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Thin film Josephson junctions for the characterization of iron-based superconductors

Trilateral workshop on Hot Topics in HTSC
29.Sep.-02.Okt.2013

DFG
SPP 1458

IRON-SEA
Establishing the basic science and technology for IRON-Based Superconducting electronics applications

Outline

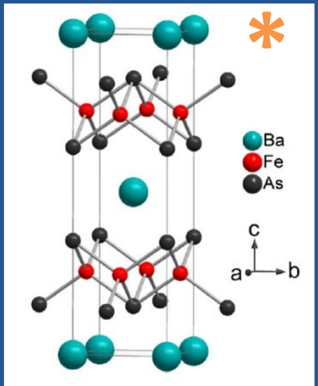
- Tasks
- Junction preparation
- Results of planar junctions
    - Au barrier
    - TiO_x barrier
- Results of edge-type junctions
- Junctions on single crystals
- Summary
- Outlook

Motivation/Tasks

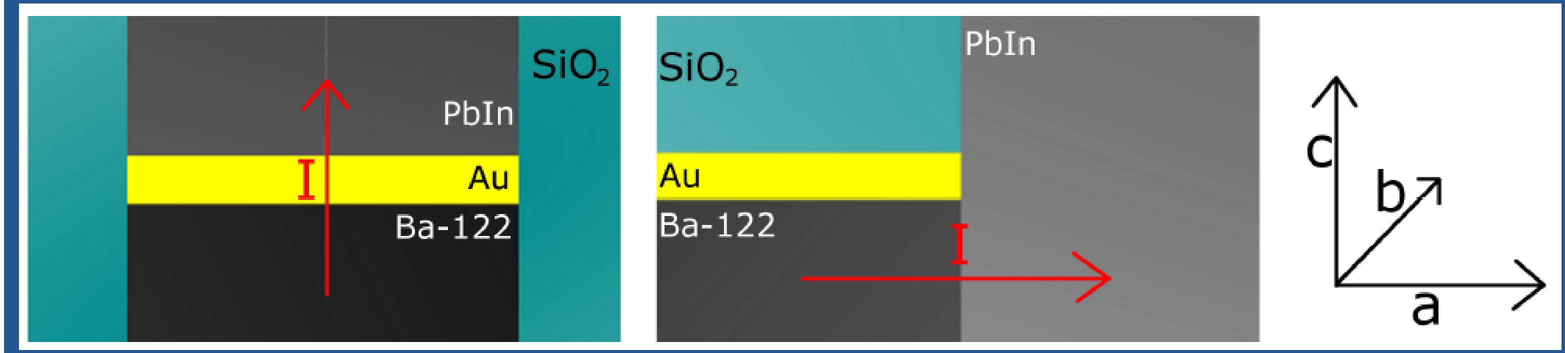
- Deposition of the high-quality thin films of $Ba(Fe_{1-x}Co_x)_2As_2$ at IFW Dresden
  substrates: STO, LSAT, MgO, CaF_2
- Co-doped Ba-122 single crystals at KIT Karlsruhe
- Preparation of junctions
- Investigation of superconducting properties
  - Critical current density
  - Order parameter
- Tuning of junction properties
  - IcRn product
  - Barrier transparency

Preparation

Junction types



planar SXS'-junction | edge-type junction

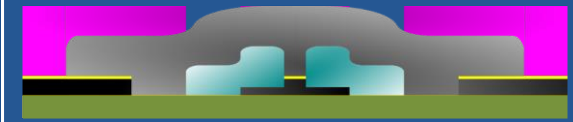


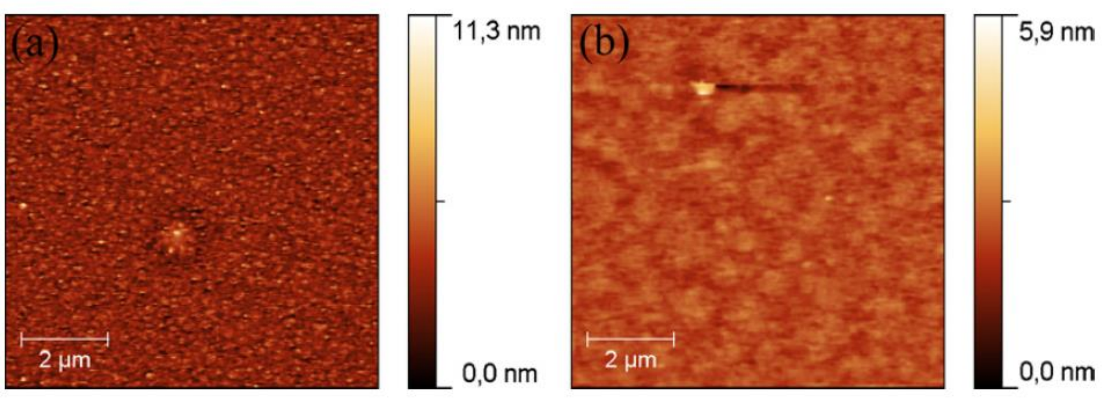
current direction	**c-axis**	**ab-plane**
barrier	Au layer (5…10nm) Au+TiO_x (1…3nm)	Interface engineered (ion beam, chemicals, air)

* Rotter et al. *Phys. Rev. Lett.* **101** (2008) 107006

Preparation

Process steps

	planar SNS-junction	edge-type junction
		
Process(es):	IBE, SiO2 sputtering / Photolithography	
	Lift-off	Lift-off / Lift-off
Affected part:	Insulation layer / Complete sample / Base electrode	Insulation layer



Döring et al. *Physica* C **478** (2012) 15-18

Preparation

Titanium oxide barriers

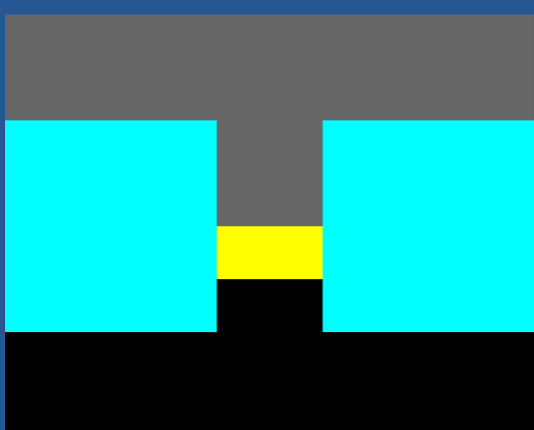
Preparation of planar junctions

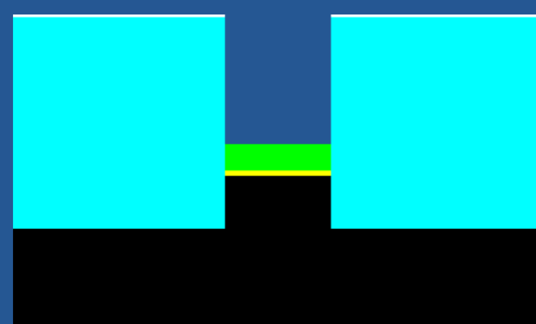
Döring et al. arXiv.org 1309.2331
Submitted to Appl. Phys. Lett.

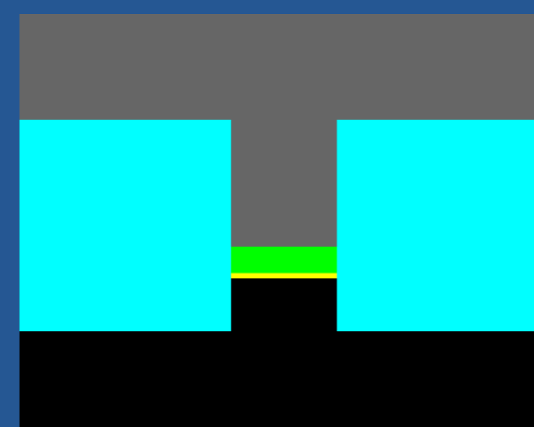
previously
new

- Patterning junction area by SiO_2 framework
- Etching (5s) to reduce gold layer thickness
- Evaporating Pb and In as counter electrode
- Sputtering Ti (1..3nm)
- Heating and oxidation in atmosphere
- Evaporating Pb and In as counter electrode

Ba-122
SiO_2
Gold
Pb
TiO_x

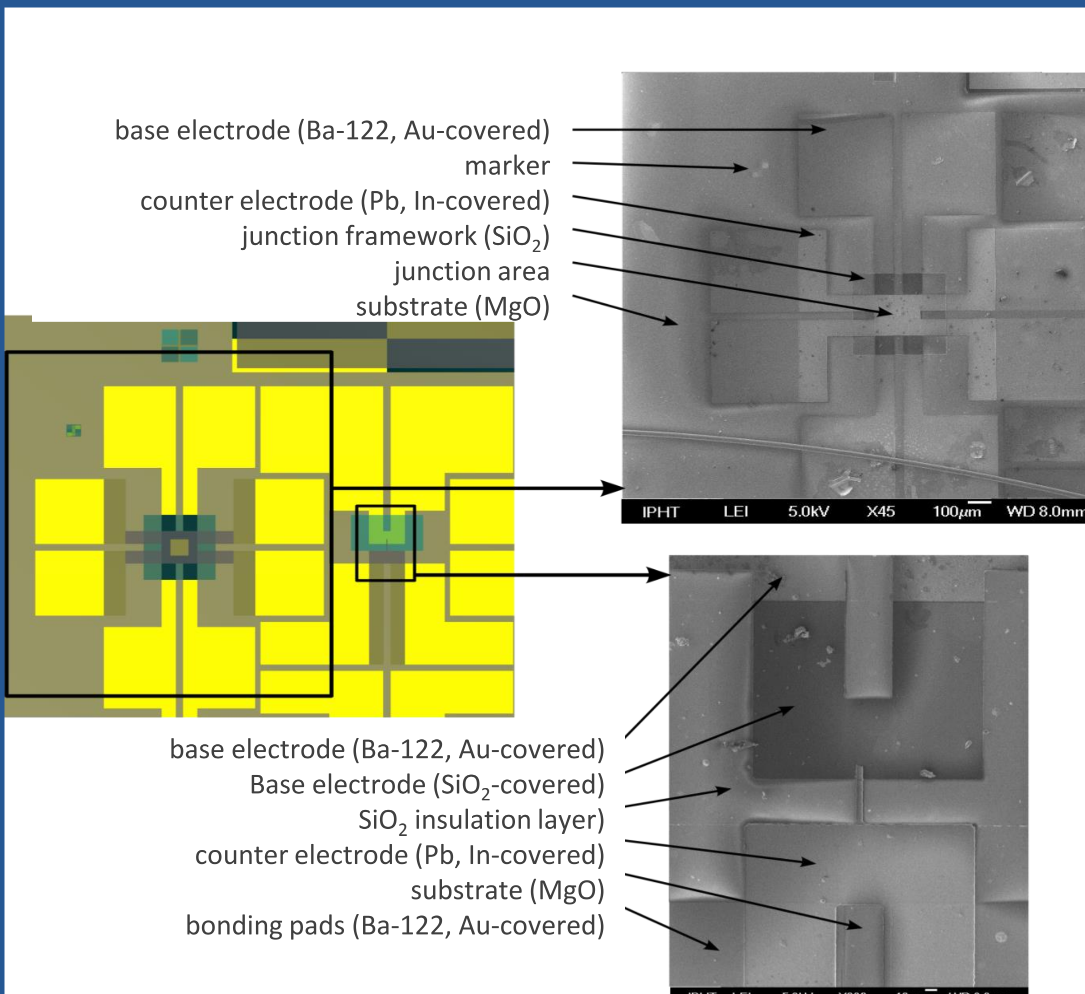






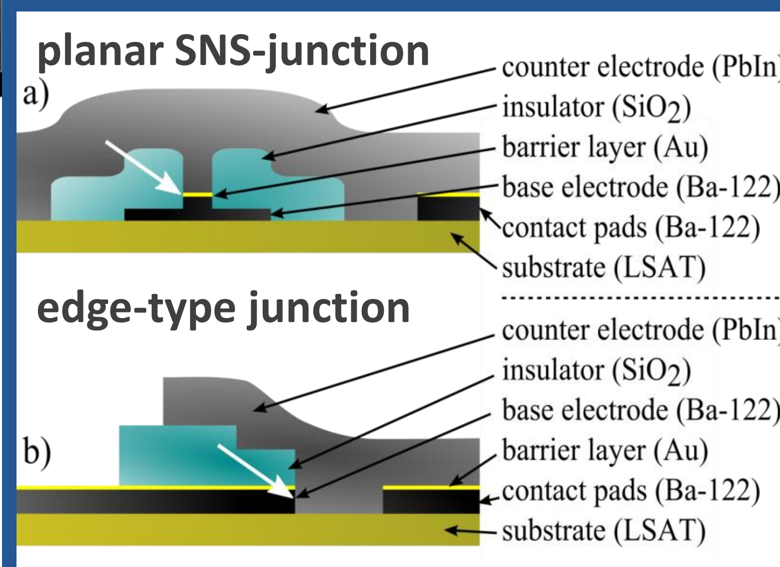
Preparation

Overview



Single sample:
- 5mm x 10mm
- 10 planar junctions
- 5 edge junctions

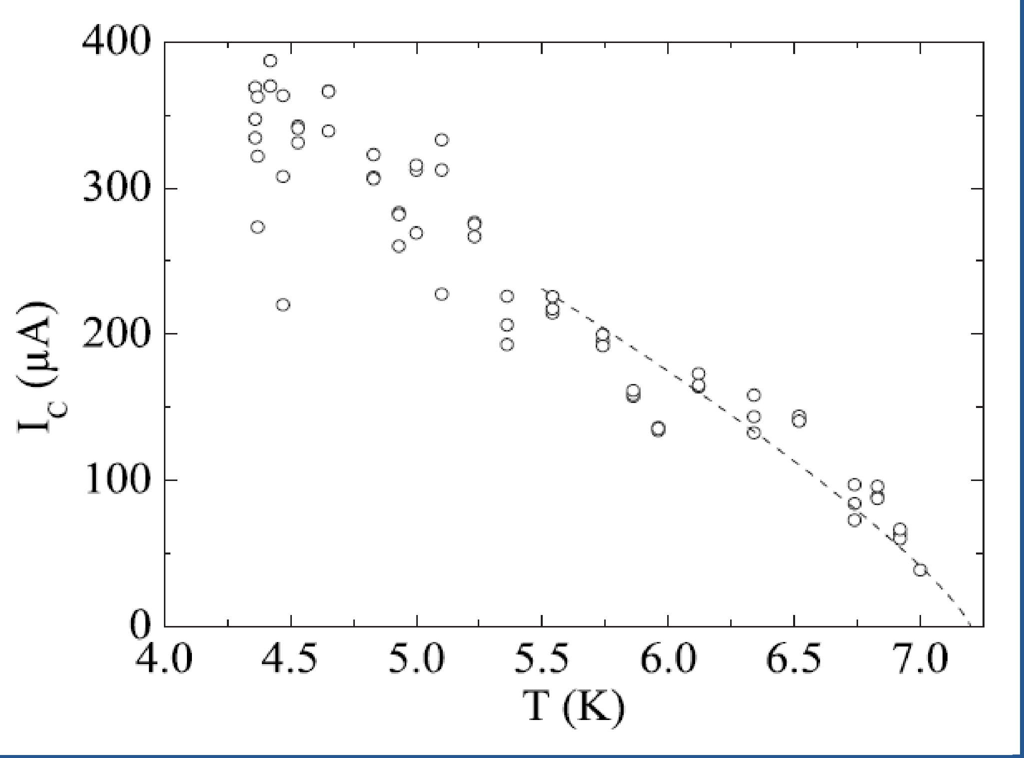
Junction areas:
Planar: 3x3…100x100 μm^2
Edge-type: 3…20µm x film thickness



Results on planar junctions

Junctions with Au barrier

planar SNS-junction (5nm Au)



Schmidt et al. *Appl. Phys. Lett.* **97** (2010) 172504

I-V-characteristic:
Asymmetric shape

- $I_c \approx 350\mu A$
- $R_n = 53 m\Omega$
- $I_{ex} \approx 200\mu A$
- $I_c R_n = 18\mu V$, corr: $I_c R_n = 7.9\mu V$

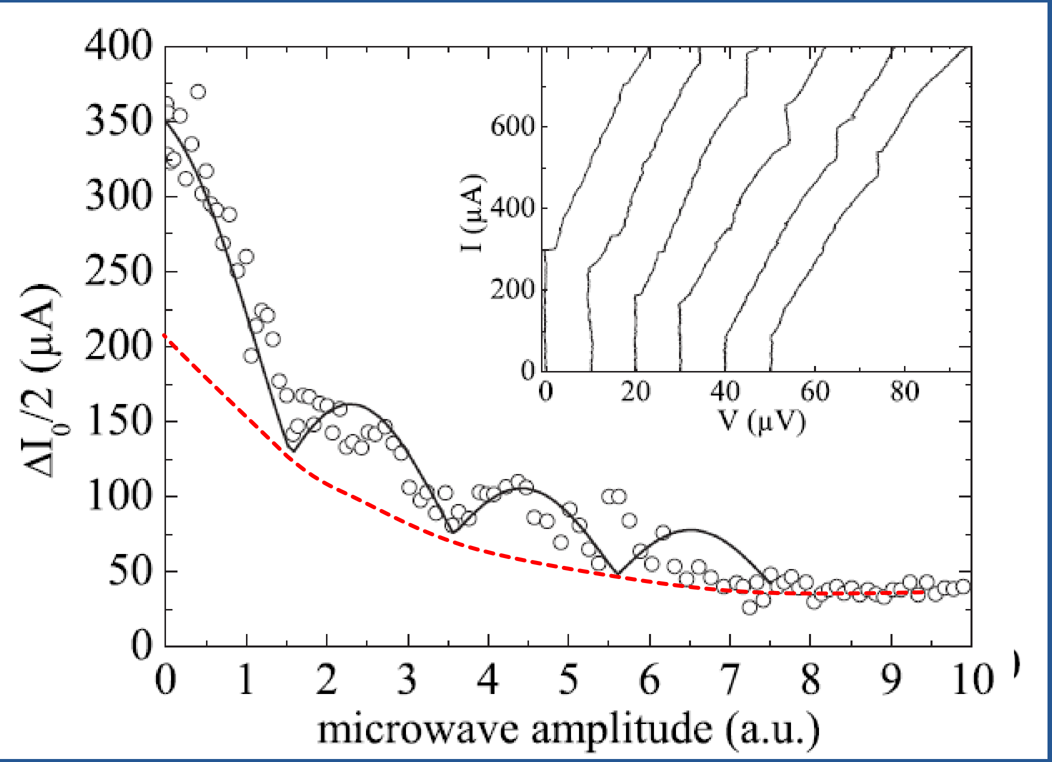
I_c – T dependence:

- nearly linear

Results on planar junctions

Junctions with Au barrier

planar SNS-junction (5nm Au)



Shapiro steps
n=2eV/hf

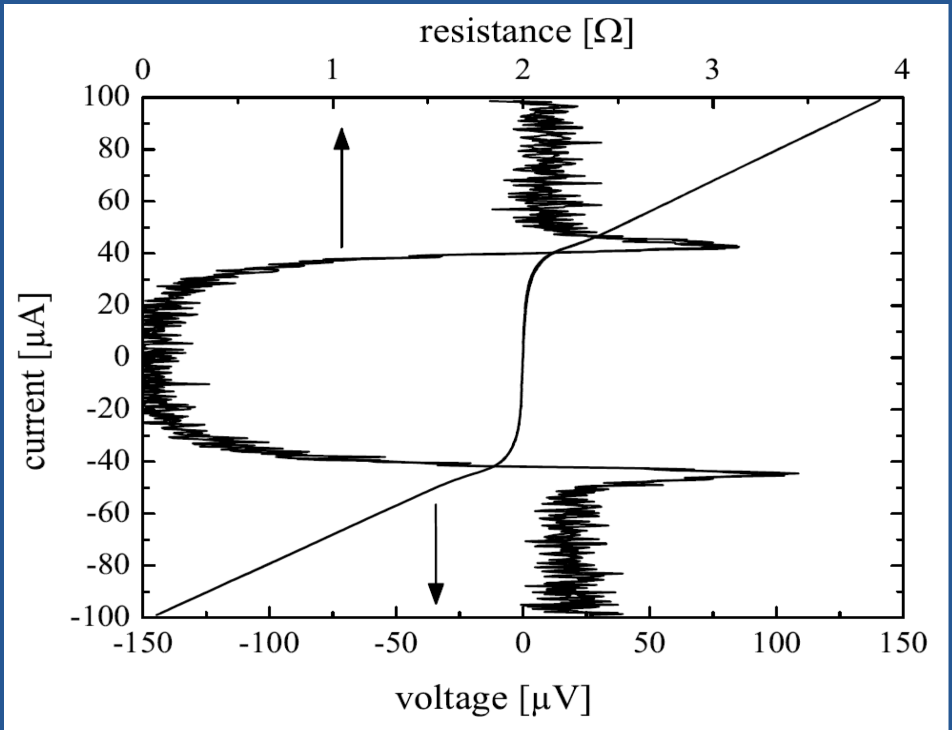
Microwave dependence (12GHz):
- Bessel behavior
- Exponential underground
- Offset ≈30µA

Schmidt et al. *Appl. Phys. Lett.* **97** (2010) 172504

Results on planar junctions

Junctions with TiO_x barrier

Planar junction (1.5nm TiO_x)



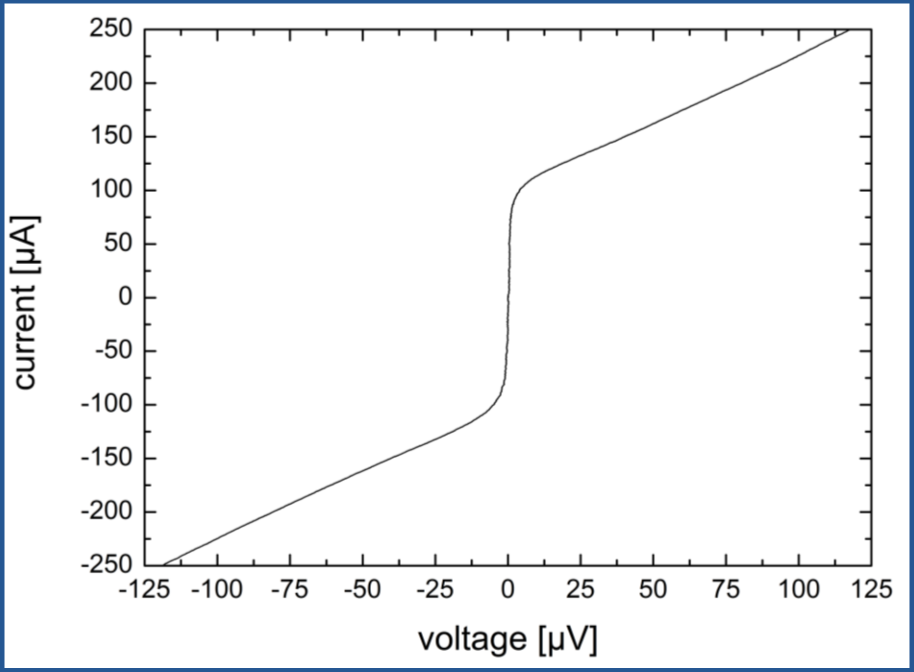
Döring et al. arXiv.org 1309.2331

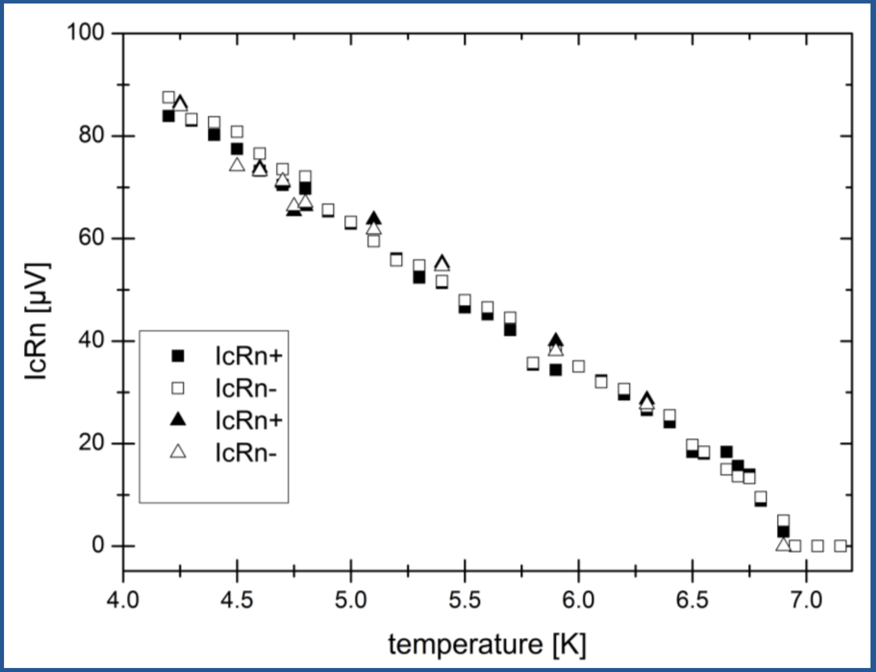
- Symmetric I-V-characteristic
- RSJ + Flux Flow
- $I_c \approx 40\ \mu A$
- $R_n = 2.2\ \Omega$
- $I_c R_n \approx 90\ \mu V$
- =>increase by factor 5

Results on planar junctions

Junctions with TiO_x barrier

Planar junction (2.0nm TiO_x)





Results on planar junctions

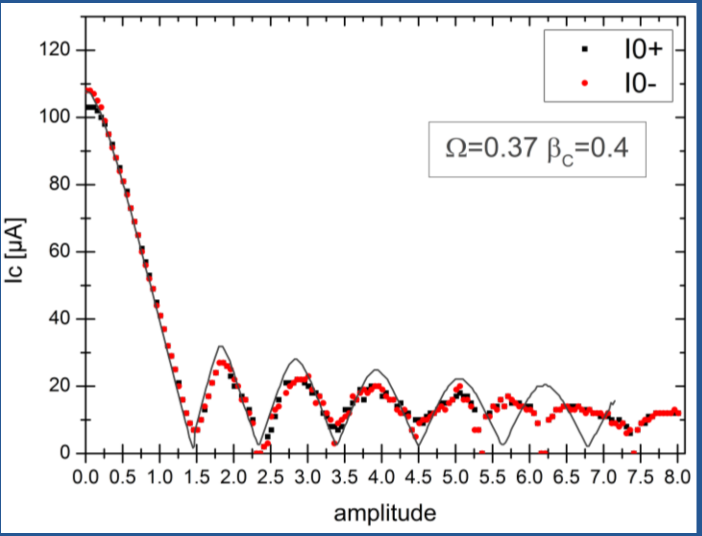
Junctions with TiO_x barrier

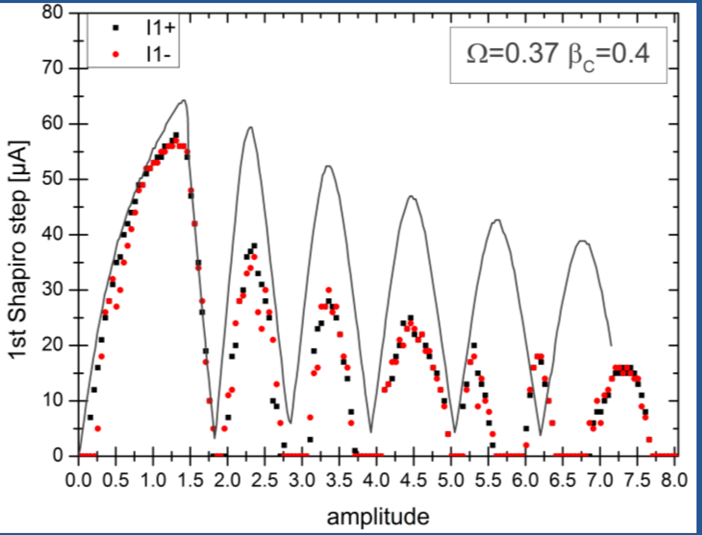
Planar junction (2.0nm TiO_x)

$$\beta_C \ddot{\varphi} + \dot{\varphi} + \sin\varphi = i_b + i_m \sin\Omega\tau$$

Microwave dependence:

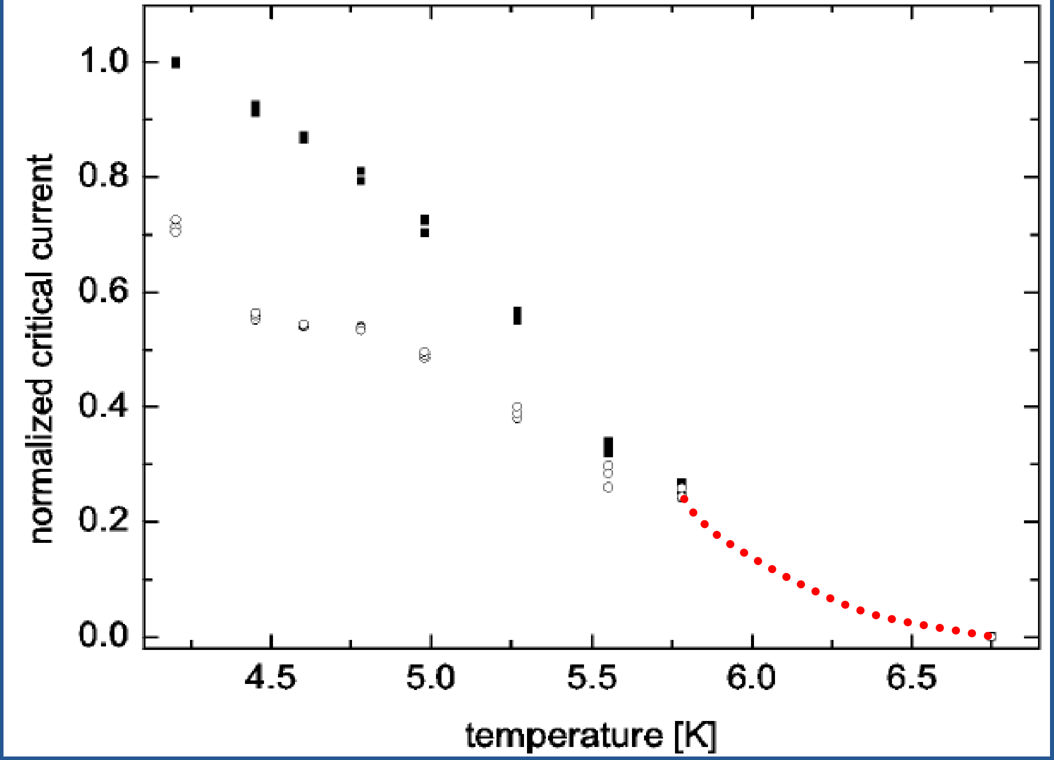
- Fitable within simple Josephson equation
- No background needed
- Good periodicity





Results on edge-type junctions

Edge-type junction



I-V-characteristic:
Asymmetric shape

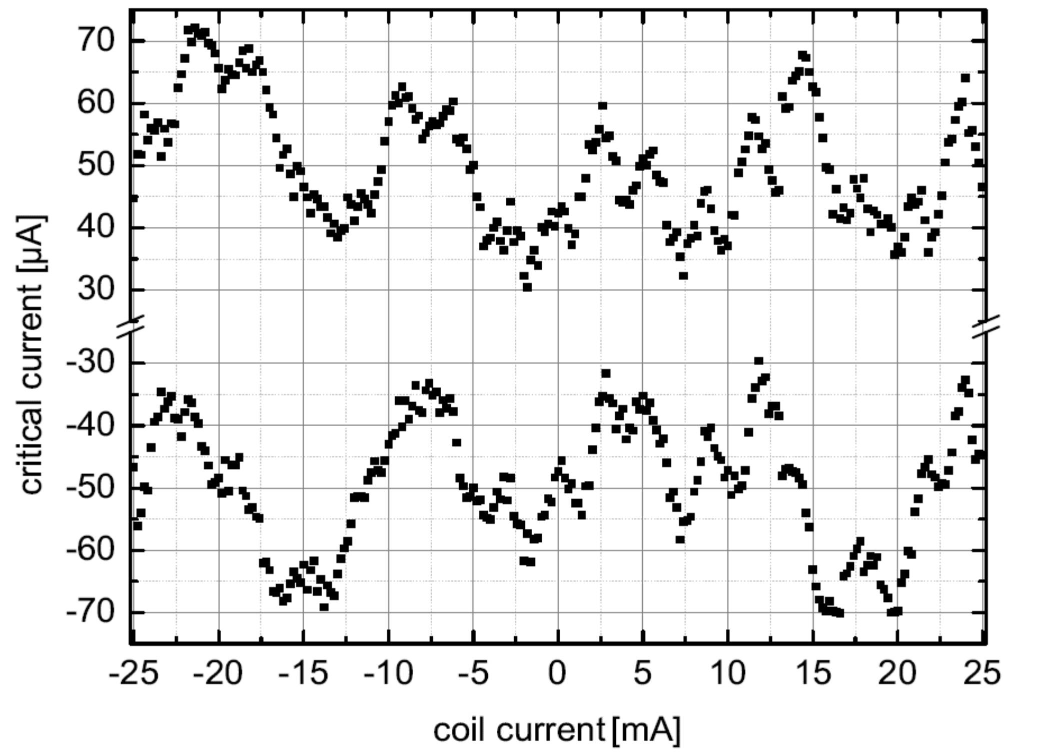
Parameter	positive	negative
I_c	59µA	42µA
R_n	217mΩ	197mΩ
I_{ex}	24µA	22µA
I_cR_n	12.7µV	8.2µV
I_cR_n (corr.)	7.7µV	3.9µV

I_c – T dependence
- Asymmetric but uncertain near T_c

Döring et al. *Supercond. Sci. Technol.* **25** (2012), 084020

Results on ede-type junctions

Edge-type junction



Shapiro steps

Microwave dependence (6GHz):

- Uncertain
- No offset

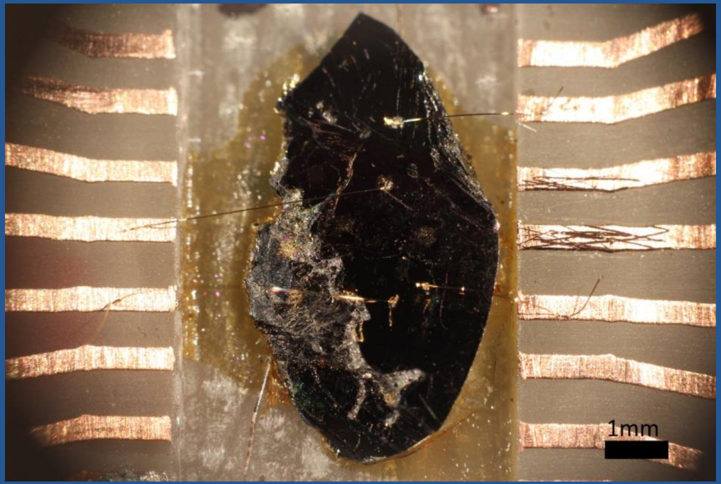
Magnetic field dependence:

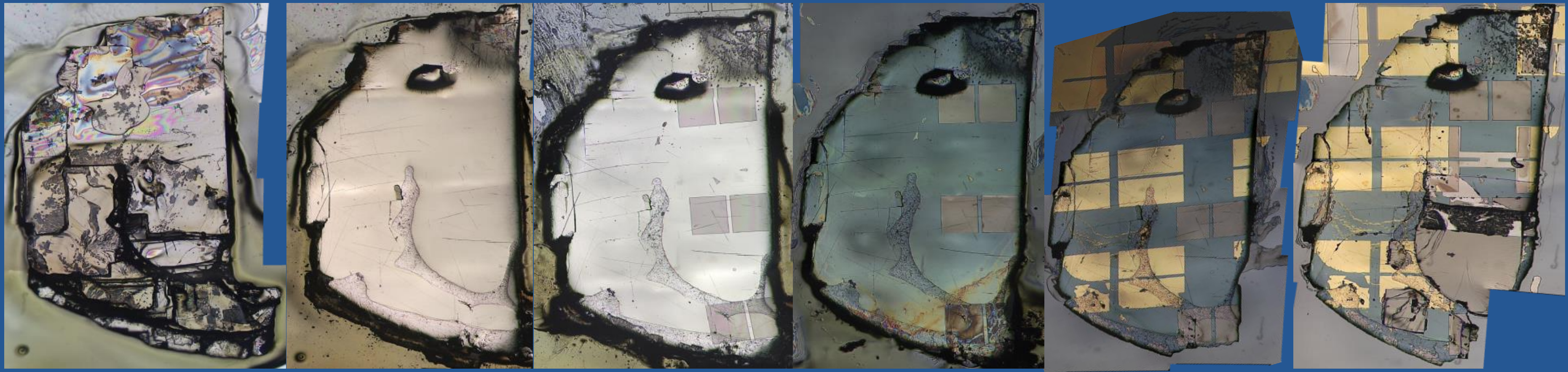
- Countercyclical behavior
- Offset: 30µA
- No suppression of I_c

Döring et al. *Supercond. Sci. Technol.* **25** (2012), 084020

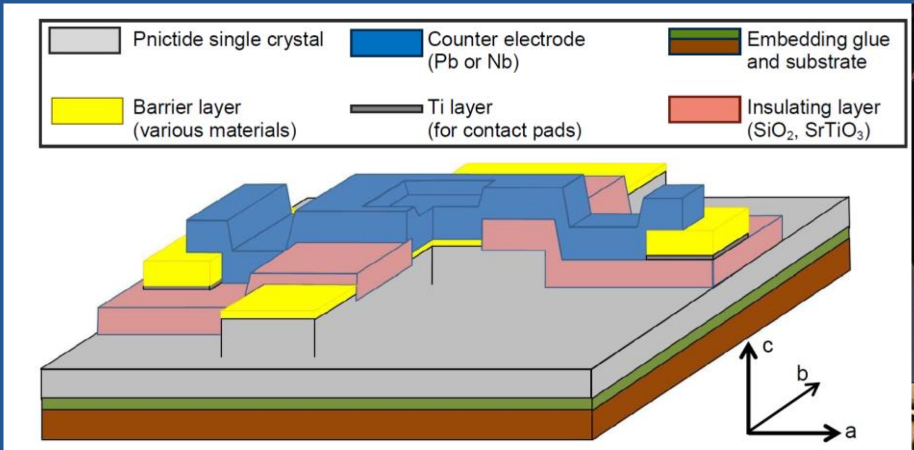
Single crystals

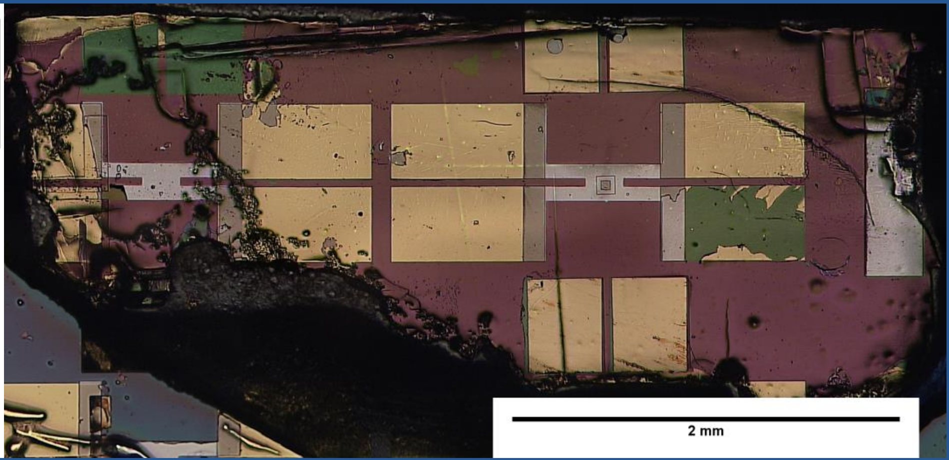
- Junction designs are transferable to single crystals
- Additional competitions:
  - Embedding (Epoxy clue)
  - Polishing (RMS<2nm)
  - Insulation (SiO2 d=400nm)

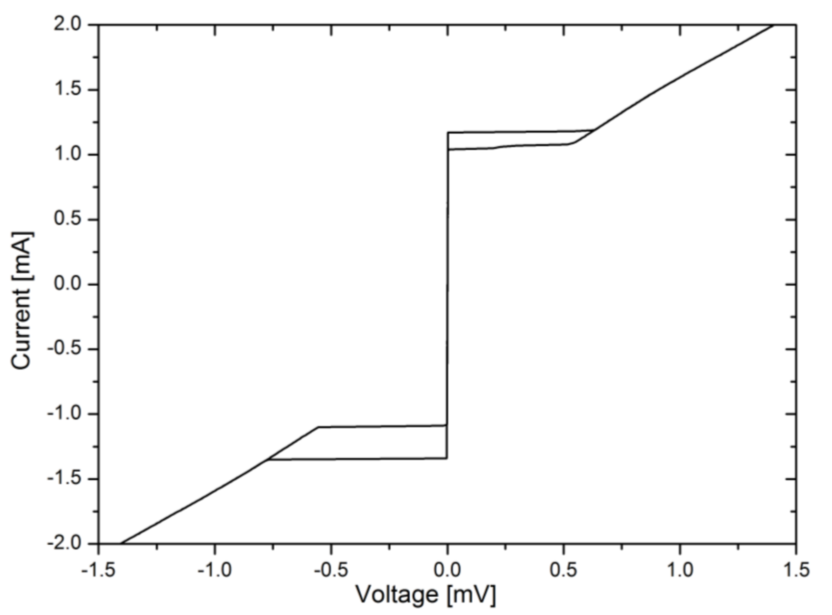




Single crystals







Planar junction with 2.5nm TiOx barrier:

I_c=1.2mA
R_n=1Ω
I_cR_n=1.2mV

Hysteretical I-V characterisitic:
Insulating barrier
β_c>1

Summary

- Preparation of planar and edge-type junctions from Ba-122 thin films
- Josephson effect observed for both types
- Problems with Au barriers and edge-types
- TiOx barriers:
  - Increase of I_cR_n
  - Avoid of disturbing effects
- Successful transfer to single crystals

Outlook

- Real tunneling (SIS) junctions
- Controlling and tuning the properties of edge-type junctions
- Explanation of low IcRn products
- Combination of junctions for phase-sensitive test

Спасибо за ваше внимание!
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