# PC1-1-INV

## Scanning SQUID Microscopy on Chiral Superconductor Candidates $Sr_2RuO_4$ and $URu_2Si_2$

*YUSUKE IGUCHI[1]

Department of Applied Physics, Stanford University[1]

A chiral superconductor is defined as one in which a complex superconducting gap function breaks time-reversal symmetry[1]. In this talk, I will review the superconductivity of chiral superconductor candidates $Sr_2RuO_4$ and $URu_2Si_2$, and introduce our recent studies, especially of time-reversal symmetry breaking(TRSB) using Scanning SQUID Microscopy(SSM). Our scanning SQUID microscope has a gradiometric SQUID layout with integrated pickup loops and field coils, enabling simultaneous measurements of the local magnetic flux and the local ac susceptibility[2].

$Sr_2RuO_4$ has been extensively studied as a possible chiral *p*-wave superconductor because of evidence for a nodal gap structure, spin triplet state, and TRSB[3]. However, a recent NMR Knight shift study suggested a spin singlet state in $Sr_2RuO_4$[4]. In addition, TRSB is still being discussed, because TRSB has been observed by $\mu$-SR and polar Kerr[5], but not by our SSM[6]. On the other hand, in a chiral *p*-wave superconductor, it is theoretically predicted that the superconducting critical temperature $T_c$ increases linearly as the uniaxial stress increases, with a cusp at zero stress, but non-local ac susceptibility measurements and local measurements by our SSM have shown a smooth and non-linear response of $T_c$ to uniaxial stress[7].

$URu_2Si_2$ has also been studied as a candidate for a chiral *d*-wave superconductor[8]. TRSB in $URu_2Si_2$ has been reported by $\mu$-SR and polar Kerr[9]. We will report on our studies of TRSB in the superconducting state of $URu_2Si_2$ using our SSM.

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Keywords: Chiral superconductor, Sr2RuO4, URu2Si2, Scanning SQUID Microscopy

## PC1-2-INV

# Superconductivity and Electronic structure in Ca-intercalated Graphene

*Satoru Ichinokura[1]

Tokyo Institute of Technology[1]

Through the enormous research focused on graphene since 2004, introducing superconductivity in graphene has grown into an attractive issue of research. To date, manipulation of stacking or intercalation of guest metal has been demonstrated to turn graphene into a superconductor by significant electronic band structures such as flat band(FB) or interlayer band(ILB). When the bilayer graphene is twisted each other by 1.1°, a FB is created by the band folding due to the moiré superlattice potential. Recently, it was shown that the superconductivity was driven by controlling FB at the Fermi level by field effect[1]. On the other hand, intercalation of an alkali or alkaline earth metal into graphene is believed to give ILB-driven superconductivity because they promote the occupation of the ILB, which is a criterion of the superconductivity in graphite intercalation compounds[2]. However, there was no specific evidence of superconductivity in graphene by intercalation because of difficulties in synthesizing high-quality samples and high reactivity of metal-intercalated graphene in the air.
Our group overcame these difficulties by the combination of the molecular beam epitaxy and the *in situ* 4-point-probe conductivity measurements under ultrahigh vacuum. In this paper, the author shows the electric transport properties of the Ca- and Li-intercalated bilayer-graphene on 6H-SiC(0001) substrates[3]. While the Ca-intercalated bilayer graphene exhibited the superconducting transition with $T_c^{onset}$ of 4 K, pristine and Li-intercalated bilayer graphene did not show superconductivity down to 0.8 K, as shown in the Figure. These experimental results are explained by the occupation-criterion of ILB, as seen in their electronic structure observed by the angle-resolved photoemission spectroscopy[4] and theory[5]. The author will also report on the recent progress about Ca-intercalation into monolayer graphene.

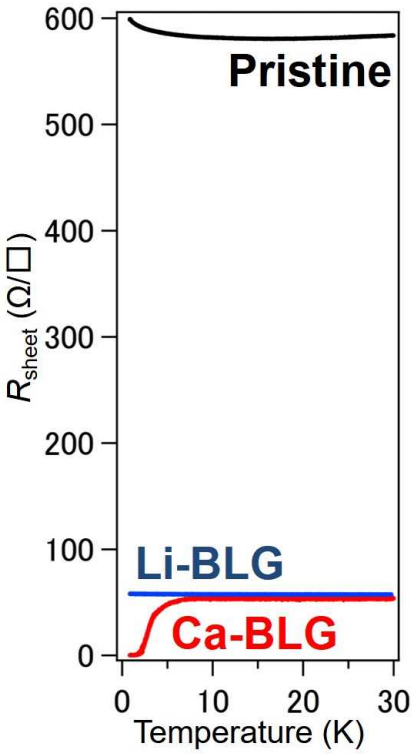


Fig. Temperature dependence of sheet resistances $R_{sheet}$ for pristine(black), Li-(blue) and Ca-(red)intercalated bilayer graphene under zero magnetic field.

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Keywords: graphene, intercalation

## PC1-3

# Structural quantum criticality, soft phonons and strong-coupling superconductivity in $(Ca_xSr_{1-x})_3Rh_4Sn_{13}$

Yiu Wing Cheung[1], Wing Chi Yu[1], Yajian Hu[1], Paul J. Saines[2], Malte Grosche[3], Satoshi Tsutsui[4], Koji Kaneko[5], Kazuyoshi Yoshimura[6], *Swee K. Goh[1]

The Chinese University of Hong Kong, China[1]
University of Oxford, U. K.[2]
University of Cambrige, U. K.[3]
Japan Synchrotron Radiation Research Institute (JASRI), SPring-8, Japan[4]
Materials Sciences Research Center, JAEA, Japan[5]
Kyoto University, Japan[6]

Approaching a quantum critical point (QCP) has been an effective route to stabilize superconductivity. While the role of magnetic QCPs has been extensively discussed, similar exploration of a structural QCP is scarce due to the lack of suitable systems with a continuous structural transition that can be conveniently tuned to 0 K. In this presentation, I will demonstrate the existence of a structural QCP in $(Ca_xSr_{1-x})_3Rh4Sn_{13}$ (Figure 1 and Ref. [1]), examine the evolution of the phonon spectrum as a function of the calcium content from inelastic x-ray scattering (Figure 2 and Ref. [2]) and heat capacity data [3]. Specifically, the inelastic x-ray scattering data unambiguously point to the softening of phonon modes around the **M** point of the Brillouin zone on cooling towards the structural transition. At x = 0.85, the soft mode energy squared at the **M** point extrapolates to zero at (-5.7 ± 7.7) K (Figure 2(h)), providing the first compelling microscopic evidence of a structural QCP in $(Ca_xSr_{1-x})_3Rh_4Sn_{13}$. Our spectroscopic, thermodynamic and transport data show that the tuning of the phonon spectra in $(Ca_xSr_{1-x})_3Rh_4Sn_{13}$ offers a systematic route to realize strong-coupling superconductivity.

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Keywords: structural quantum critical point, soft phonons, strong-coupling superconductivity

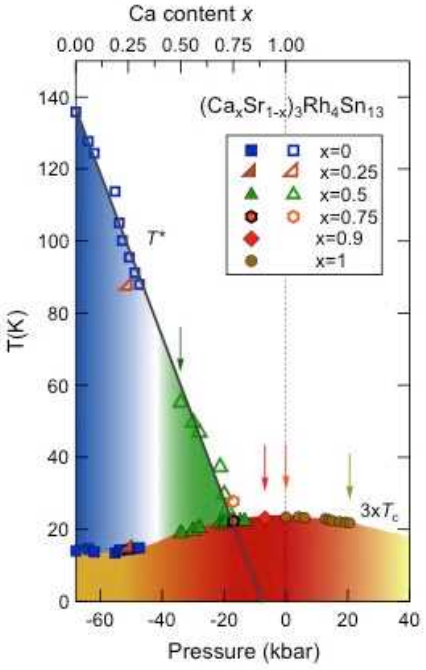


Figure 1

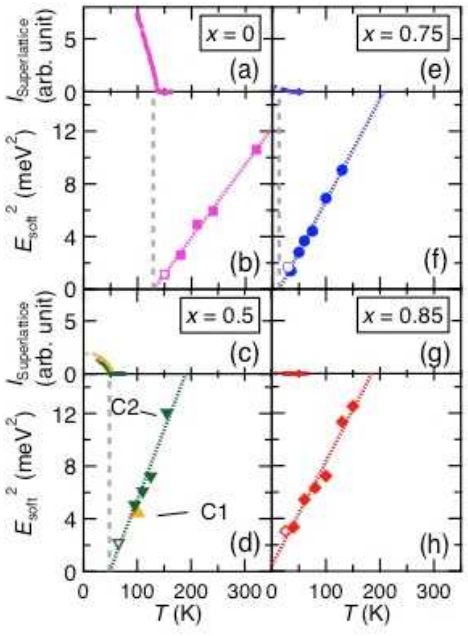


Figure 2