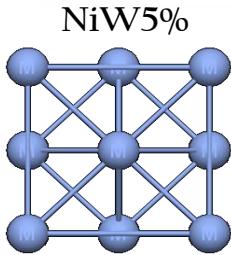
It is possible to reduce or even remove buffer layers

- ⇒ Reduce complexity and costs of production
- ⇒ Obtain a larger J_e

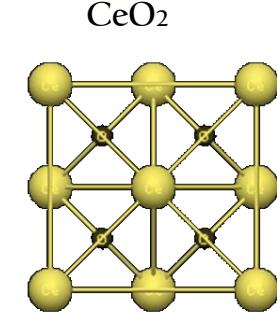
Ni alloys + buffer
(CeO₂, LaZrO₂, CZO)



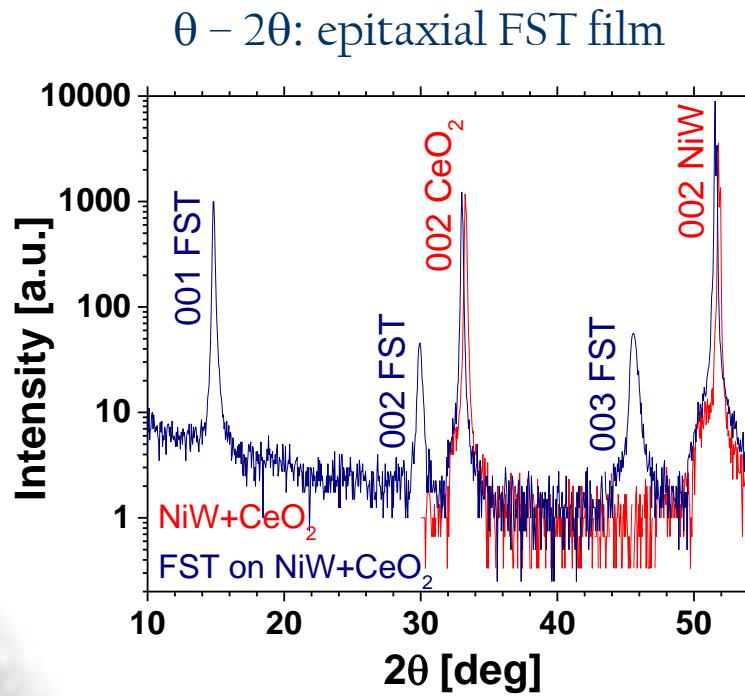
Iron alloys (Fe/Ni)



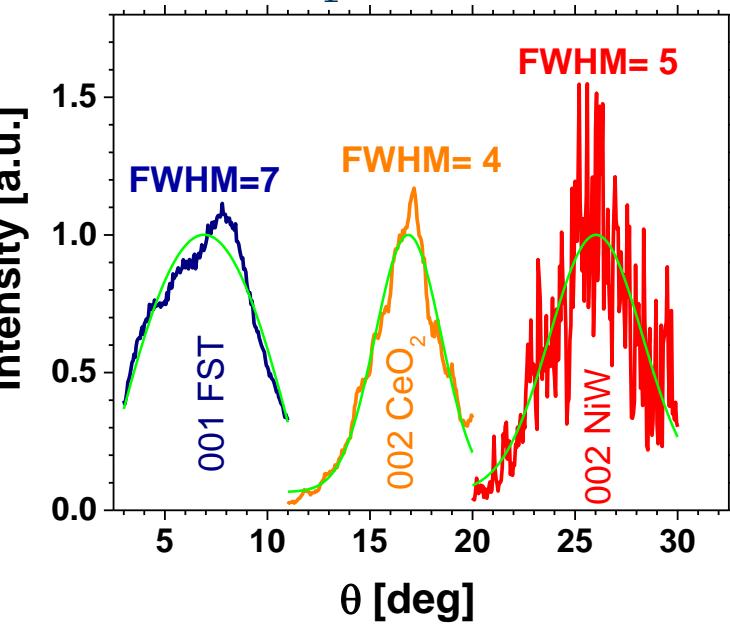
NiW biaxially textured + CeO₂ buffer layer deposited via PLD



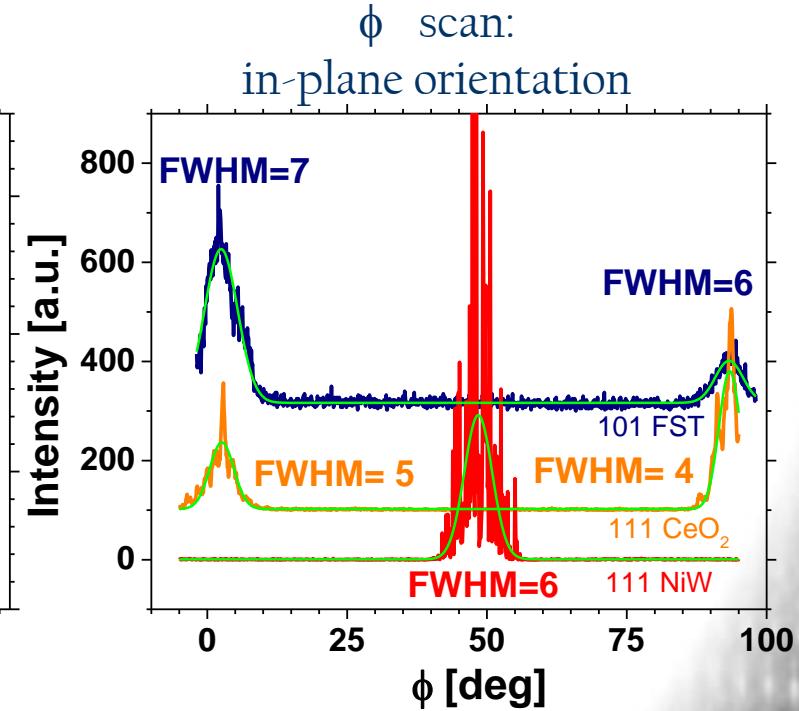
(11) thin films grow biaxially textured on NiW + CeO₂



Rocking Rolling Direction:
Out-of-plane orientation

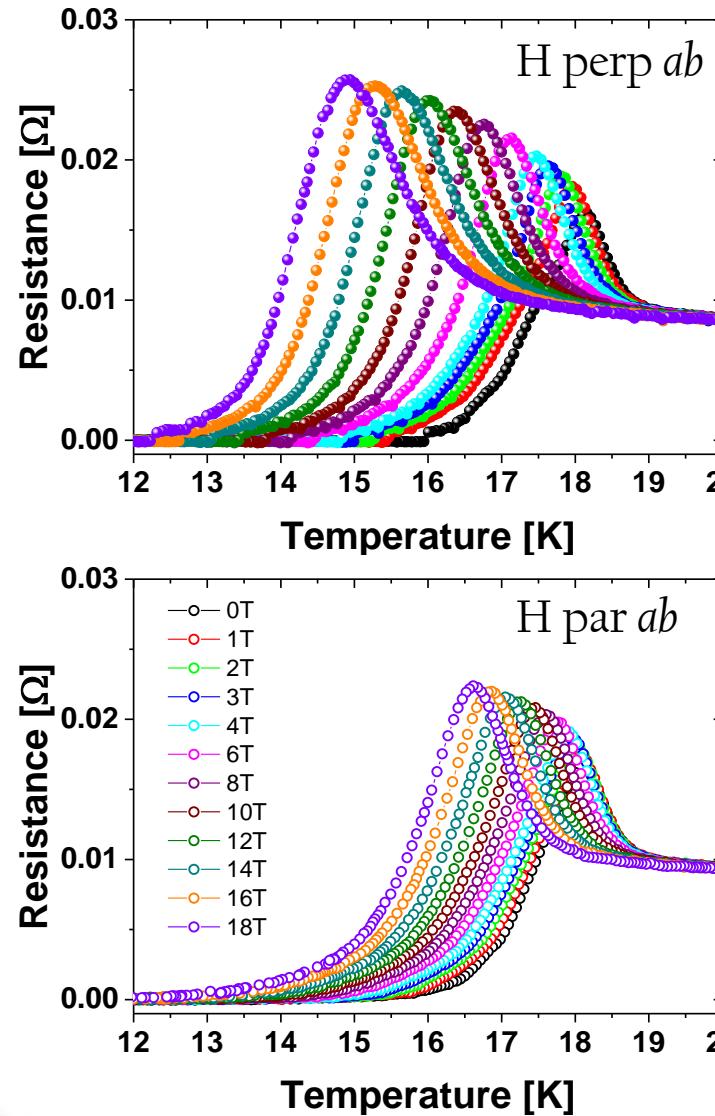


ϕ scan:
in-plane orientation

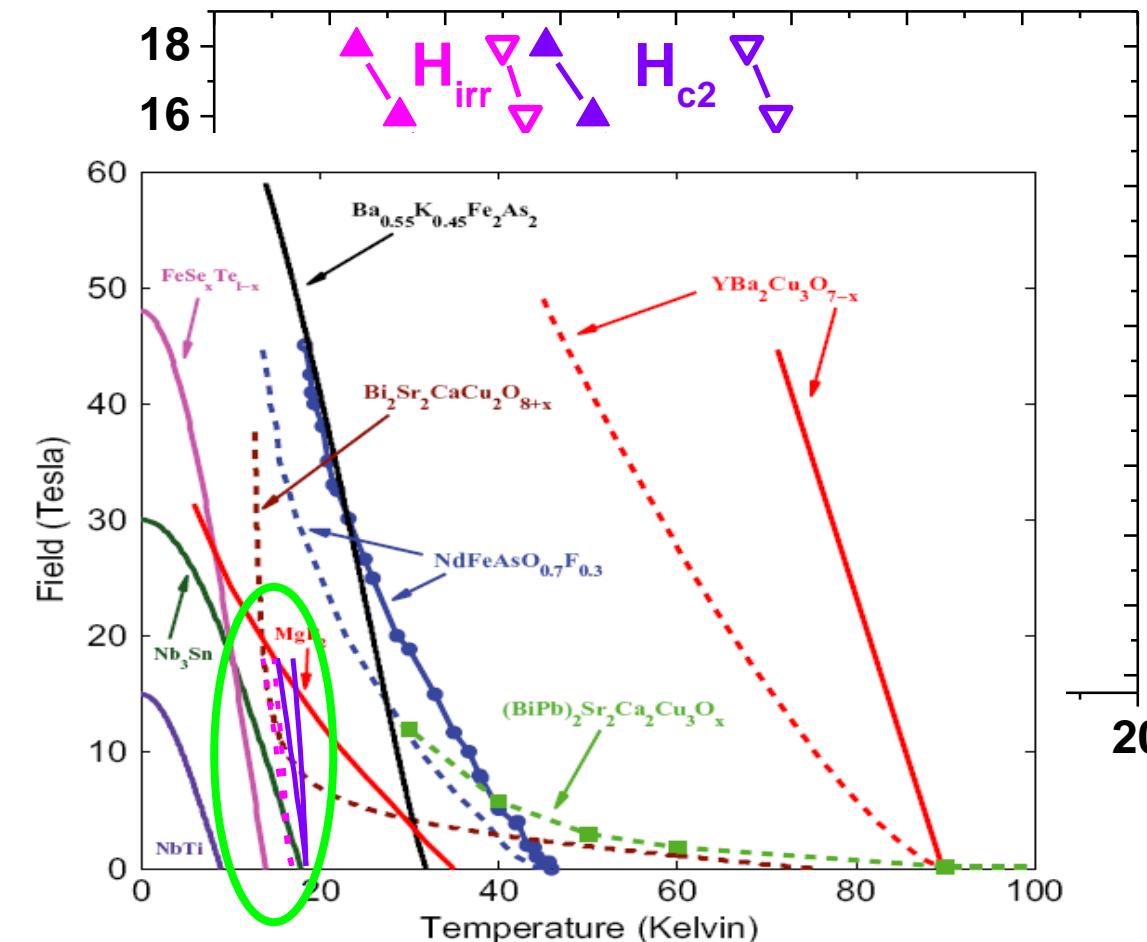


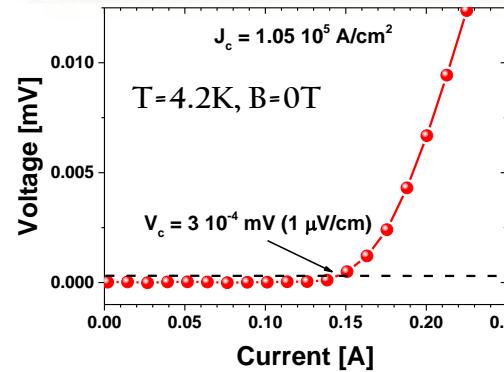
RvsHvsT measurements up to 18 T

@ ENEA Frascati

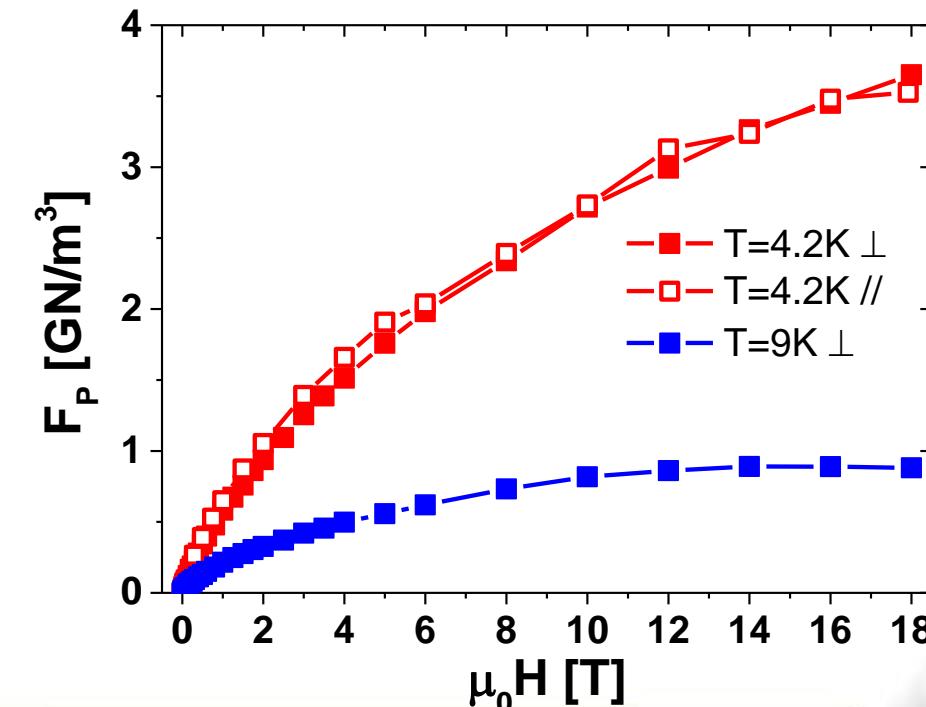
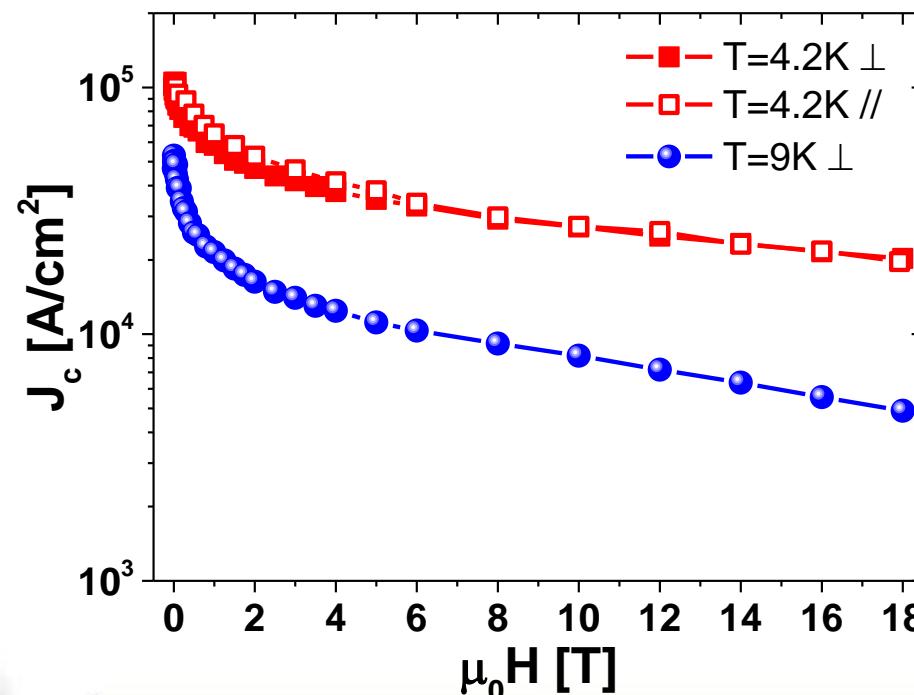


- $\Delta T_{c0} \approx 3\text{K}$ in 18 T
- H_{c2} has a very low anisotropy



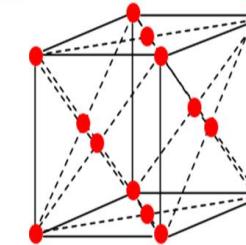


J_c is isotropic @ 4.2 K



INVAR36 (36Ni/64Fe)

- Commercial alloy 64% Fe , 36% Ni
- Low cost
- FCC structure, compatible with Fe(Se,Te)



Published crystallographic data

Space group

Fm-3m (225)

Cell parameters

$a = 0.359156(2)$, $b = 0.359156(2)$, $c = 0.359156(2)$ nm, $\alpha = 90^\circ$,
 $\beta = 90^\circ$, $\gamma = 90^\circ$

$V = 0.04633$ nm³, $a/b = 1.000$, $b/c = 1.000$, $c/a = 1.000$

Atom coordinates

Site	Elements	Wyck.	Sym.	x	y	z	SOF
M	0.64Fe + 0.36Ni	4a	m-3m	0	0	0	

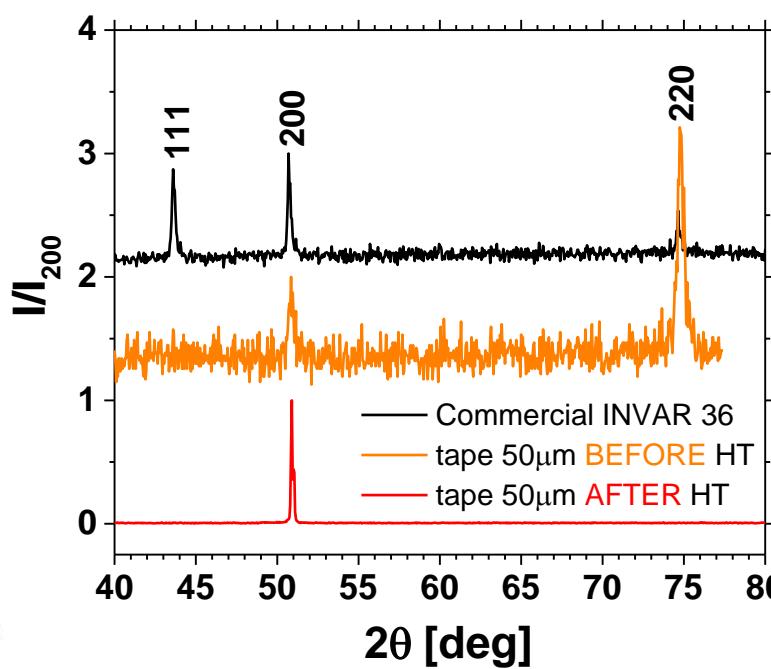
From rods Ø 2 – 10 mm => drawn / flat rolled =>
=> 50 / 70 µm + HT @ 1000 °C / 2h in Ar/H₂ atmosphere



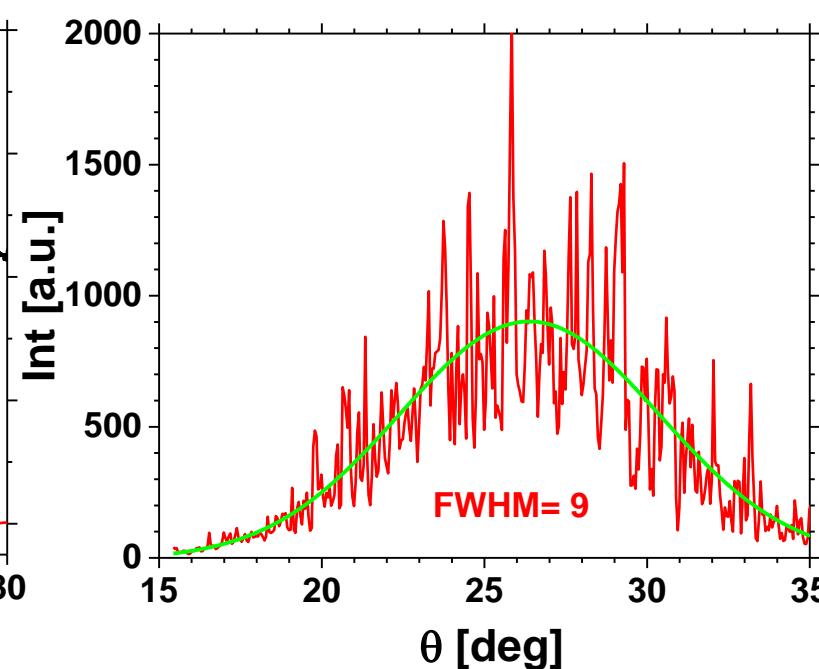
INVAR36 (36Ni/64Fe)

Commercial alloy 64% Fe , 36% Ni, FCC

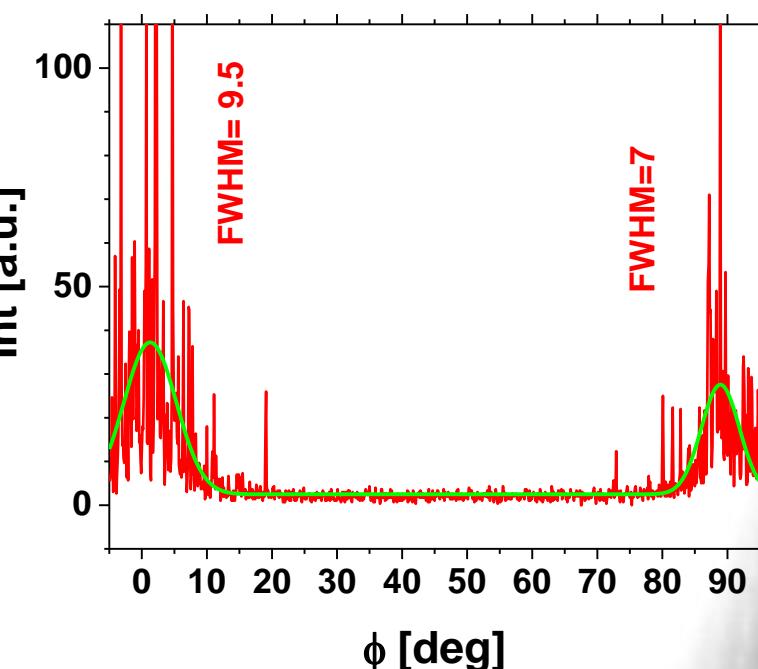
$\theta - 2\theta$



Rocking (200) Rolling Direction



ϕ scan (202)

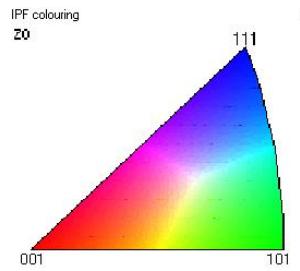
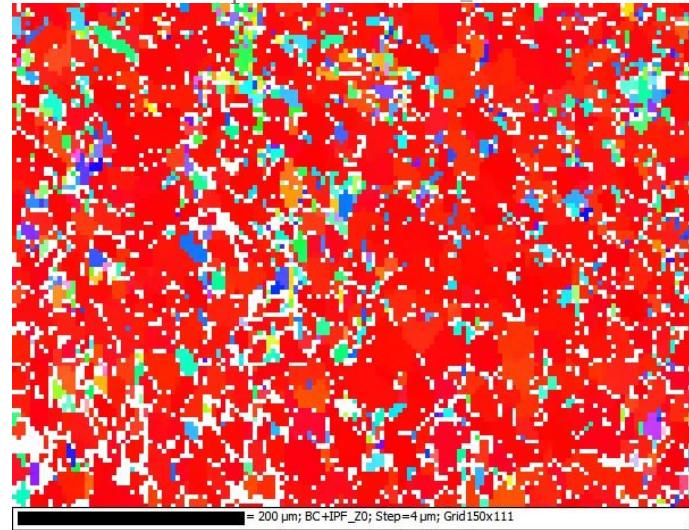


Biaxial texture

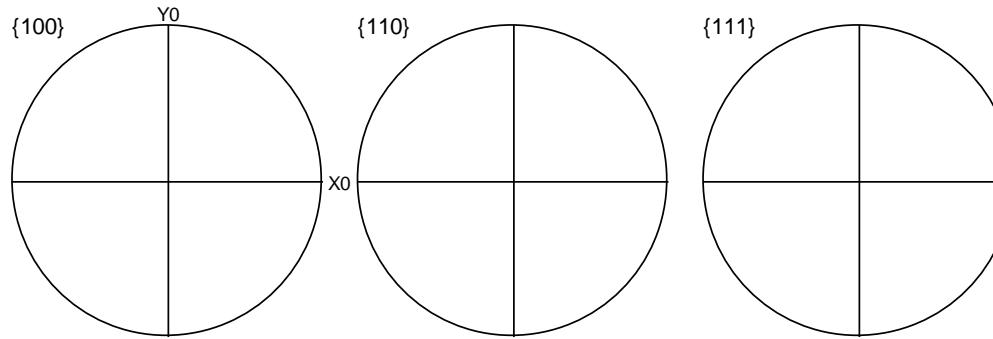
EBSD analysis on INVAR tape



INVAR 500x Map Data 1 - BC+IPF_Z0

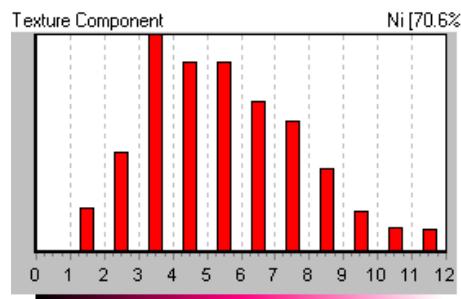
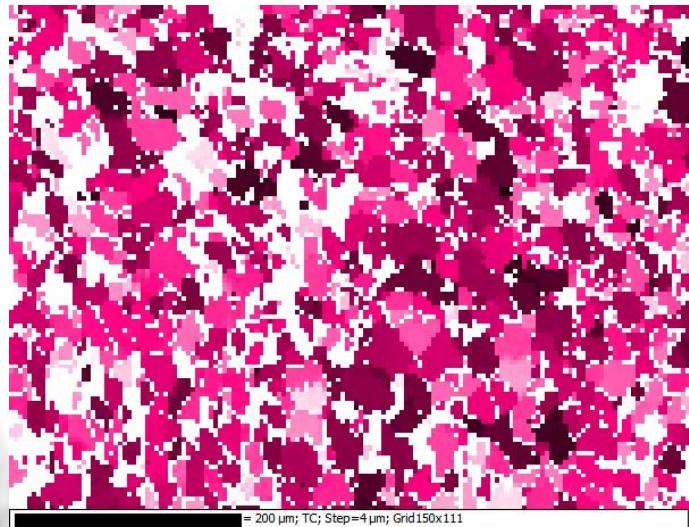


INVAR 500x Map Data 1 - Scattered Data

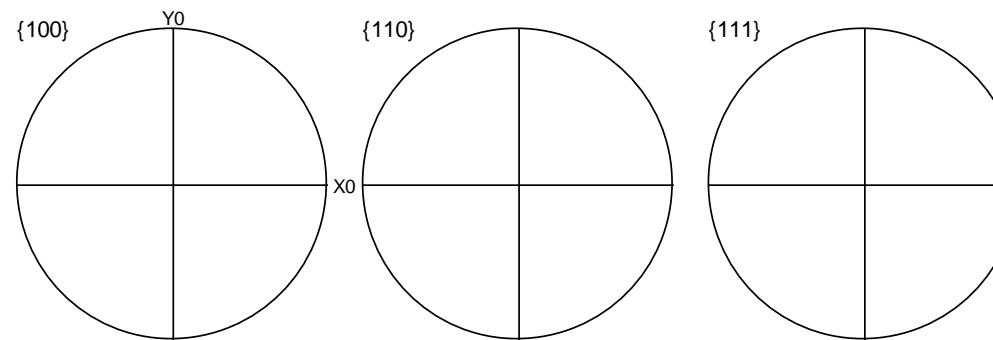


Presence of
twinned grains

INVAR 500x Map Data 1 - TC



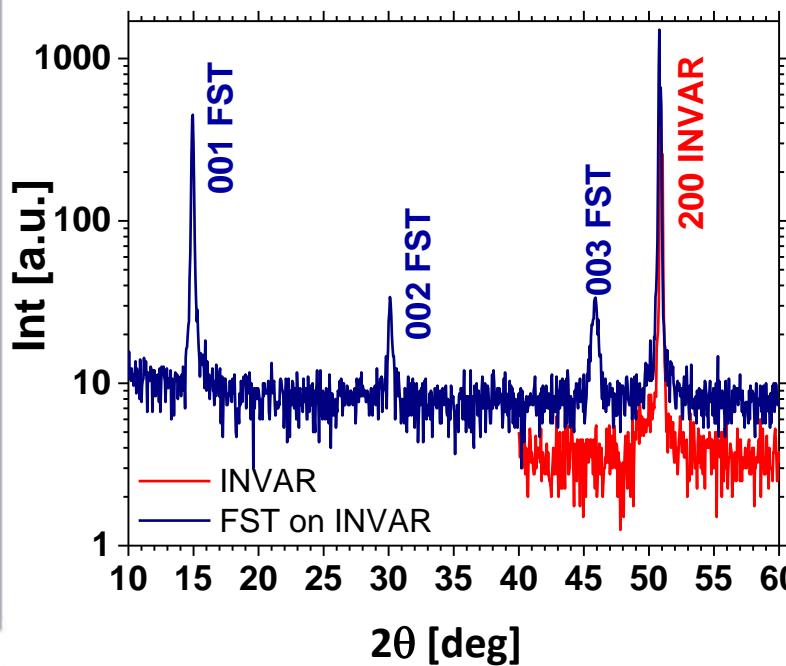
INVAR 500x Map Data 1 - Scattered Data



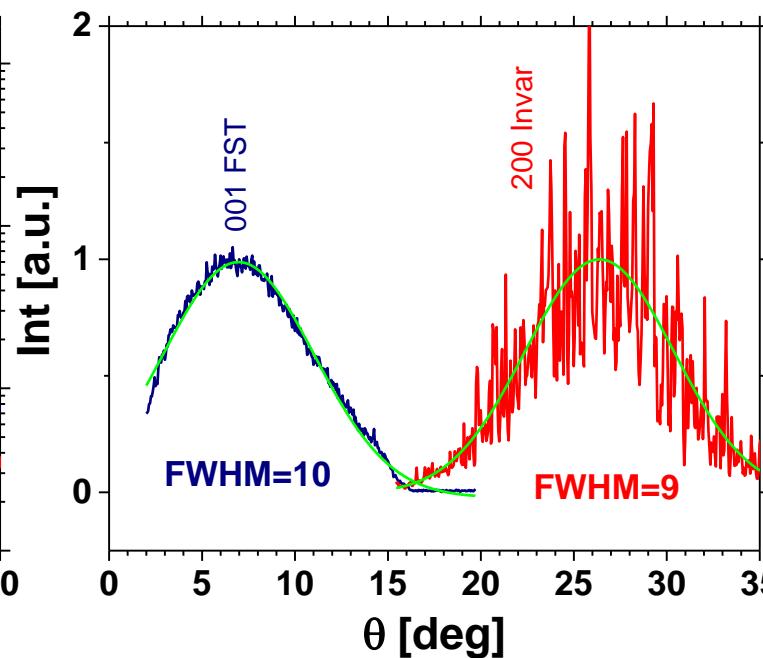
First attempts of growth of Fe(Se,Te) on textured INVAR



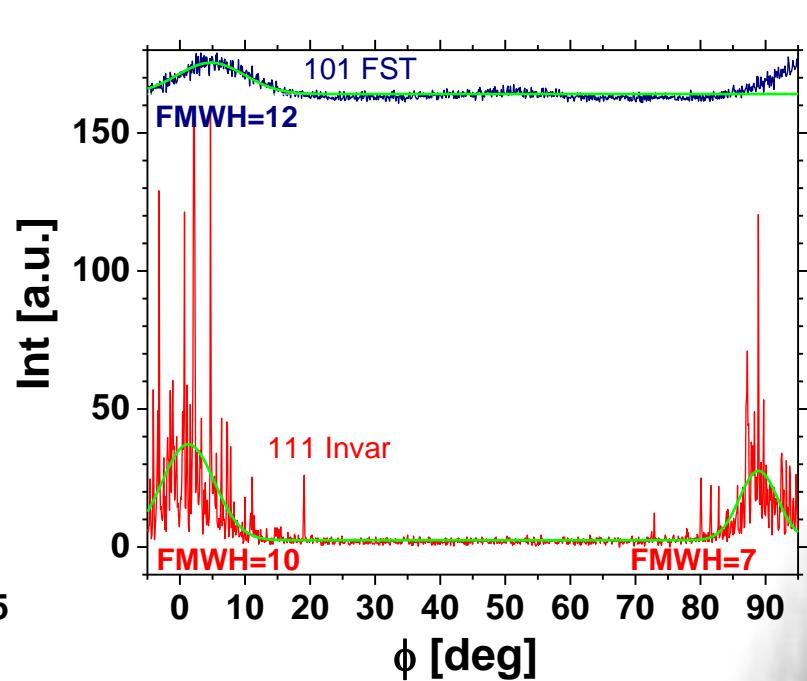
$\theta - 2\theta$: epitaxial FST film



Rocking Rolling Direction:
Out-of-plane orientation



ϕ scan:
in-plane orientation



Growth of epitaxial thin films on INVAR has been demonstrated

NiW + oxide buffer:

- We have demonstrated the possibility of growing epitaxial superconducting Fe(Se,Te) thin films on NiW + CeO₂ with high T_c and good J_c performances
- We are working with simpler buffers, i.e. oxides deposited via chemical methods much simpler than PLD used for CeO₂ and thererfore much more appealing from an applicative point of view, e.g.
 - NiW + La₂Zr₂O₇ (LZO) deposited via Metal Organic Deposition (MOD) and
 - NiW + Zr-doped CeO₂ (CZO) deposited via Chemical Solution Deposition (CSD)

INVAR (36Ni/64Fe):

- We have demonstrated the possibility of texturing FeNi (INVAR) commercial alloy and depositing epitaxial Fe(Se,Te) thin films without any buffer
- We are working to obtain good superconducting thin films