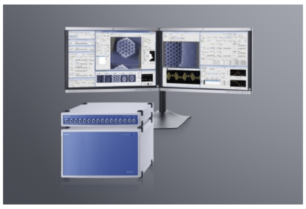

Application Note #000007

**KeyWords**
Nanonis, JT-STM, Atom Tracking
Superconductors, dI/dV Spectroscopy

Nanonis ™

# Mapping the orbital structure of impurity bound states in a superconductor

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## Nanonis Modules in Use

Base Package (BP5) | Atom Tracking software module

## System SPECS JT-STM

## Introduction

Superconductivity is a low-temperature phenomenon caused by the pairing of electrons via interactions mediated by the environment. A signature of superconductivity is that no single electron can be injected at low energies because the only possible states are the ones corresponding to pairs of electrons. Hence, an absolute gap in the density of states (DOS) is a fingerprint of conventional superconductors. In s-wave superconductors such as lead the paired electrons (i.e. the Cooper pairs) have opposite spin. An external magnetic field forces the electron spins to align, thereby breaking the pairing and destroying superconductivity.

## Results

A magnetic impurity exchange coupled to a superconductor also induces depairing of Cooper pairs by attracting one of the electrons and repelling the other.

The impurity-Cooper pair magnetic interaction results in the apparition of sharp resonances inside the superconducting gap, named Yu-Shiba-Rusinov (YSR) resonances. In the present work, Choi et al [1] investigated Cr atoms as magnetic impurities in a Pb surface, and demonstrate that a pair of YSR resonances appear for every spin of the impurity. Since chromium has five spin-polarized orbitals in the d-subshell, scanning tunneling spectra obtained at 1.2 K with the JT-STM from SPECS Surface Nano Analysis resolved five pairs of YSR excitations in the spectra (Figure 1). The spatial distribution of each pair of YSR resonances, measured with a matrix of dI/dV spectra over the atomic impurity, was found to reflect the shape of the spin-polarized d-orbitals of the Cr atom itself, as deduced by DFT simulations.

The dI/dV measurements were obtained using a lockin amplifier with its outputs connected to extra inputs on the BP5 and the atom tracking module was used to remain over the atom in order to measure a large number of curves.

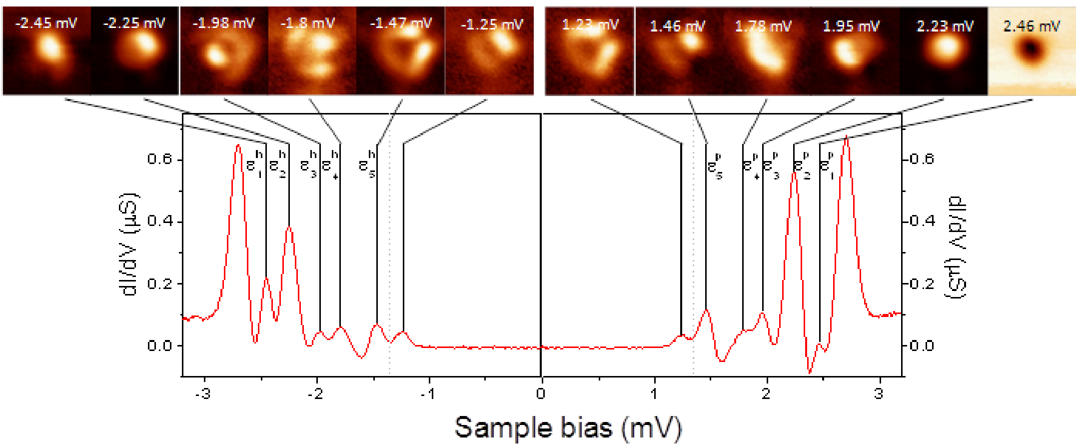


**Figure 1 Orbital structures depending on the Shiba states given in Cr adatom/Pb(111) surface.**

[1] Nature Communications 8, 15175 (2017)