# Structures and electrical conductance at the initial stages of magnesium growth on Si(111)-Pb surface.

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# Introduction

- Magnesium forms a silicide even at room temperature [1].

- At high flux rate or with large portions of a single magnesium deposition act, a film of $Mg_2Si$ silicide is formed in the structure $\frac{2}{3}\sqrt{3}x\frac{2}{3}\sqrt{3}$-Mg, then a polycrystalline magnesium film grows [1, 2]. At low flux rate or small portions, silicide islands grow without a silicide film, then a polycrystalline magnesium film grows [1, 2]. In all cases there is a large mass transport of silicon.

- When magnesium is deposited on the 1x1-Pb surface phase, other structures 4x4 - Mg, Pb and 6x6 - Mg, Pb [3, 4] are formed, where silicon mass transport is hindered up to 1 ML of magnesium.

- This can affect the formation of silicide and the growth of the magnesium film.


1. *Konstantin N. Galkin, Mahesh Kumarb, S.M. Shivaprasadb, Nikolay G. Galkin, Physics Procedia 11 (2011) 47–50*
2. *Dohyun Lee, Geunseop Lee, Sehun Kim, Chanyong Hwang, Ja-Yong Koo and Hangil Lee, J. Phys.: Condens. Matter 19 (2007) 266004*
3. *A.Y.Tupchaya, L.V. Bondarenko, A.A. Yakovlev, A.N. Mihalyuk, D.V. Gruznev, N.S. Denisov, A.V. Matetskiy, A.Yu. Aladyshkin, A.V. Zotov, A.A. Saranin (in press)*

# Samples, sources and methods

## Samples, cleaning

Si(111) 15x5x0,3 мм$^3$
n-type (P-doped), 20-100 Ohm*cm

Heating for several hours at 600 C$^o$ and
flashing at 1350 C$^o$

## Sources, calibration

Mg, heated tantalum cell
4x4-Pb(1ML), Mg(0,4ML),
6x6-Pb(1ML), Mg(1ML) [1]

Pb, heated tantalum cell
1x1-Pb(1ML) [2]

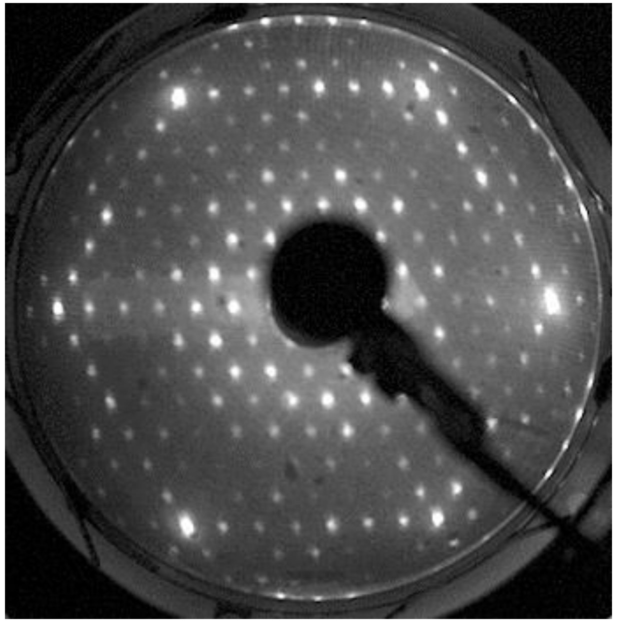
The LEED patterns correspond to the Mg or Pb cover in the each structure. Maximum intensity of superreflexes corresponds to the adsorbate metal cover.


1. *A.Y.Tupchaya, L.V. Bondarenko, A.A. Yakovlev, A.N. Mihalyuk, D.V. Gruznev, N.S. Denisov, A.V. Matetskiy, A.Yu. Aladyshkin, A.V. Zotov, A.A. Saranin (in press)*
2. *V.G.Lifshits, A.A.Saranin and A.V.Zotov «Surface Phases on Silicon»*

# Samples, sources and methods

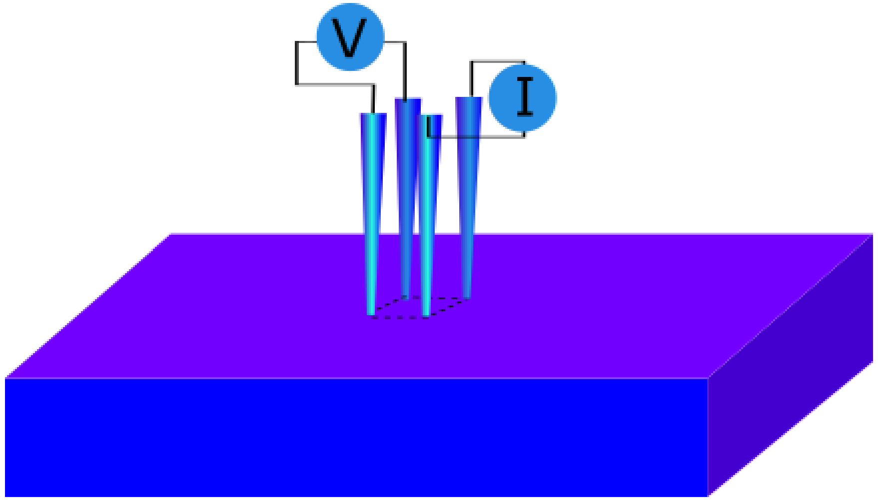
## Methods:

1. Low energy electron diffraction (LEED)



Si(111)7x7- silicon surface after cleaning, $E_p$=40eV

2. Four-point-probe method (4PP)



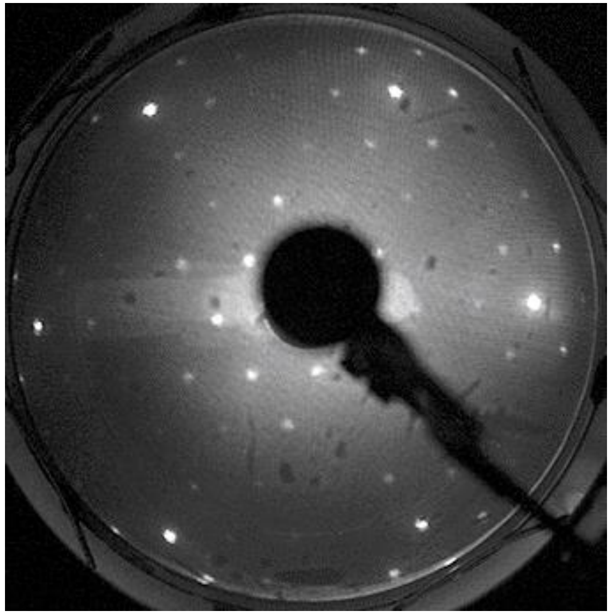

$$\sigma\left(\frac{S}{\square}\right) = \frac{\ln(2)}{2\pi R_{measure}}$$

where $R_{measure}=\frac{U}{I}$

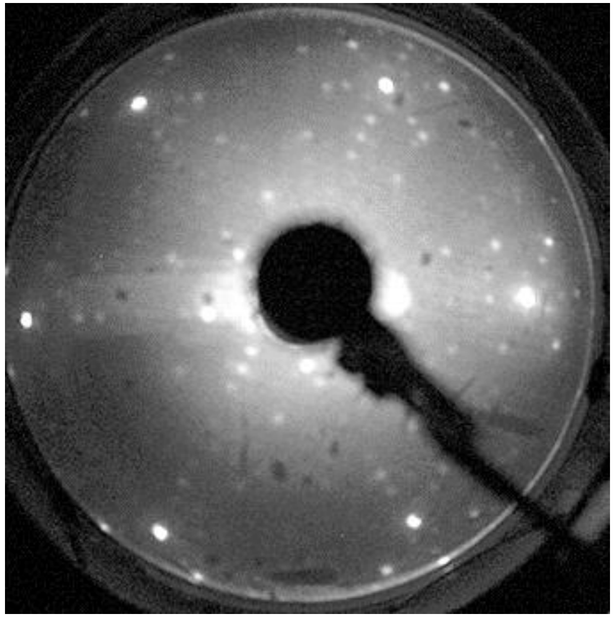
# Results and analysis

## Deposition of Mg on Si(111)-Pb at room temperature

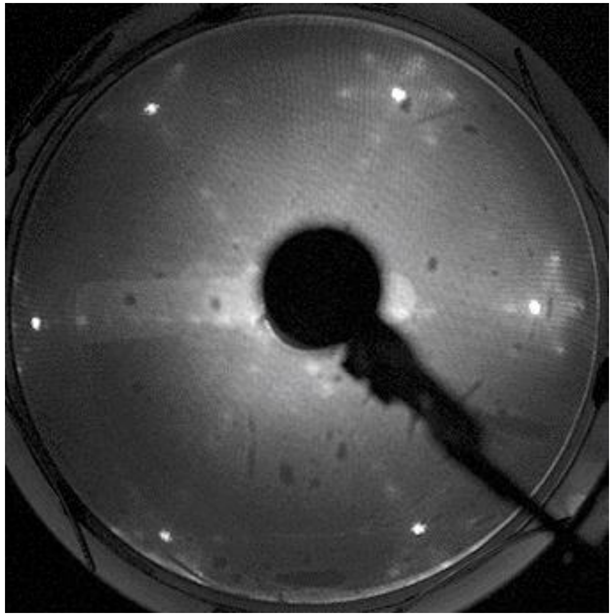
1. Mg/1x1-Pb



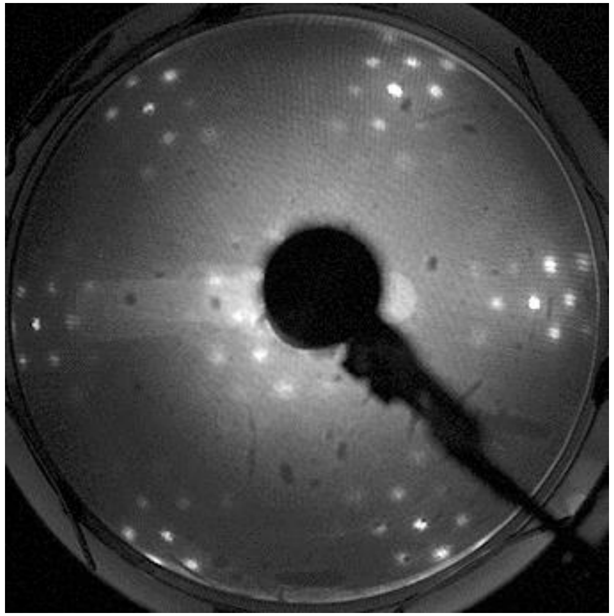
4x4 - Pb, Mg (0,4ML)



4x4 +6√3- Pb, Mg (0,6ML)



“perforated ribbons” phase (0,6ML)

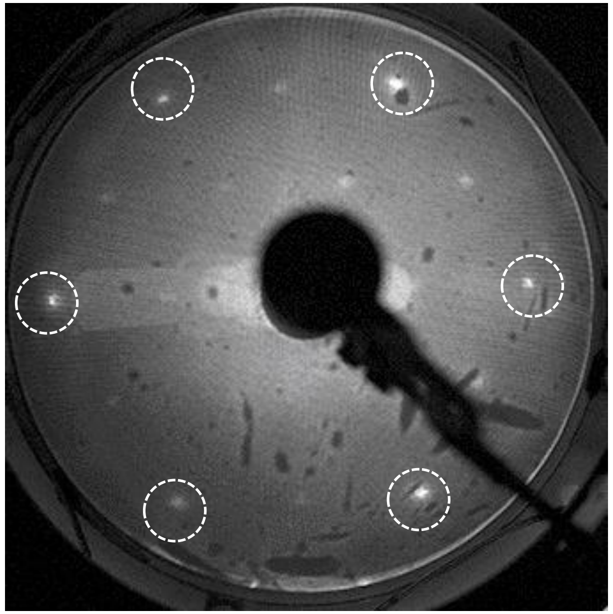


6x6 - Pb, Mg (1ML)

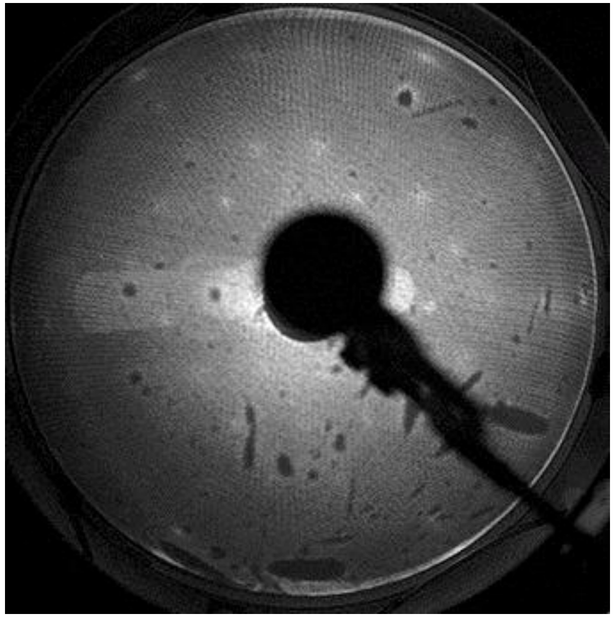
# Results and analysis

## Deposition of Mg on Si(111)-Pb at room temperature

1. Mg/1x1-Pb



2x2 - Pb, Mg (6ML)



4x4 (6ML)

4x4 LEED pattern
Mg deposition of large portion (1-2ML) at the deposition act

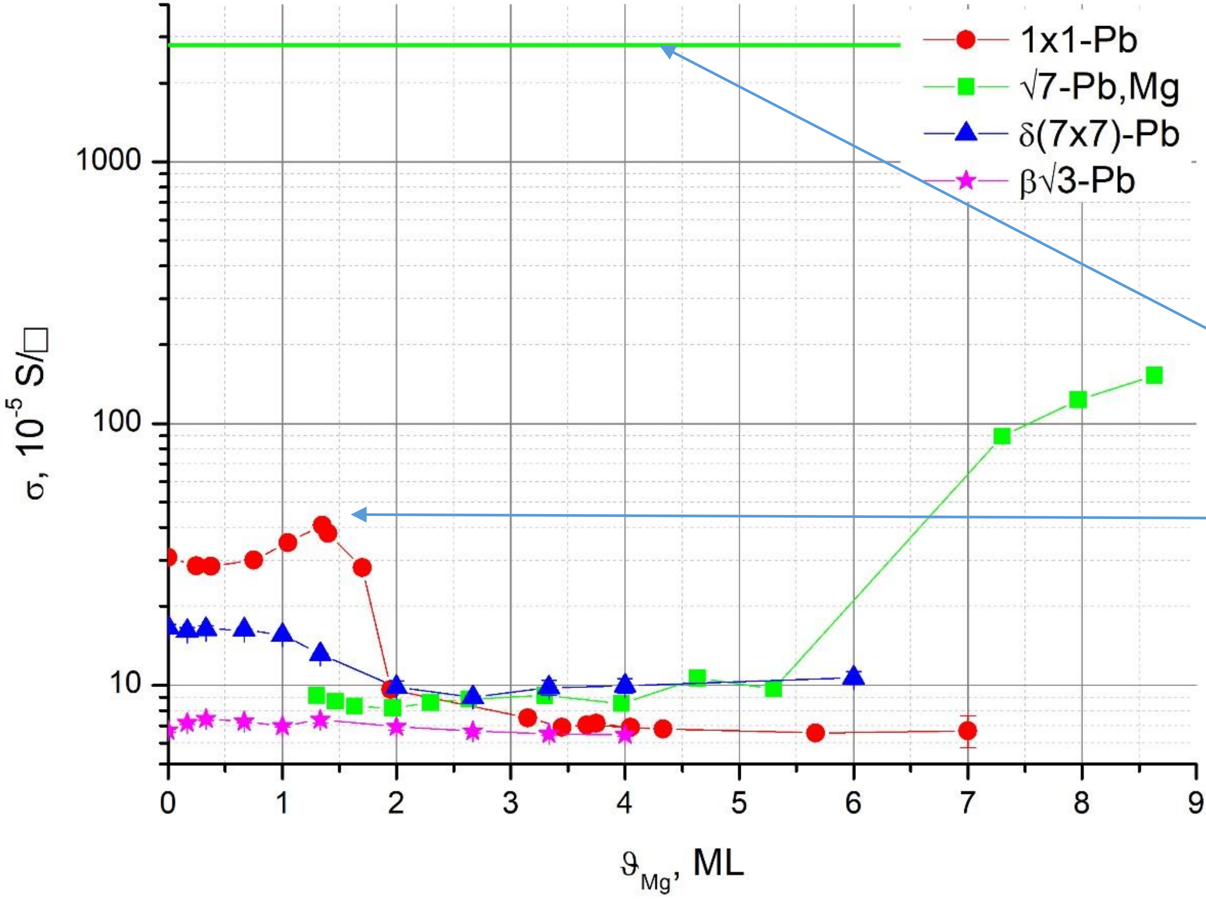
2x2 LEED pattern
Mg deposition of small portion (0.5-1ML) at the deposition act

1x1-spots in rounds

1x1-Pb - 1ML of Pb in structure

# Results and analysis

## Surface electrical conductance for Mg deposition on Si(111)-Pb



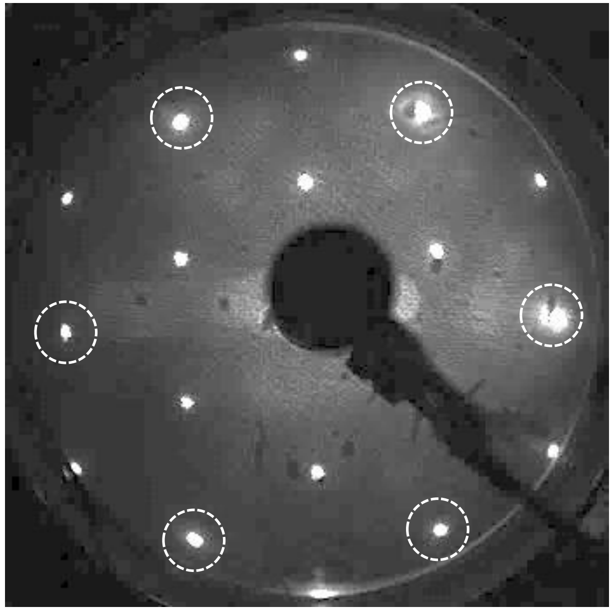

calculated value 2800 S/□ for Mg monocrystalline layer of 1,4 nm

formation of 6x6-Pb,Mg, formation metallic layer

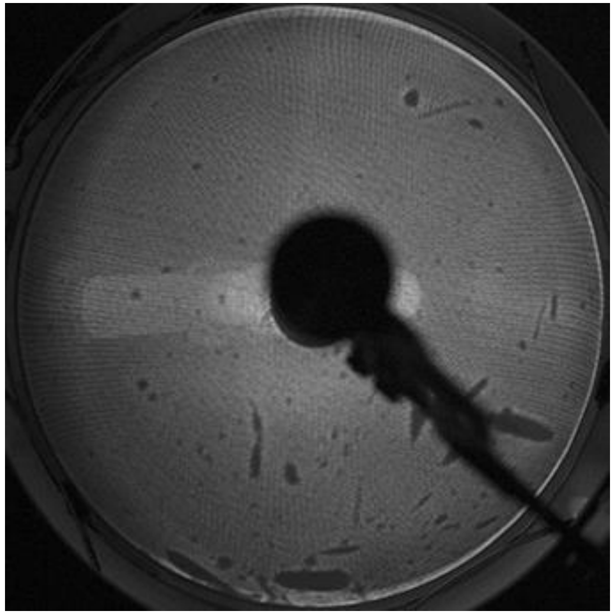
# Results and analysis

## Deposition of Mg on Si(111)-Pb at room temperature

2. Mg/$\beta\sqrt{3}$-Pb



$\beta\sqrt{3}$-Pb



Background at 6ML

background LEED pattern
Mg deposition of small portion (0.5-1ML) at the deposition act

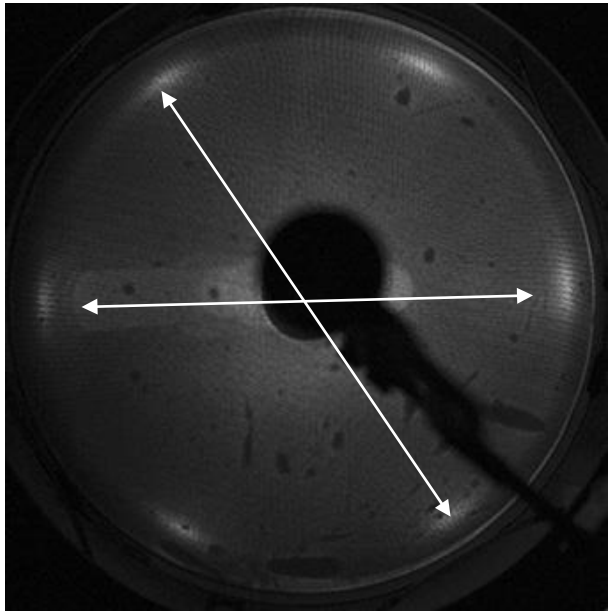
1x1-spots in rounds

$\beta\sqrt{3}$-Pb- 0.3ML of Pb in structure

# Results and analysis

## Deposition of Mg on Si(111)-Pb at room temperature

2. Mg/$\beta\sqrt{3}$-Pb



LEED of Mg(0001) film at 6ML
Ratio Mg/Si is 0.86

Magnesium growth

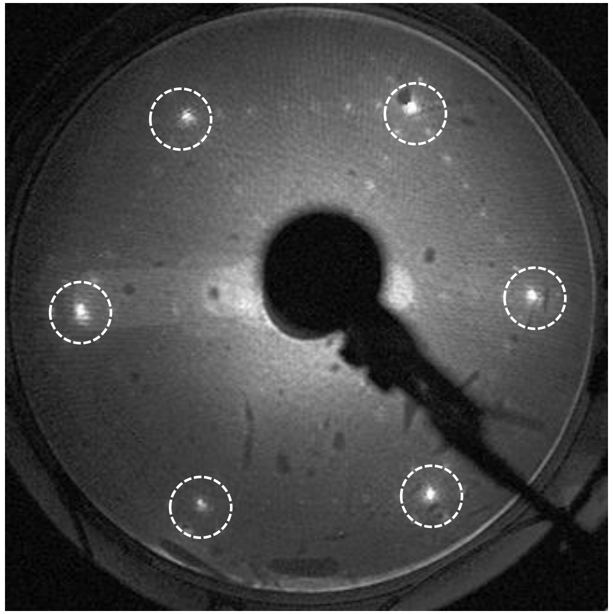
Mg(0001) LEED pattern
Mg deposition of large portion (1-2ML) at the deposition act

$$\frac{Mg(0001)\ 3{,}204\text{Å}}{Si(111)\ 3{,}84\text{Å}} = \boxed{0{,}84}$$

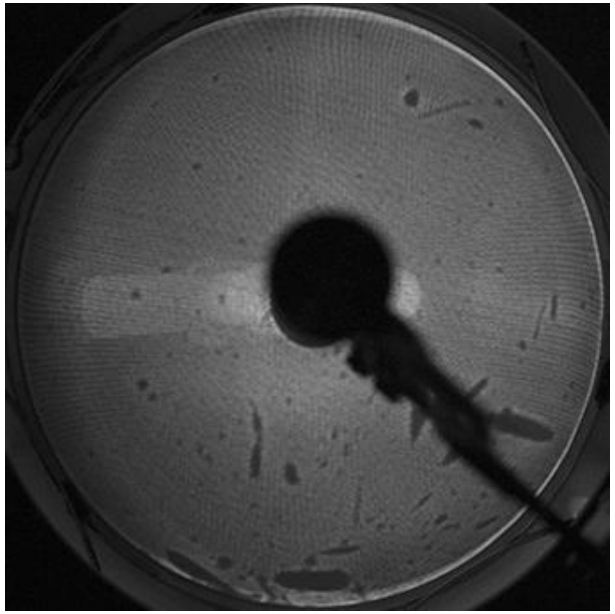
# Results and analysis

## Deposition of Mg on Si(111)-Pb at room temperature

3. Mg/$\delta$(7x7) -Pb



$\delta$(7x7) -Pb



Background at 2.5ML

Background at Mg deposition of small portion (0.5-1ML) at the deposition act

1x1-spots in rounds

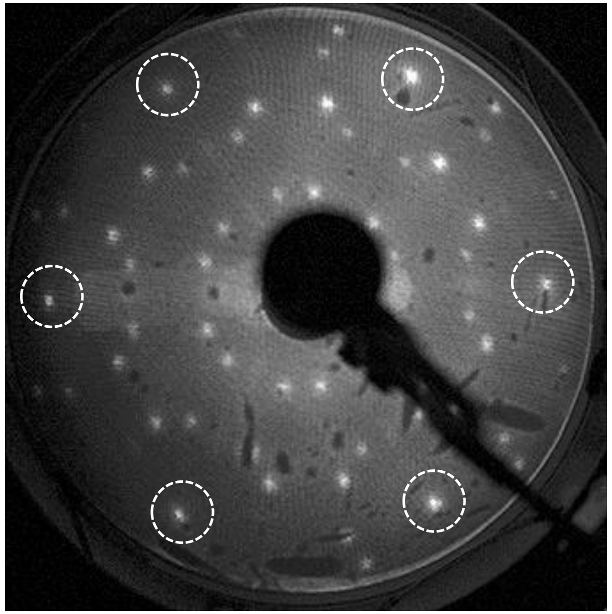
$\delta$(7x7) - 1ML of Pb in the structure

LEED patterns, 60eV

# Results and analysis

## New surface phases Si(111)-Pb, Mg

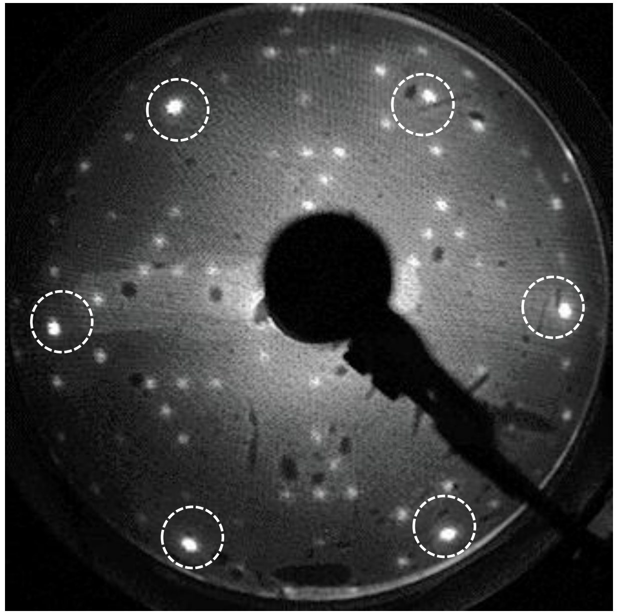
1. √7x√7 - Pb, Mg


√7x√7 – Pb, Mg

1x1-spots in rounds

The optimal conditions are 1-1.3 ML of Mg on β√3-Pb, 30 seconds at 250C$^{o}$

2. √3x√19 - Pb, Mg

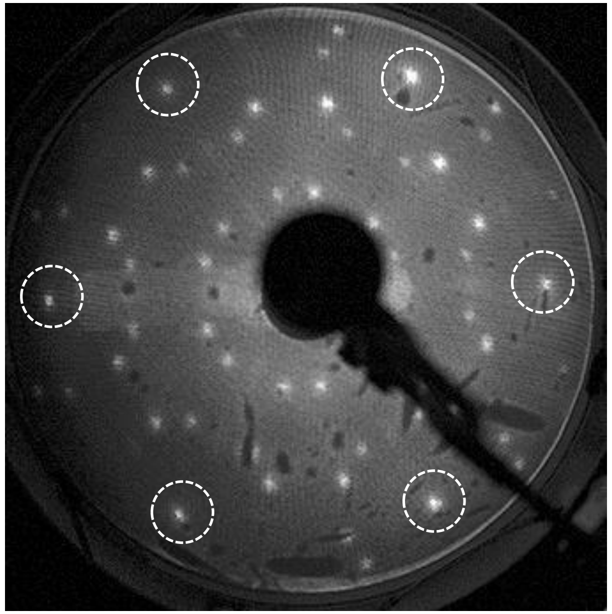

√3x√19 – Pb, Mg

The optimal conditions are 0.6-0.9 ML of Mg on β√3-Pb, 30 seconds at 350C$^{o}$

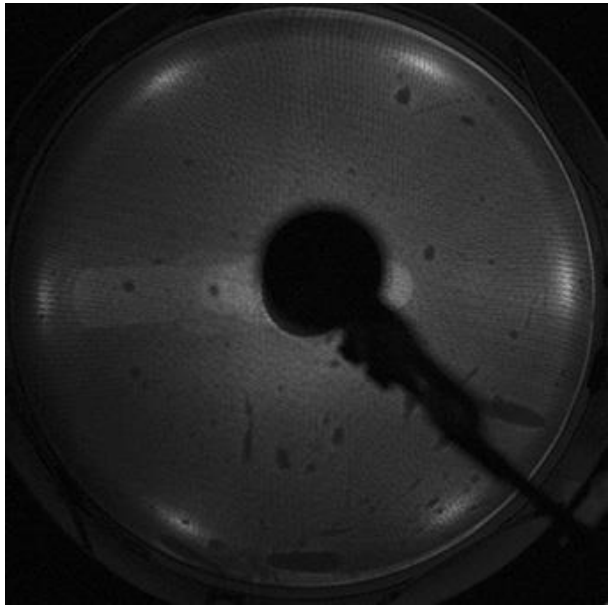
# Results and analysis

## Deposition of Mg on Si(111)-Pb, Mg at room temperature

4. Mg/ √7x√7 - Pb, Mg



√7x√7 – Pb, Mg



Mg(0001) at 7ML

The changes in Mg deposition manner for √7 - Pb, Mg don’t lead to changes in magnesium growth

1x1-spots in rounds

# Results and analysis

## Surface electrical conductance σ
## and metal compounds of some surface structures.

| Structures | σ, $10^{-5}$ S/□ | $\Theta_{sum}$, MC | $\Theta_{Pb}$, MC | $\Theta_{Mg}$, MC |
|---|---|---|---|---|
| β√3-Pb | 6.7 | 0,3 | 0,3 | 0 |
| δ(7x7)-Pb | 16.6 | 1 | 1 | 0 |
| 1x1-Pb | 30.7 | 1 | 1 | 0 |
| √3x√19-Pb, Mg | 6.7 | 0.9 | 0.3 | 0.6 |
| 4x4-Pb, Mg | 28.5 | 1.4 | 1 | 0.4 |
| √7x√7-Pb, Mg | 9.1 | 1.3 | 0.3 | 1 |
| 6x6-Pb, Mg | 40.8 | 2 | 1 | 1 |
| 6√3-Pb, Mg | 28.4 | 1.7 | 1 | 0.7 |
| Mg(0001) of 8.6 ML | 152.7 | 8.9 | 0.3 | 8.6 |

# Conclusions

- The structures of Pb have a significant effect on the formation of ultrathin magnesium films on the Si (111) surface.
- For Mg on 1x1-Pb takes place the successive structure transformations whereas for the magnesium deposition on the other lead surface phases have not such changes. The surface electrical conductance changes according to the changes in the structure. The highest electrical conductance of all the presented structures, except for the magnesium film, has the surface phase 6x6-Pb, Mg with the maximum metal atoms in its structure.
- Growth of Mg films depends on the deposition manner of magnesium atoms in all cases except for the formation Mg film on the √7x√7 - Pb, Mg. The large portions (about 1-2 ML at deposition act) of Mg atoms lead to the formation Mg (0001) polycrystalline film. The small portions (about 0.5-1 ML at deposition act) lead to disordered film with the background in the LEED patterns. The corresponding electrical conductance are high for the magnesium film and low for the disordered layer. The changes in Mg deposition manner for √7 - Pb, Mg don't lead to changes in magnesium growth.
- New surface phases with Mg and Pb have been obtained √7x√7 - Pb, Mg, √19x√3 - Pb, Mg.

Thank you for your attention!