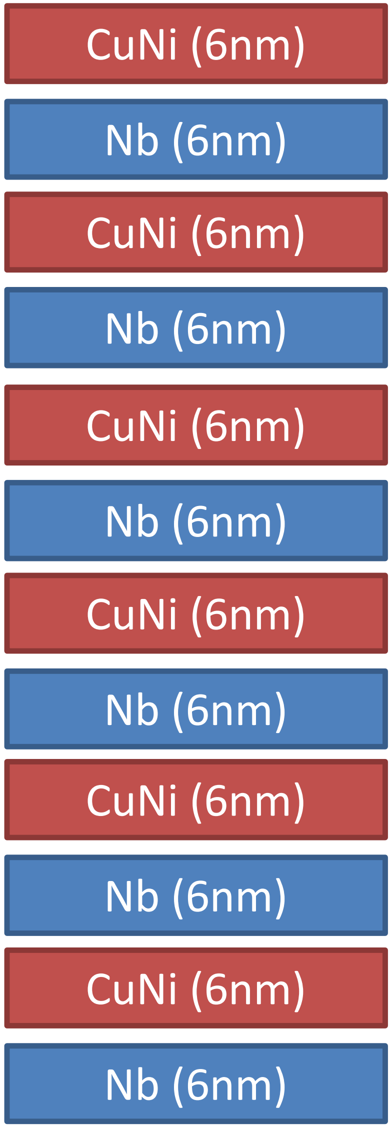
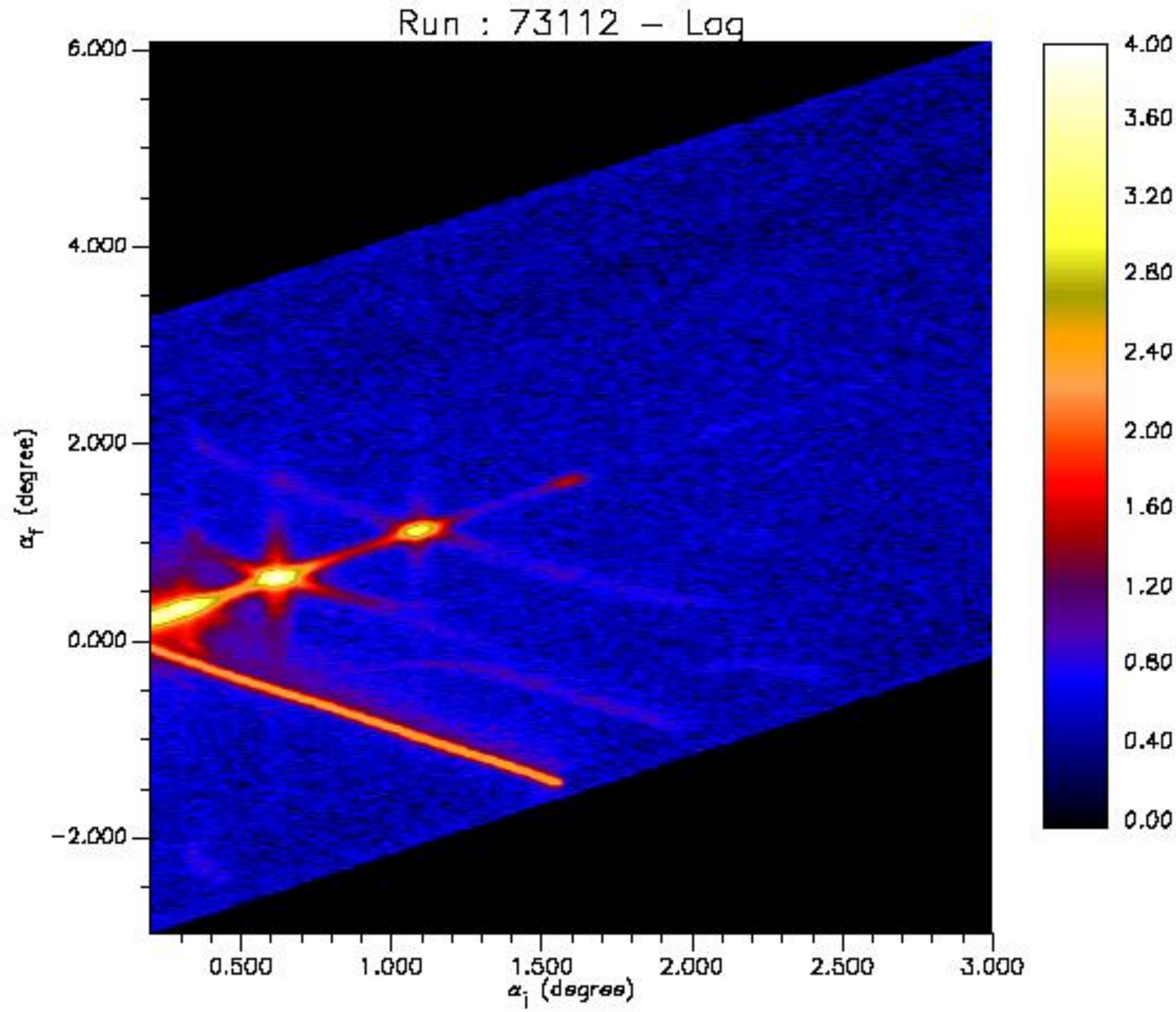
Diffuse scattering - the unique tool to control interfaces of heterostructures

Yury N. Khaydukov

Max-Planck Institute for Solid State Research, Stuttgart, Germany

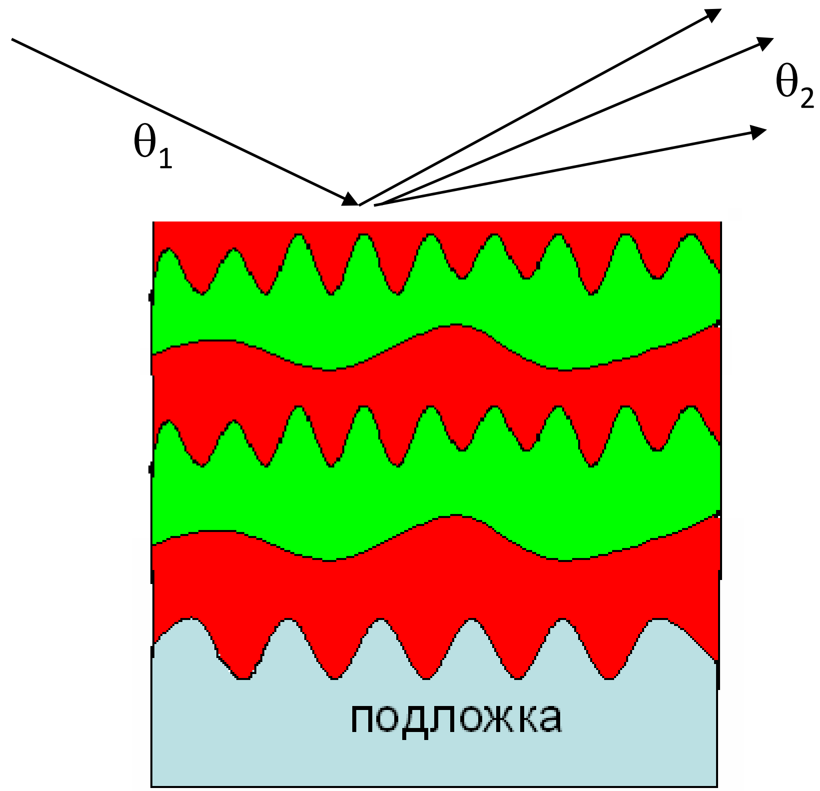
MAX-PLANCK-GESELLSCHAFT





V6 reflectometer @ HZB

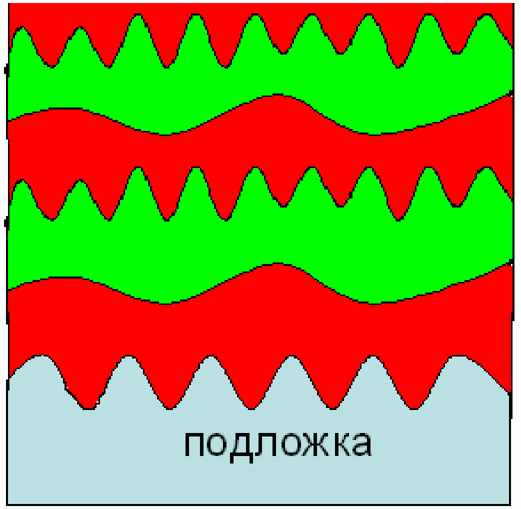
Борновское приближение искаженных волн



$$I(\theta_1,\theta_2) \propto \sum_l \sum_m \left[\Psi(\theta_2,z_l)\Psi(\theta_1,z_l)\Delta\rho_l\right]^* C_{lm}\left(\vec{Q}_X\right)\Psi(\theta_2,z_m)\Psi(\theta_1,z_m)\Delta\rho_m$$

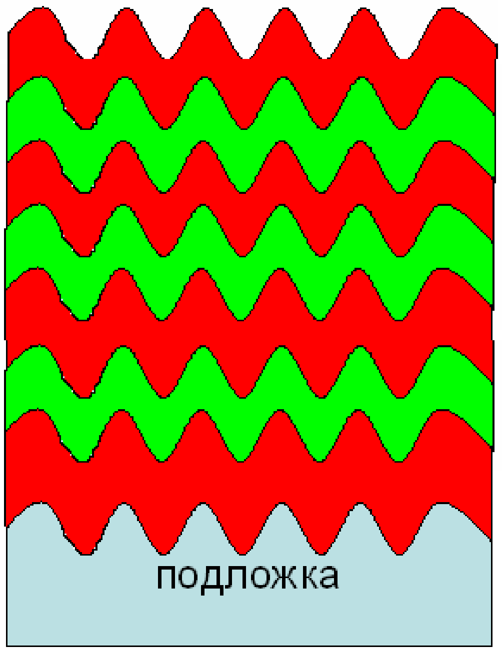
$$C_{lm}(x,y) = \left\langle \delta z_l(0,0)\,\delta z_m(x,y)\right\rangle$$

Режимы роста гетероструктур

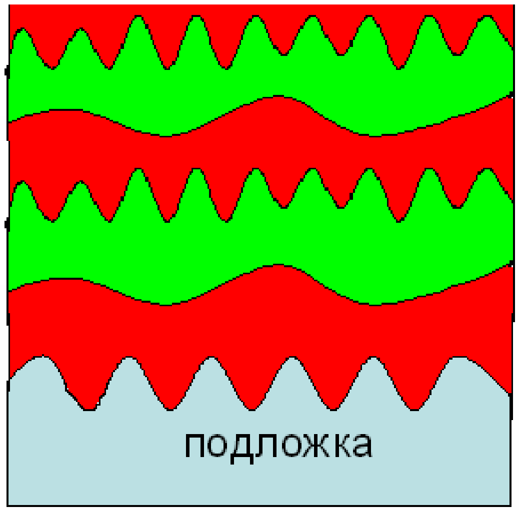


Неконформные шероховатости

Режимы роста гетероструктур

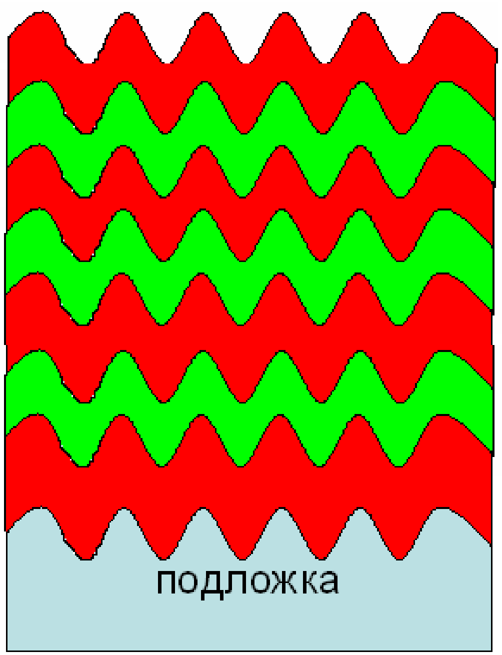


Конформные шероховатости

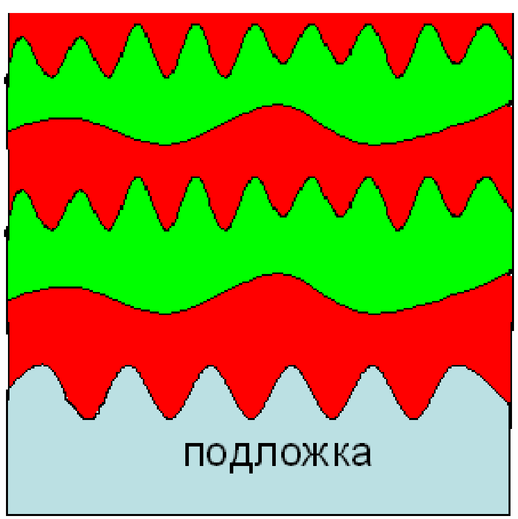


Неконформные шероховатости

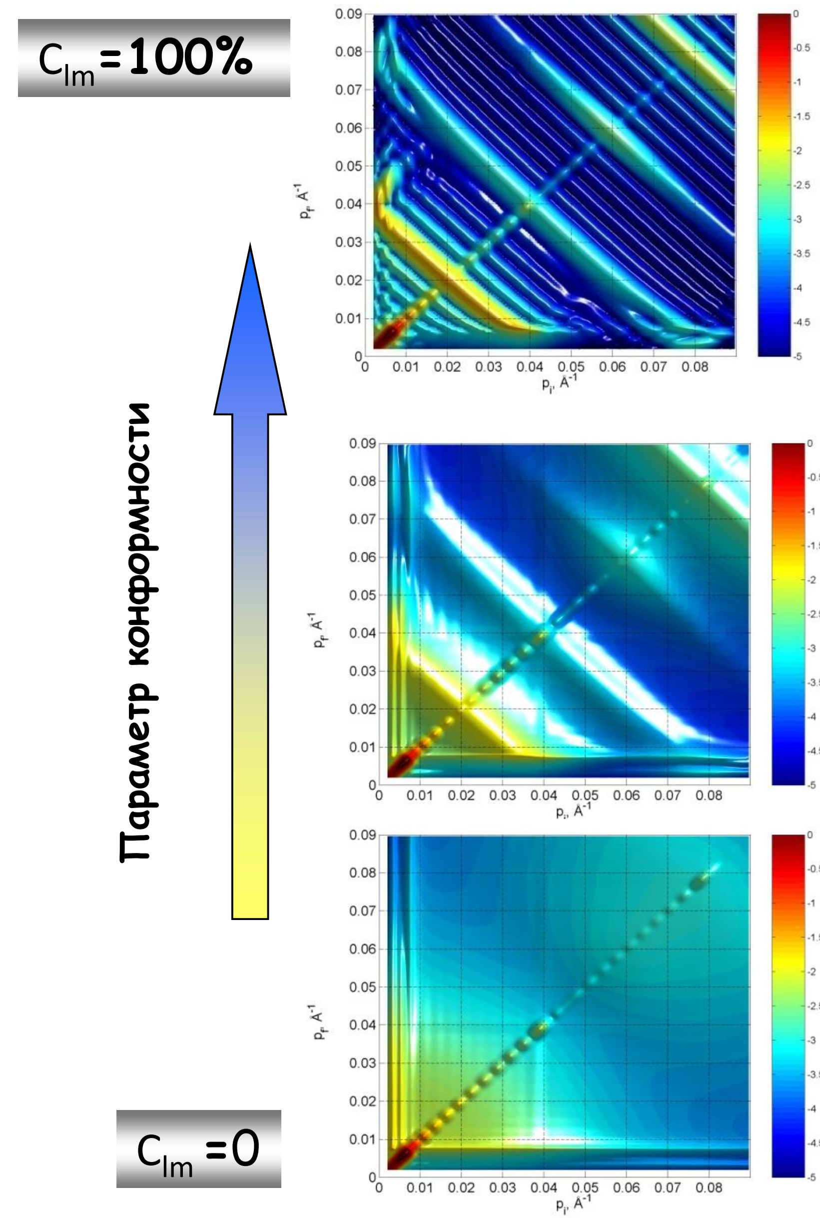
Режимы роста гетероструктур



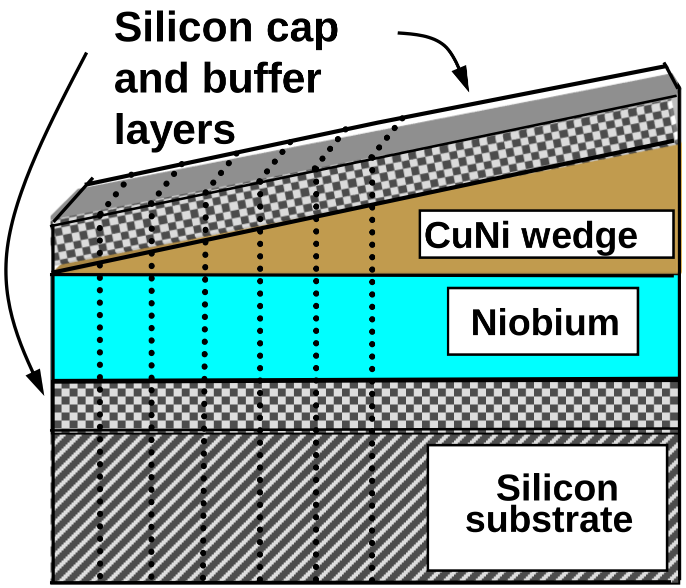
Конформные шероховатости

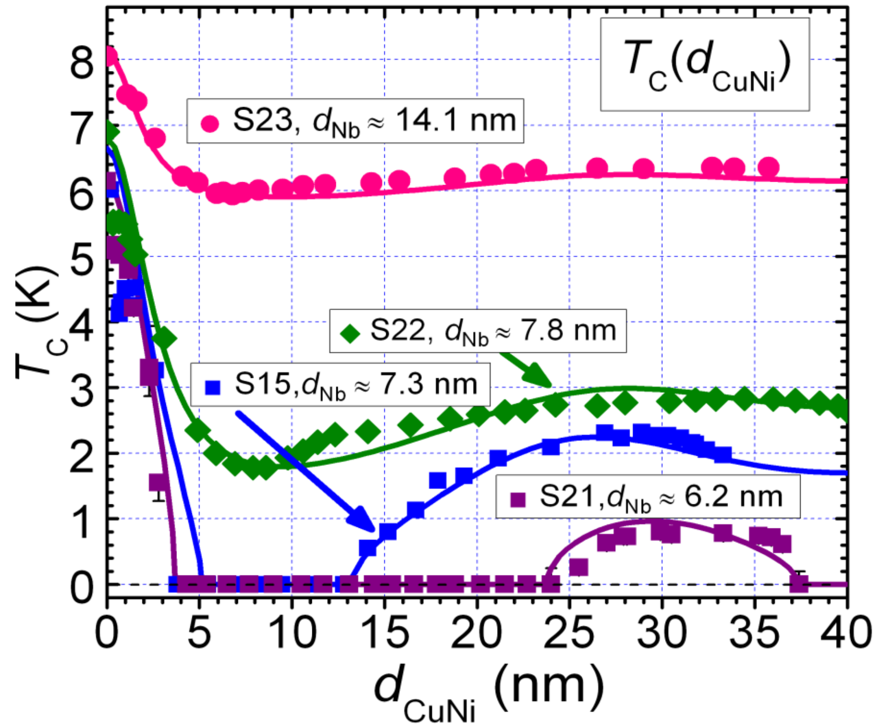


Неконформные шероховатости



Interfacial roughness and proximity effects in superconductor/ferromagnet CuNi/Nb heterostructures

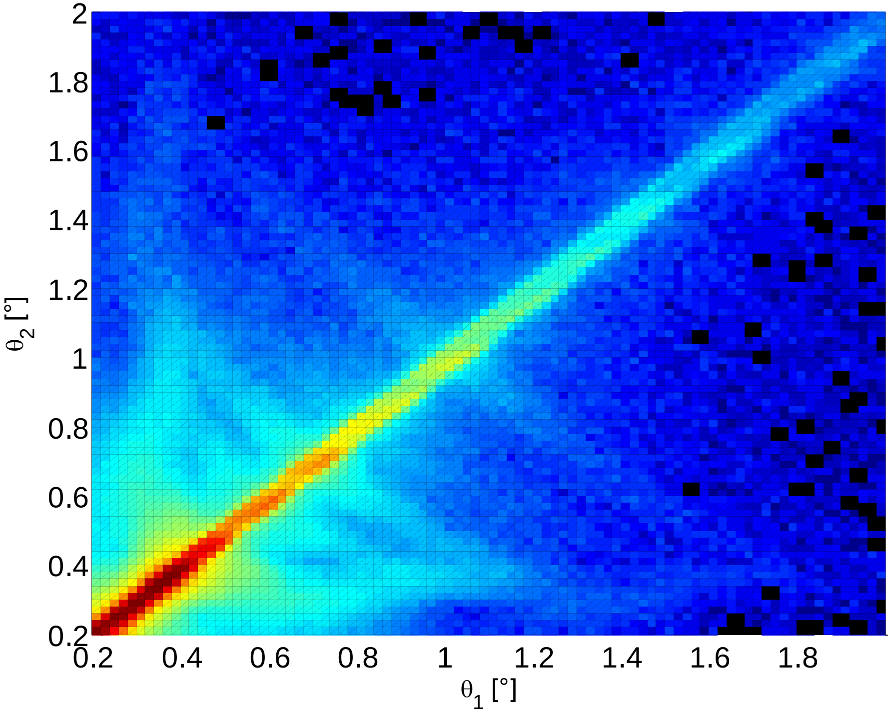




В сотрудничестве с Институтом Электронной Инженерии и Нанотехнологий (Кишинев)

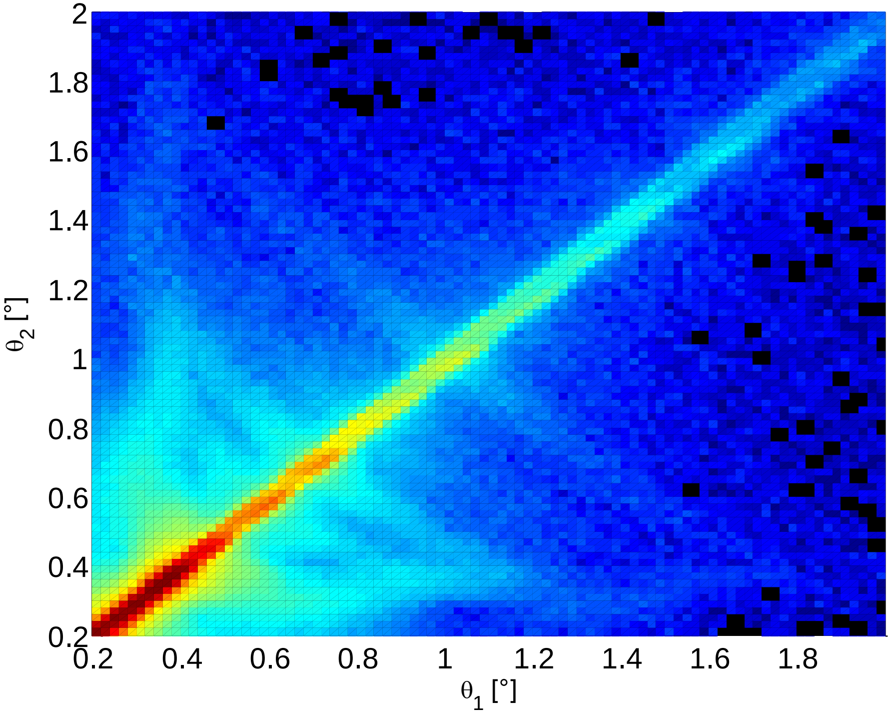
V.I. Zdravkov et al., PRL 97, 057004, 2006,
A.S. Sidorenko et al., JETP Lett. v.90, 139 (2009),
V.I. Zdravkov, *et al.*, – PRB v.82 , 054517 (2010)

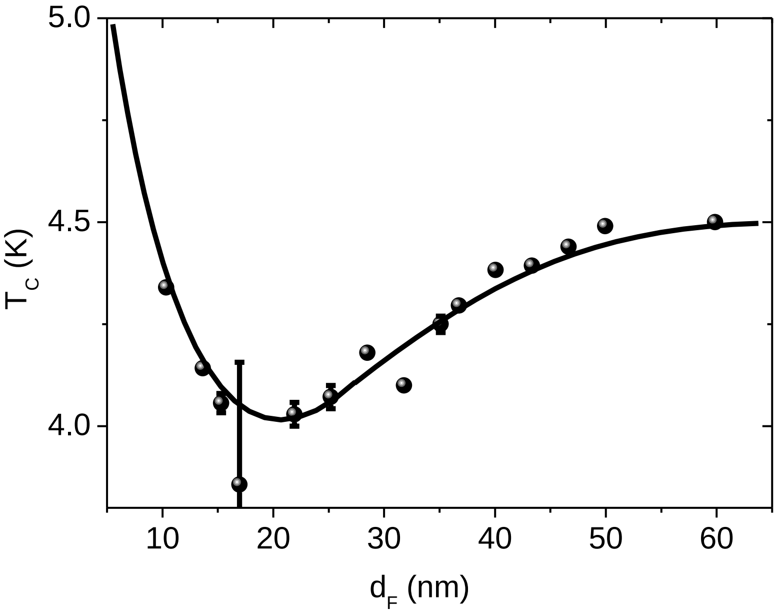
CuNi(10nm)/Nb(20nm) on Si(111) susbtrate:



Yu. Khaydukov, R. Morari, O. Soltwedel, T. Keller, G. Christiani, G. Logvenov, M. Kupriyanov, A. Sidorenko, and B. Keimer, Journal of Applied Physics **118, 213905 (2015)**

CuNi(10nm)/Nb(20nm) on Si(111) susbtrate:





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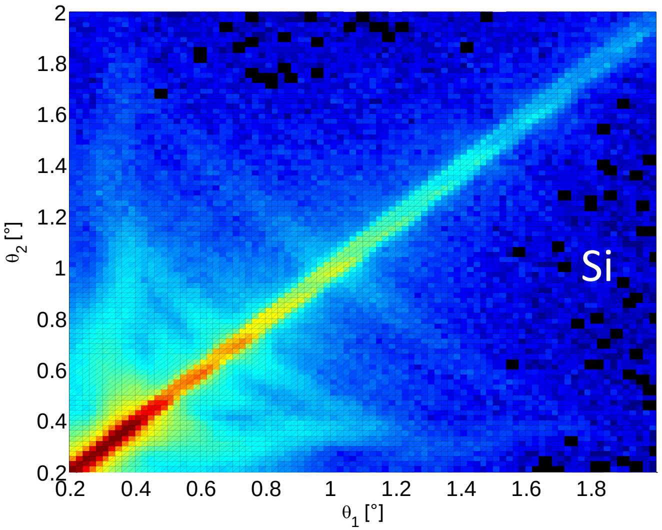
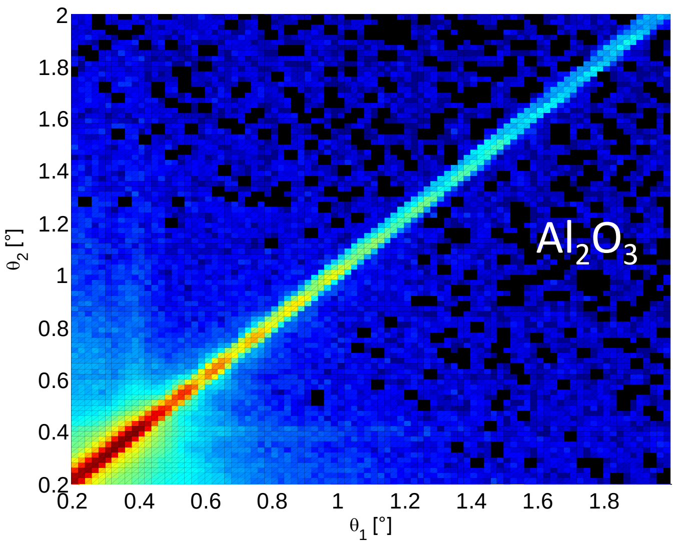
Change Si(111) susbtrate to Al_2O_3 (1-102):





Yu. Khaydukov, R. Morari, O. Soltwedel, T. Keller, G. Christiani, G. Logvenov, M. Kupriyanov, A. Sidorenko, and B. Keimer, Journal of Applied Physics **118, 213905 (2015)**

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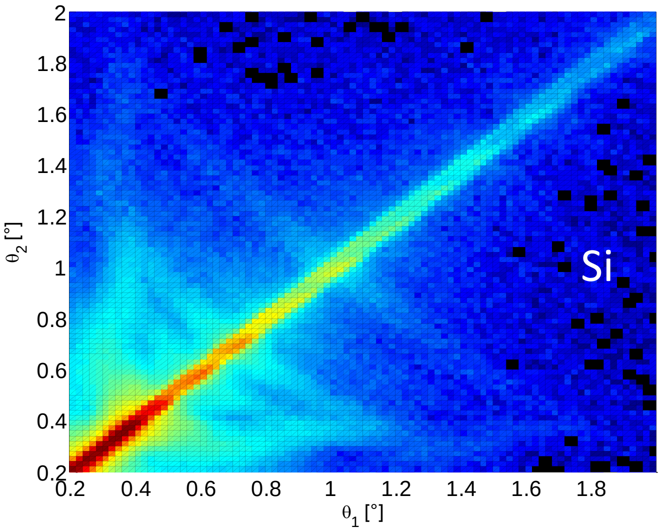
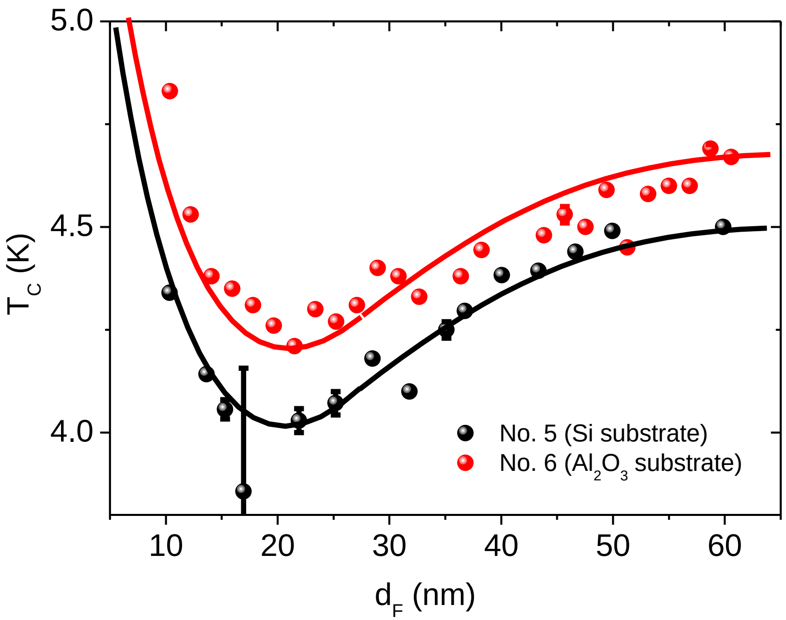
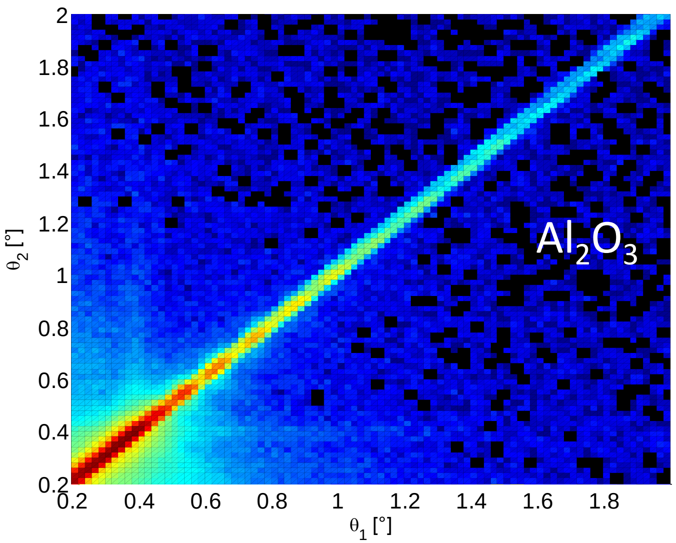




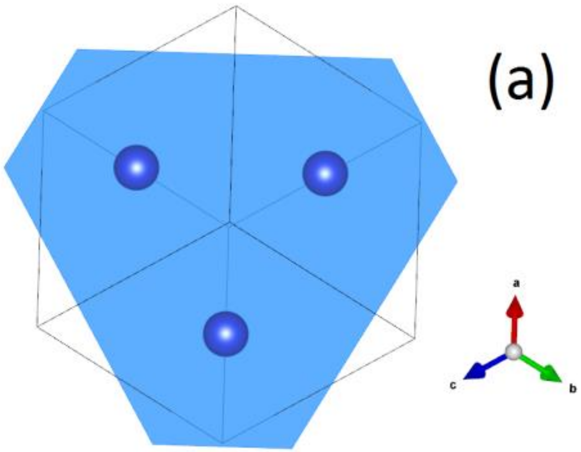


Yu. Khaydukov, R. Morari, O. Soltwedel, T. Keller, G. Christiani, G. Logvenov, M. Kupriyanov, A. Sidorenko, and B. Keimer, Journal of Applied Physics **118, 213905 (2015)**

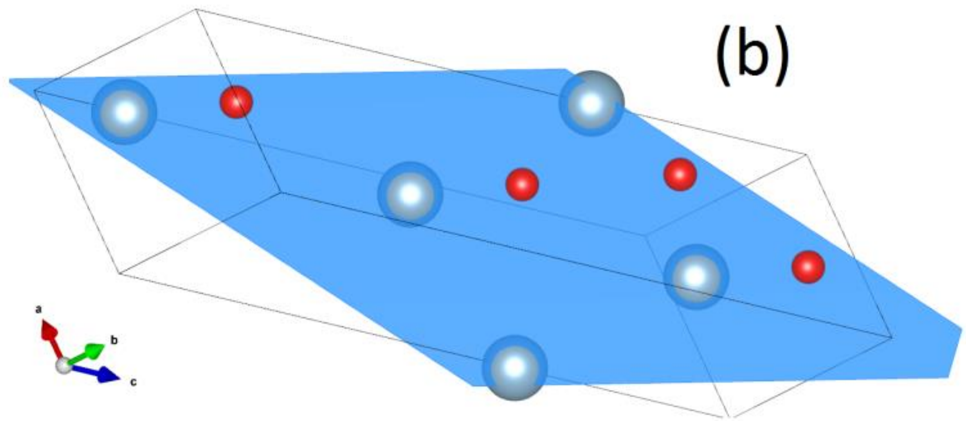
К объяснению разности режимов роста

Поверхность подложек:

Si(111)



Al_2O_3 (1-102):



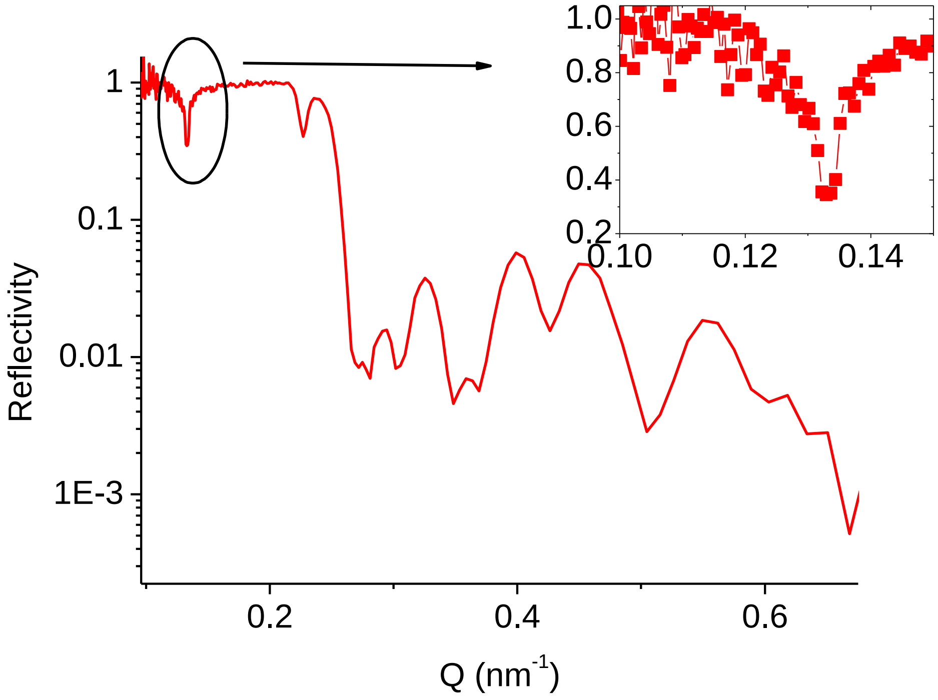
Пример 2.

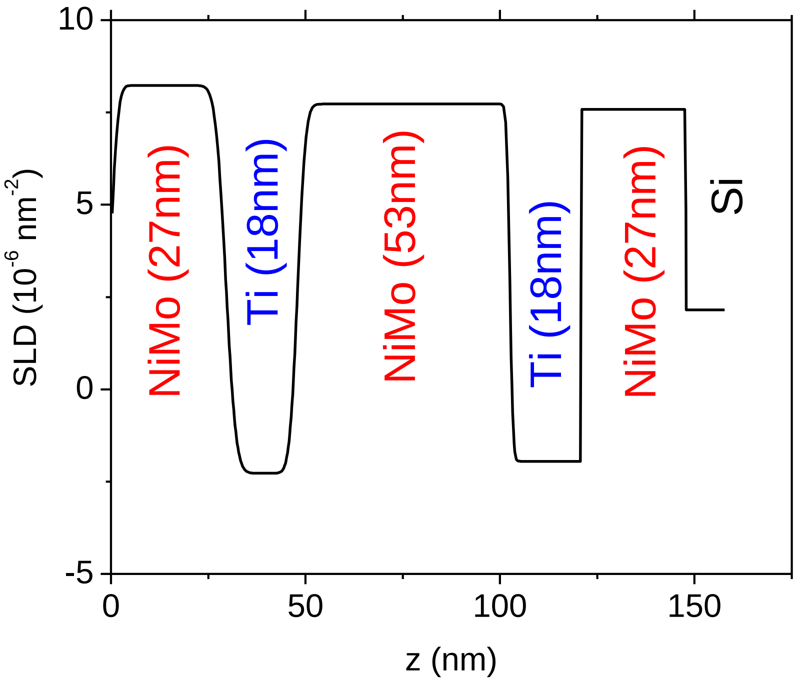
УХН фильтр

В сотрудничестве с ЛНФ ОИЯИ
(А. Франк, Г. Кулин, А. Кобзев, В. Петренко)

Кривые зеркального отражения

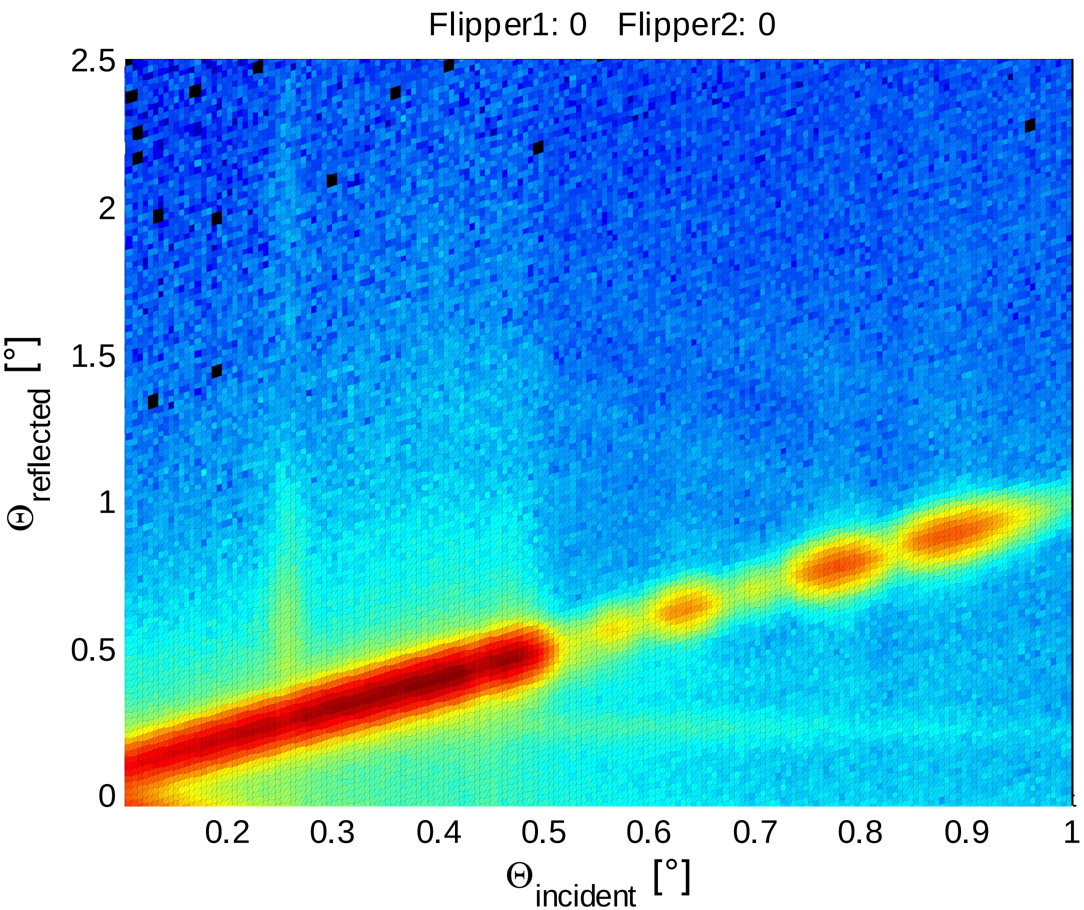
Рефлектометр GRAINS
ЛНФ ОИЯИ



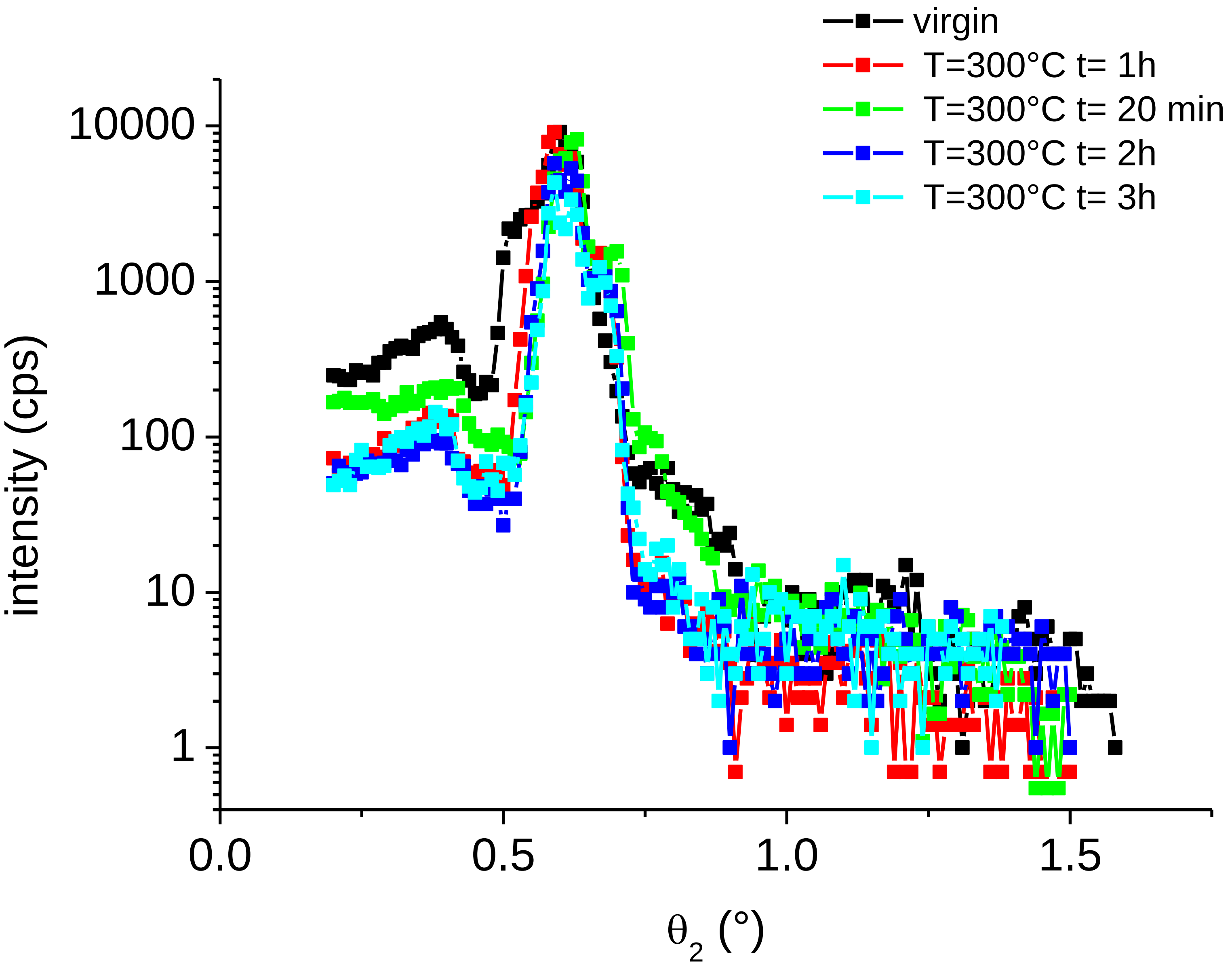


Нейтронные карты рассеяния

Рефлектометр NREX
MPI @ FRM 2

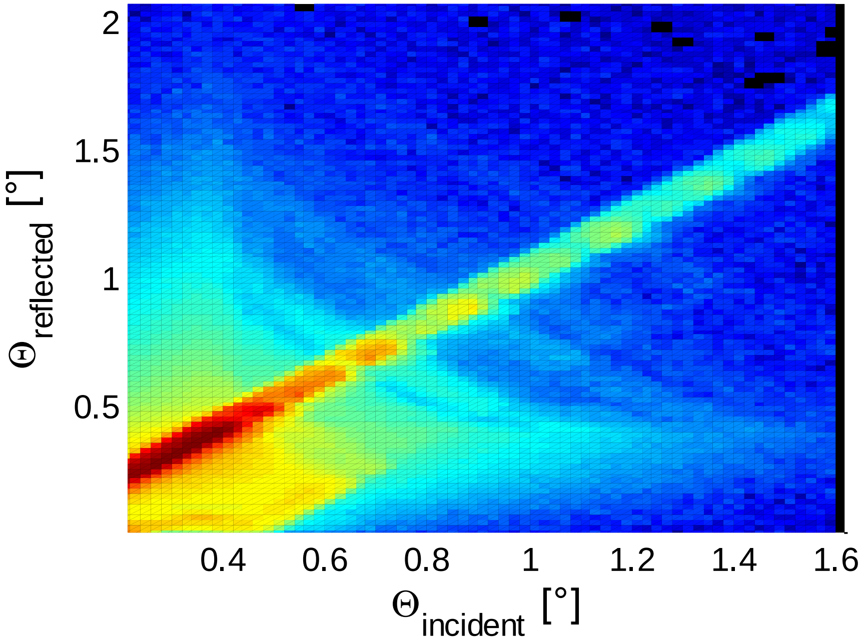


Отжиг в кислородной атмосфере

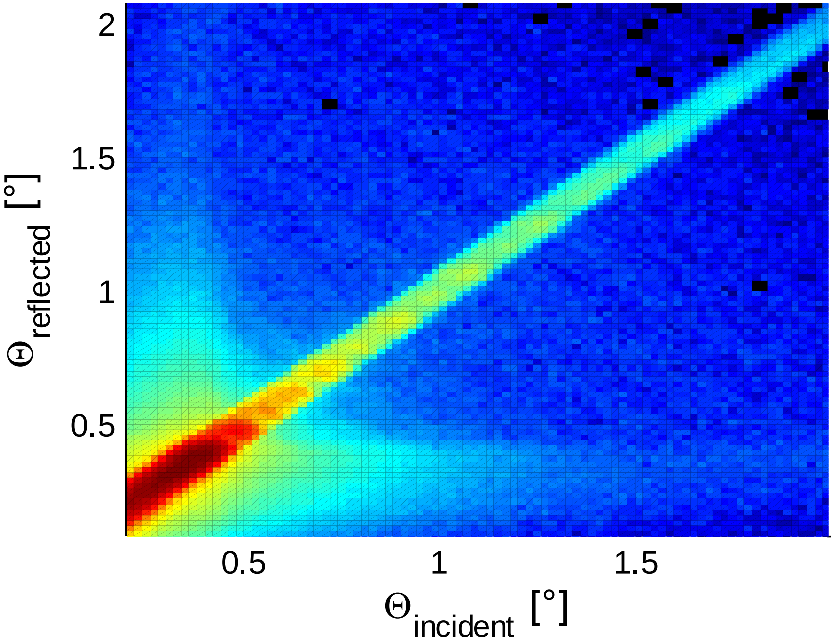


Результат отжига

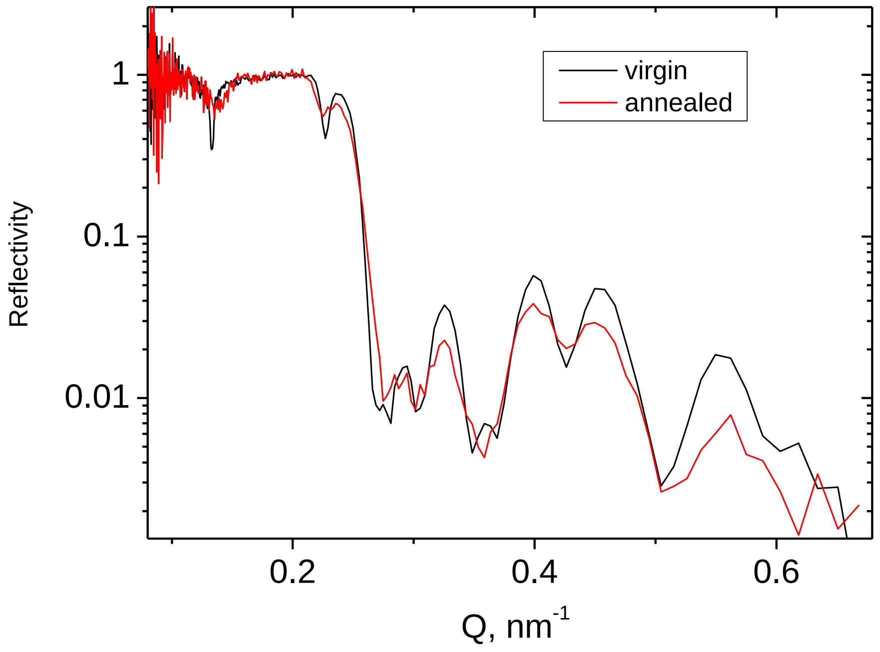
До отжига

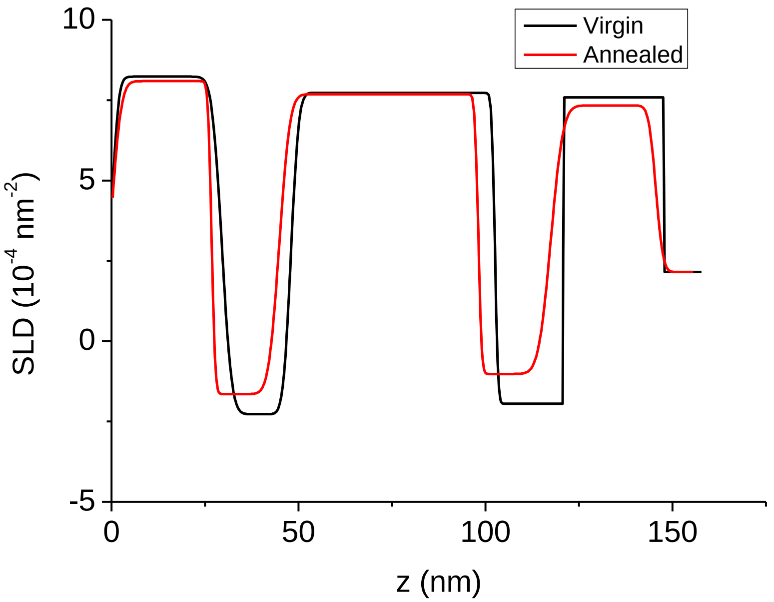


Час отжига при 300 °C



Результат отжига





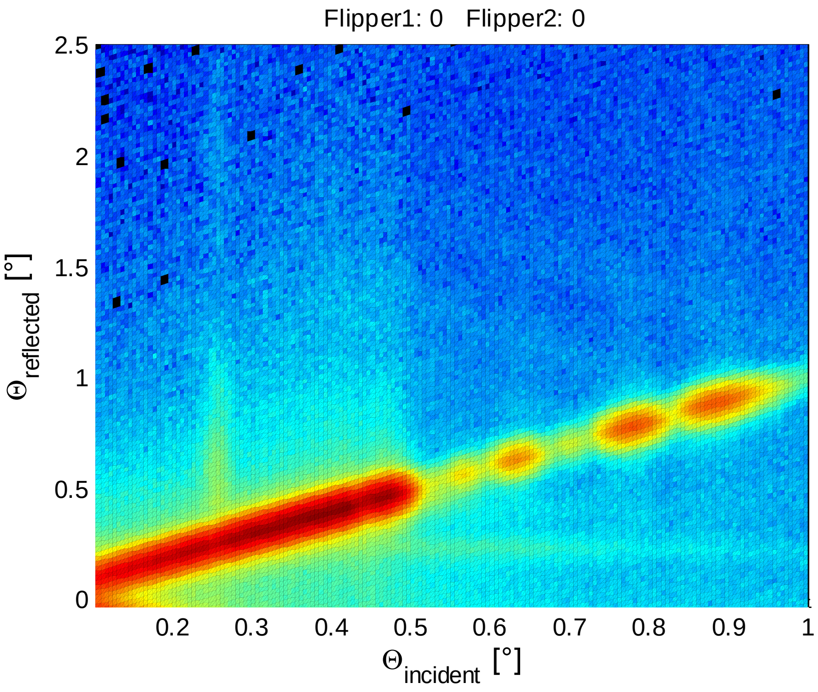
Выводы

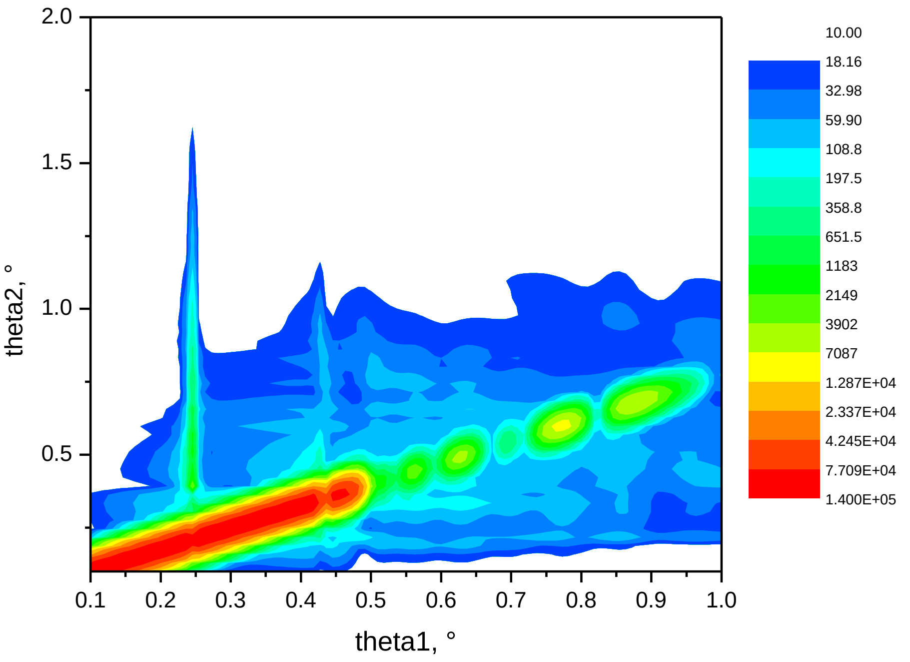
Умение контролировать режим роста является критически важным для приготовления качественных гетероструктур с большим количеством интерфейсов

Диффузное рассеяние нейтронов и рентгеновского излучения является уникальным инструментом позволяющим получить информацию о степени конформности шероховатостей границ раздела и, как следствие, повлиять на режим роста различными способами (смена подложки, отжиг, оптимизация параметров роста)

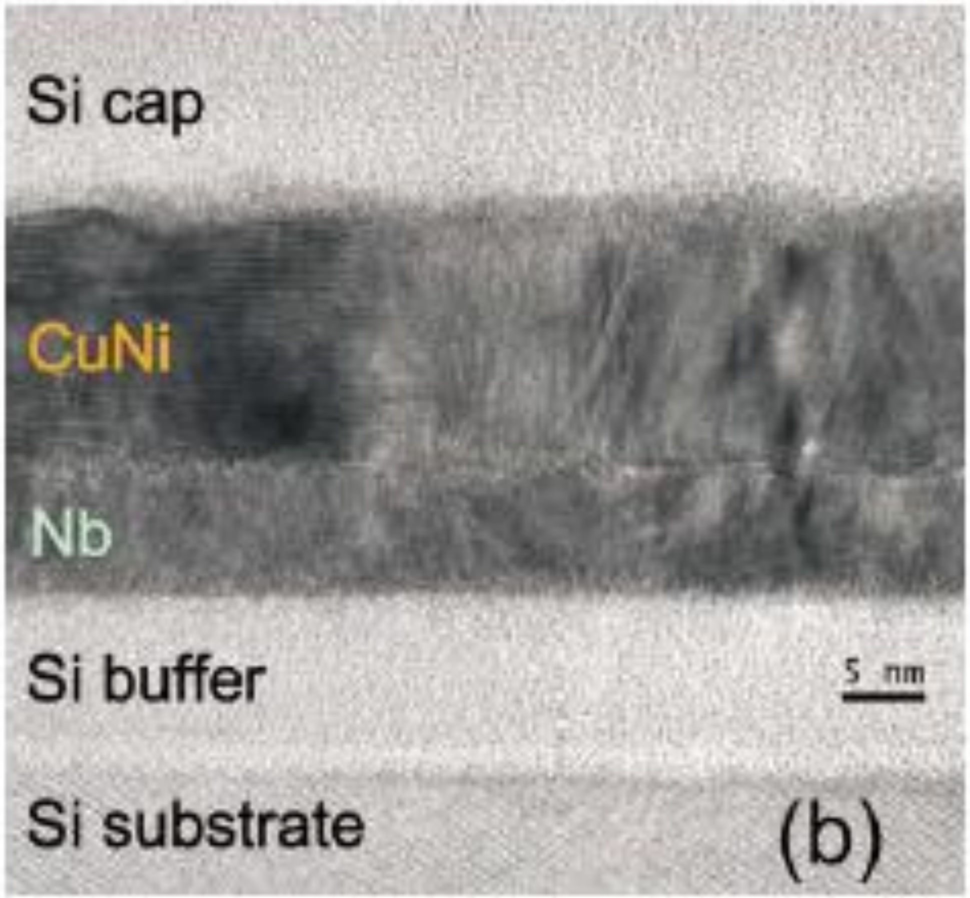
Нейтронные карты рассеяния

Рефлектометр NREX
MPI @ FRM 2

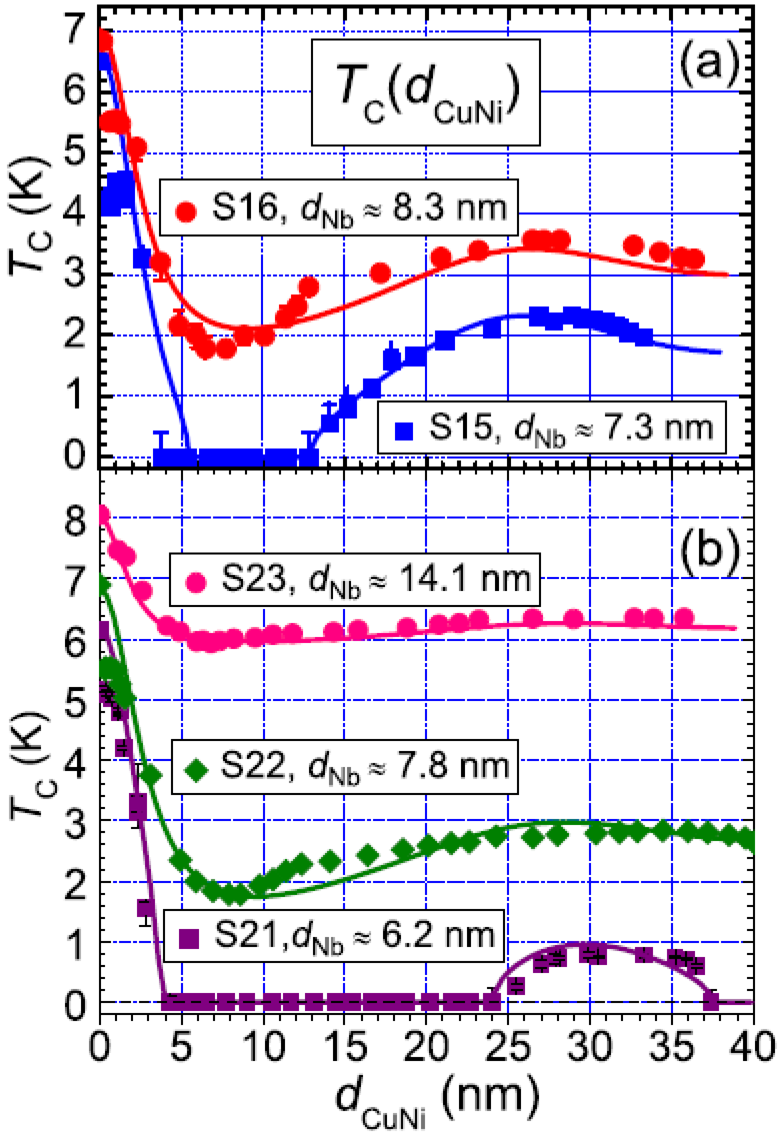




Transmission electron microscopy

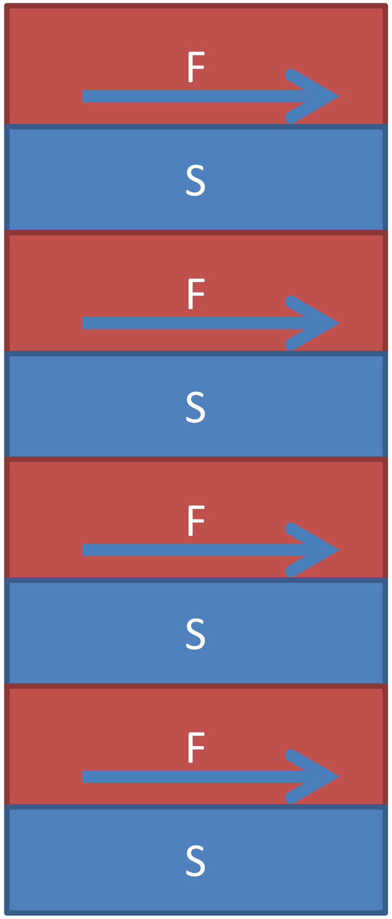


CuNi/Nb bilayer as an atom of SF metamaterial



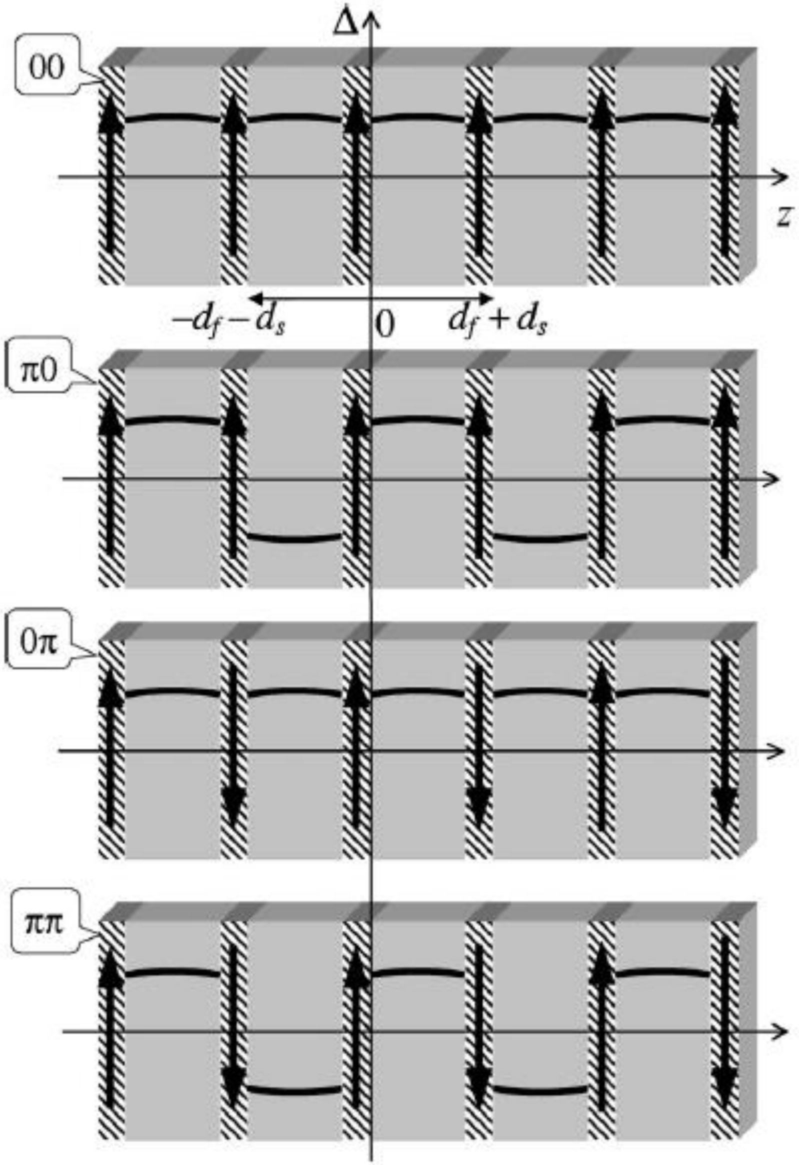
V. I. Zdravkov et al, Phys Rev. Lett. 97, (2006),
Phys. Rev. B 82, 054517 (2010)

SF superstructure



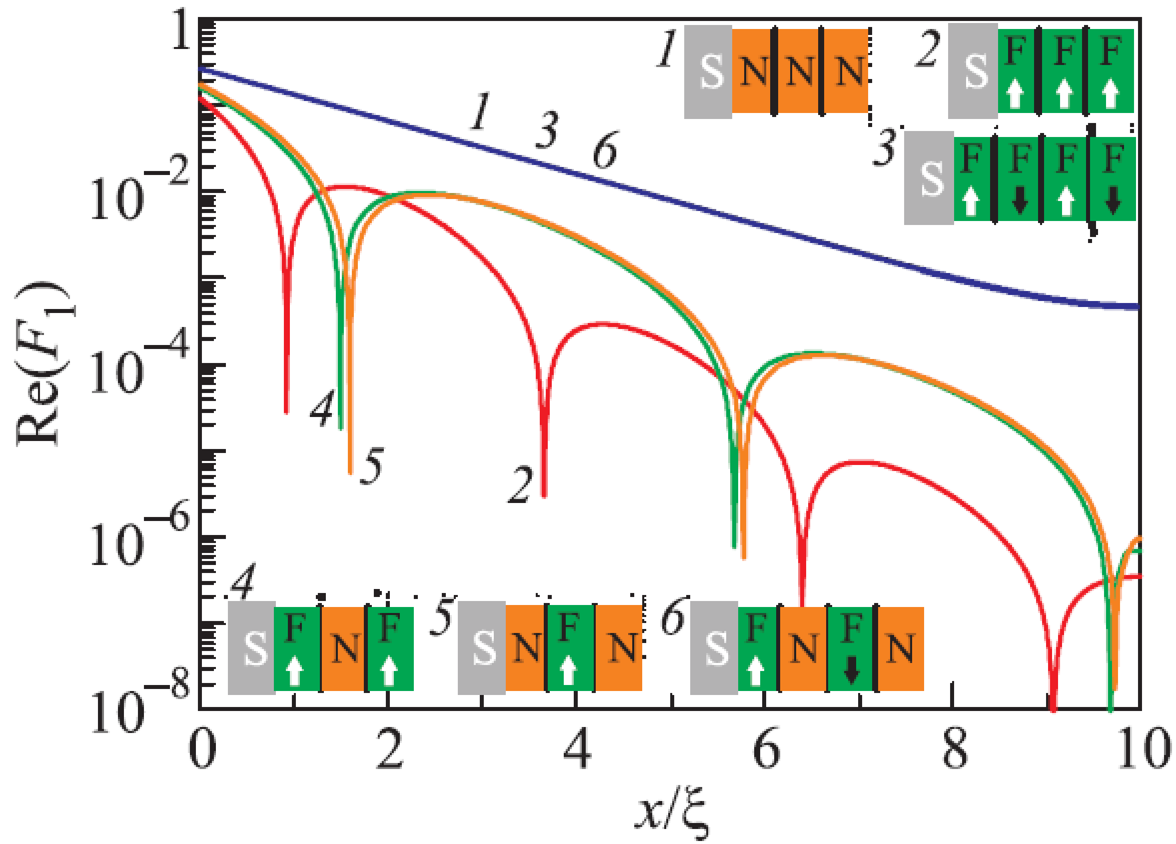
Is the same as set of *n* independent SF bilayers ?

π magnetic states of ferromagnet-superconductor superlattices



For the ferromagnetic metal/superconductor (FM/S) superlattices, 0 π and π π states with antiferromagnetic ordering of the FM layers magnetizations are predicted. If the S layer thickness ds is less than the threshold value p , these states have a higher critical temperature Tc than the earlier known ferromagnetic states 00 and
π 0.

Yu. N. Proshin, Yu. A. Izyumov, and M. G. Khusainov
PHYSICAL REVIEW B, VOLUME 64, 064522

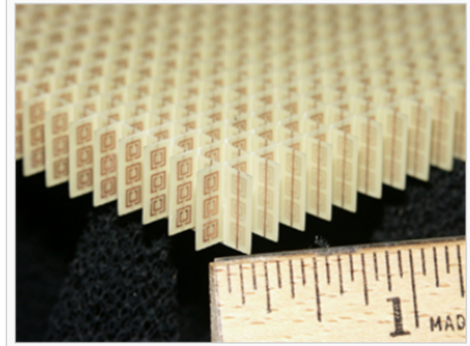


S.V. Bakursky et al. JETP lett 102 (2015)

Metamaterial

From Wikipedia, the free encyclopedia

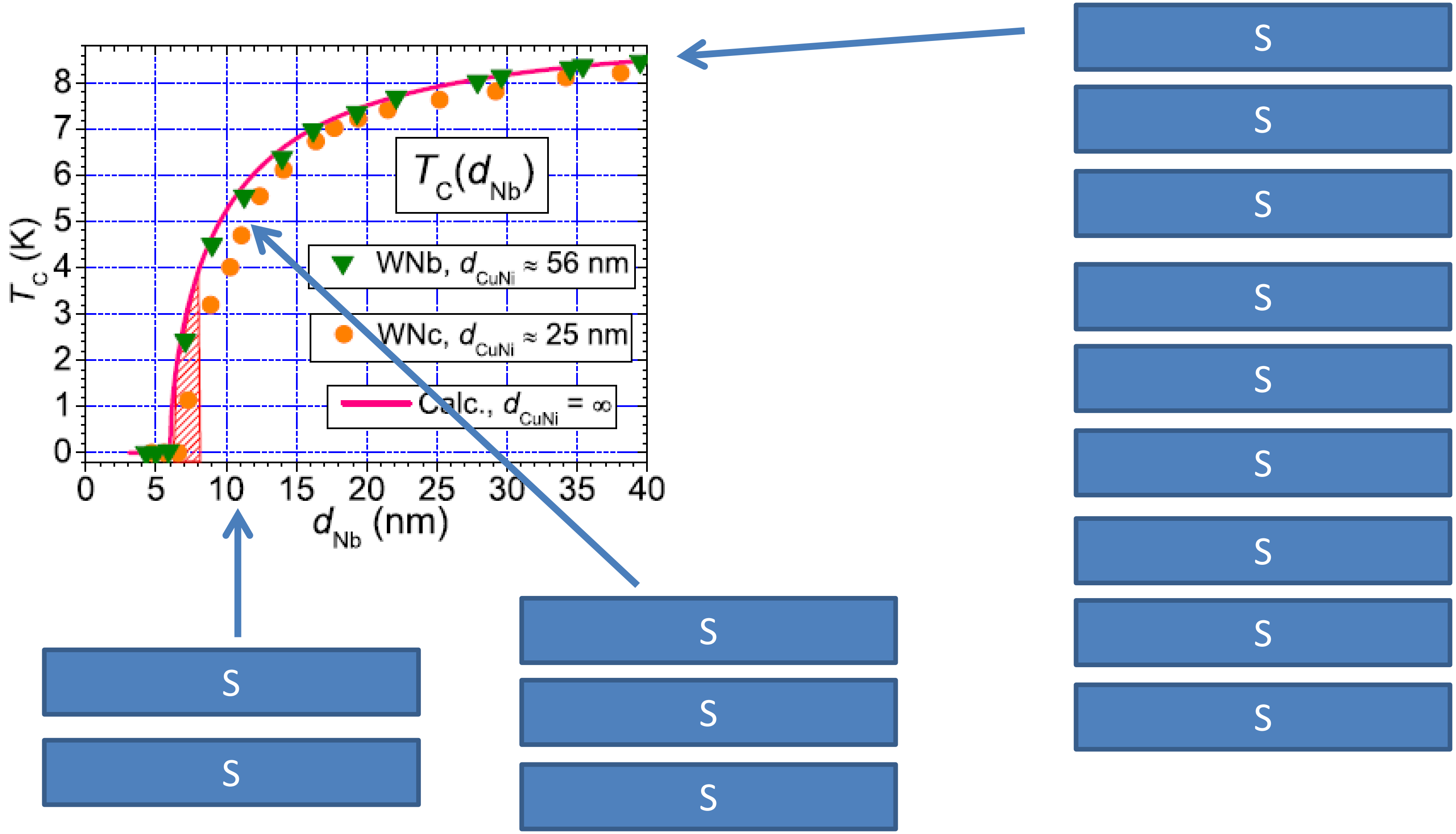
Metamaterials (from the Greek word "meta-", μετά- meaning "beyond") are materials engineered to have properties that have not yet been found in nature.[3] They are made from assemblies of multiple elements fashioned from composite materials such as metals or plastics. The materials are usually arranged in repeating patterns, at scales that are smaller than the wavelengths of the phenomena they influence. Metamaterials derive their properties not from the properties of the base materials, but from their newly designed structures. Their precise shape, geometry, size, orientation and arrangement gives them their smart properties capable of manipulating electromagnetic waves: by blocking, absorbing, enhancing, bending waves, to achieve benefits that go beyond what is possible with conventional materials.



Negative-index metamaterial array configuration, which was constructed of copper split-ring resonators and wires mounted on interlocking sheets of fiberglass circuit board. The total array consists of 3 by 20×20 unit cells with overall dimensions of 10 mm

Appropriately designed metamaterials can affect waves of electromagnetic radiation or sound in a manner not observed in bulk materials.[4][5][6] Those that exhibit a negative index of refraction for particular wavelengths have attracted significant research.[7][8][9] These materials are known as negative-index metamaterials.

Potential applications of metamaterials are diverse and include optical filters, medical devices, remote aerospace applications, sensor detection and infrastructure monitoring, smart solar power management, crowd



$T_C(d_{Nb})$
WNb, $d_{CuNi} \approx 56$ nm
WNc, $d_{CuNi} \approx 25$ nm
Calc., $d_{CuNi} = \infty$
T_C (K)
d_{Nb} (nm)
0 1 2 3 4 5 6 7 8
0 5 10 15 20 25 30 35 40
S
S
S
S
S
S
S
S
S
S
S
S
S
S