

agreement with theoretical values.

According to the researchers, the ability to generate soft x-rays from moderate-energy electron sources makes tabletop sources of soft x-rays feasible, with possible applications in extreme-ultraviolet laboratory lithography, x-ray microscopy in the water window (284–543 eV), and x-ray fluorescence analysis of low-atomic-number elements.

TIM PALUCKA

### STM Induces Luminescence from Metallic Quantum Wells

The tunneling current of a scanning tunneling microscope (STM) has been shown to induce light emission from the metallic quantum well system Na on Cu(111). Using photoluminescence induced by an STM, researchers from the Christian-Albrechts-Universität zu Kiel in Germany have examined the role of confinement on the electronic structure of ultrathin Na overlayers on Cu(111) substrates. The research team has determined that the tunneling spectra and tunneling junction fluorescence from quantum-well states arise from confinement created by the vacuum barrier on one side of the Na overlayer and the local bandgap of the

Cu(111) substrate on the other.

As reported in the October 22 issue of *Physical Review Letters*, 0.6–2.0 monolayers (ML) of Na were prepared on Cu(111) in an ultrahigh-vacuum (UHV) STM apparatus with a lens system coupling light output from the tunneling junction to a grating spectrometer with a liquid-nitrogen-cooled CCD detection camera. The research team recorded, at positive sample voltages, tunneling spectra of the differential conductance. Measurements were taken at 4.6 K.

The researchers reported that tunneling spectroscopy from a 0.6-ML Na sample showed features at sample biases of ~0.4 V, ~2.0 V, and ~2.9 V that correspond to three distinct quantum-well states. Their fluorescence measurements showed emission for low sample biases of less than ~2.0 V, with the emission maximum exhibiting a strong blue-shift for more positive biases. The research team attributes the high-energy cutoff of this peak to radiative decay of coupled plasmons excited by inelastic tunneling from the STM tip to the lowest unoccupied quantum-well state at ~0.4 V. A second emission for sample biases greater than 2.1 V showed a weak dependence on sample bias. The research team said this emission matches the energy separation of sample biases at ~2.0 V and ~0.4 V, indicating that fluorescence occurs from a transition between these two states.

At a coverage of 2 ML, the researchers found radiative transitions between the quantum-well states and fluorescence due to radiative decay of a coupled plasmon of the tip and sample excited by inelastic tunneling from an initial state in the STM tip to quantum-well states at ~0.15 V, ~2.2 V, or ~3.3 V. At this coverage, the energies of the quantum-well states are shifted, causing the cutoff, transition, and threshold energies to be altered from the 0.6-ML samples.

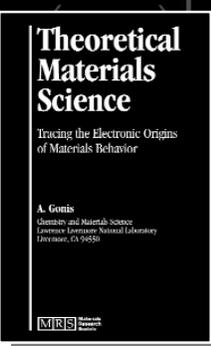
“Our work shows that sample related electronic transitions can be resolved spectroscopically in STM-induced light emission, not only from semiconductors but from metals,” said researcher Germar Hoffman.

According to the researchers, this technique benefits from the lateral spatial resolution of the STM, which does not average over macroscopic areas like other methods. Hoffman said, “This spatial resolution is essential in getting reliable numbers which are not affected by impurities and other defects.”

CHRISTOPHER MATRANGA



$$\frac{1}{\omega} \int_{-\infty}^t dt' e^{i\omega(t-t')} \langle \Psi_0 | [j_{\alpha}^{\dagger}(\mathbf{q}, t), j_{\alpha}(\mathbf{q}, t')] | \Psi_0 \rangle$$



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