# Superconductor-Metal-Insulator transitions in $Y_xSi_{1-x}$ thin films

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## Abstract

We report on the low-temperature study of thick amorphous $Y_xSi_{1-x}$ films. In these disordered thin films, transport properties are governed by the interplay between localization, Coulomb interactions and superconductivity. We have studied the temperature dependence of the resistance as a function of the stoichiometry of the alloy. We have determined a preliminary phase diagram for the 3D $Y_xSi_{1-x}$ alloy. Besides that, on the insulating side, our preliminary results indicate a strong electron-phonon decoupling, which could be the signature of many-body localized states in this system.

## Major Questions!

### How low is $Y_xSi_{1-x}$'s specific heat capacity $C_v$ ?

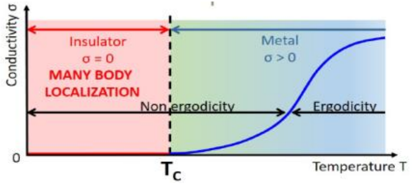
Studies on amorphous $Nb_xSi_{1-x}$ films have shown that the specific heat is very important at very low temperature due to the nuclear specific heat in this compound [1].
$Y_xSi_{1-x}$ films should have a lower specific heat which makes it a very promising candidate for thermometric applications.

### Many-Body Localization (MBL)

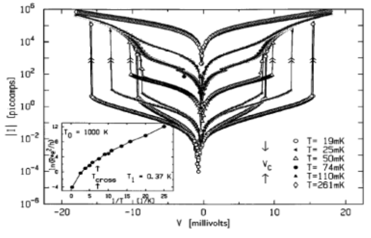
MBL is a new theoretically predicted electronic states, where disorder and Coulomb interactions give rise to a collective mode corresponding to a finite temperature insulator. Electron-phonon decoupling is a requirement for this state to emerge [2].

Thus,

$T < T_c \quad \sigma(T) = 0$



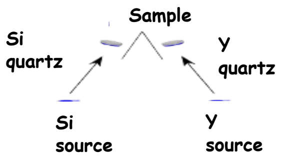
Strong electron-phonon decoupling



[3]

## Sample

Schematic representation of the e-gun co-deposition process.

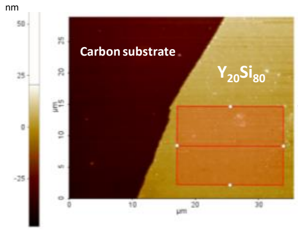


Side view

- Under ultrahigh vacuum by e-gun co-deposition.
- $x \in [5, 32]$ %
- Thicknesses $\in [30, 60]$ nm
- In-situ control of **x** & **thickness** by pairs of quartz

## Sample homogeneity & morphological structure

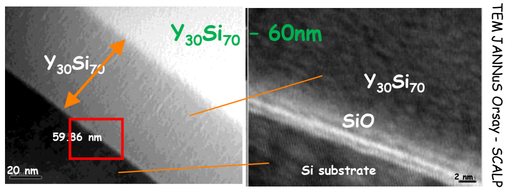
### Atomic Force Microscopy (AFM)



$Y_{20}Si_{80}$ – 60nm

- Thickness consistent with in situ quartz measurements.
- Low film roughness (~ 0.4 nm)

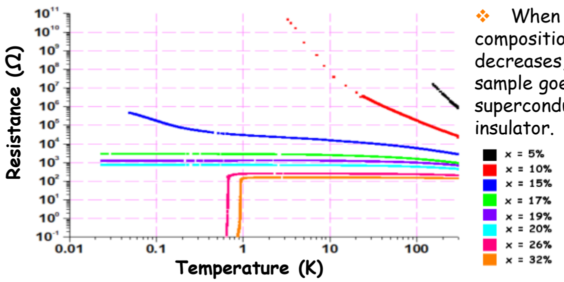
### Transmission Electron Microscopy (TEM)



- No sign of atomic arrangement ➡ our films can be considered to be amorphous.

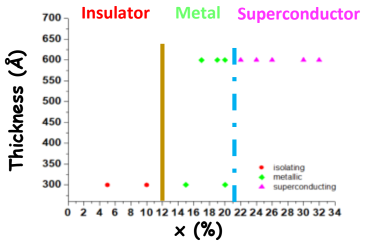
## Results obtained

### Transport measurements R(T)

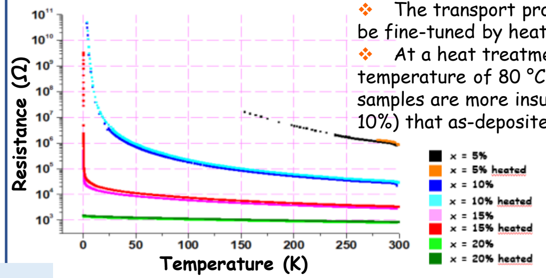


- When the composition in Y decreases, the sample goes from superconductor to insulator.

### Preliminary 3D phase diagram



### Effects of heat treatment on the disorder

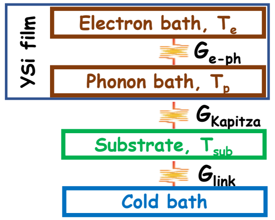


- The transport properties can be fine-tuned by heat treatments.
- At a heat treatment temperature of 80 °C, the samples are more insulating (by ~ 10%) that as-deposited.

### Weak electron-phonon coupling

At high electrical power, electrons can thermally decouple from phonons.

Schematic diagram of the hot electron model



*Heat-balance equation:*

Electrical power
Sample's volume

$$P = \Gamma_{e-ph}\Omega(T_{el}^5 - T_{ph}^5)$$ [3]

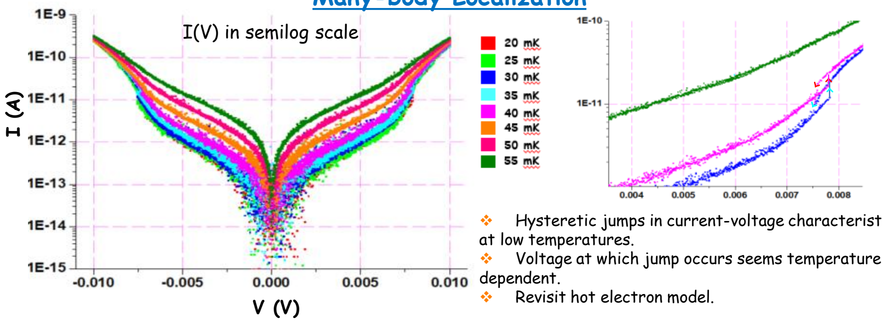
e-ph coupling

$\Gamma_{e-ph} \simeq 6-8\times10^{-2} nW/\mu m^3.K^5$ for T ≤ 50 mK

↳ Weaker than values in $Nb_xSi_{1-x}$

$\Gamma_{e-ph} \simeq 0.15 nW/\mu m^3.K^5$

### Many-body Localization



- Hysteretic jumps in current-voltage characteristics at low temperatures.
- Voltage at which jump occurs seems temperature-dependent.
- Revisit hot electron model.

## Conclusions

- Our films are homogeneous both in composition and thickness, with a film roughness of about 4 Å.
- Thick amorphous $Y_xSi_{1-x}$ films can exist under various states – superconducting, metallic and insulating.
- With a weak electron-phonon coupling, a-$Y_xSi_{1-x}$ could be an interesting material to probe this theorically-predicted new state and possibly evidence a finite-temperature insulator[2].

## Future plans

- ✓ Complete the first phase diagram (thickness, x).
- ✓ Establish how the electron-phonon decoupling evolves with the temperature.
- ✓ Systematic R(T) measurements at lower thickness and with heat treatment.
- ✓ Morphological characterizations with and without heat treatment.

## References

[1] Couches minces d'isolant d'Anderson application à la bométrie à très basse température, Stefanos Marnieros, 1998, [Doctoral thesis, University Paris XI], https://www.theses.fr/1998PA112119

[2] Possible experimental manifestations of the many-body localization, D. M. Basko, I. L. Aleiner, and B. L. Altshuler Phys. Rev. B 76, 099902 (2007)

[3] Depinning transition in Mott-Anderson insulators F. Ladieu, M. Sanquer, and J. P. Bouchaud, Phys. Rev. B 53, 973

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