between SSRs, as demonstrated through simulations and measurements. The researchers conclude that by combining two SRR metamaterials, one with negative μ and the other with negative ε, a 3D negative index material could be achieved. In addition to the media-favorite of invisibility cloaking, such a material could find application in optical computing, nanoscale imaging, and high-speed communications.

ALISON HATT

Atomistic Approach Predicts Resonance Frequency of Viral Capsids for Mechanodestruction Treatment

Viruses cause many severe diseases for humans, animals, and plants, adversely affecting public health and agricultural production. Treatment options for viral infections are typically based on drug chemotherapies or vaccines, which often lead to negative side effects. Furthermore, mutations in the virus structure may make vaccines ineffective. Recently, researchers have proposed to attack viruses not through chemical but through mechanical means, by using hypersound, T-rays, or light scattering radiation. These methods are based on the idea to excite low-frequency mode vibrations at their resonance frequency, which leads to rupture of the viral capsid structure and thereby a destruction of the virus. A similar phenomenon is known at macroscopic scales from bridges and buildings, which may suddenly collapse if excited at their resonance frequencies by wind loads. In order to optimally apply this new treatment option, it is desirable to know the resonance frequencies of the virus structure.

How can one predict these resonance frequencies, provided the atomic structure of the virus is known? In the January 18 issue of *Physical Review Letters* (028101; DOI: 10.1103/PhysRevLett.100.028101), E.C. Dykeman and O.F. Sankey of Arizona State University describe a new computational method to predict the low-frequency vibrational modes of biological structures based on their atomistic geometry. The new approach is based on an energy functional from electronic structure theory and provides a much more efficient strategy to analyze the atomistic properties of virus vibrations than earlier attempts. The method is robust and is now being applied to plant viruses (e.g., cowpea chlorotic mottle virus), bacteriophages (e.g., M13 bacteriophage), and human viruses (e.g., polio and hepatitis B).

A significant advantage of Dykeman and Sankey's approach is that it allows for an all-atom description of the vibrational mode patterns based on the atomistic structure of the virus, which can be obtained from an x-ray diffraction analysis of the virus geometry.

Using the new approach, Dykeman and Sankey calculated the vibrational modes of the *satellite tobacco necrosis virus* based on the atomistic geometry obtained from an earlier x-ray diffraction analysis. Their calculations result in the prediction of the specific resonance frequencies of excitation that will most likely lead to a destruction of the virus. It also provides insight into the particular molecular deformation mechanisms, such as shearing of beta-sheets. This new tool could be an important computational tool in developing new treatment options for newly discovered types of viruses, according to the researchers.

This theoretical group works in close collaboration with an experimental effort led by colleague K.-T. Tsen of Arizona State, who has had success in inactivating viruses by inelastic light scattering. Future studies may include experimental verification of the predicted vibrational frequencies of specific viruses.

MARKUS J. BUEHLER

CNT FET with Asymmetric Contact Shows Single Electron Transistor Characteristics at Low Temperature

Recent studies have shown that carbon nanotube (CNT) room-temperature single electron transistors (RTSETs) have been obtained by manipulation with an atomic force microscope (AFM) and by local chemical modification. However, almost all reported studies on RTSETs are with symmetric drain (D) and source (S) electrodes. Now, H. Li and Q. Zhang from Nanyang Technological University, Singapore and N. Marzari from the Massachusetts Institute of Technology have reported on a type of short single-walled CNT (SWCNT)-field-effect transistor (FET), which shows coulomb blockade effects with asymmetric D and S electrodes at low temperatures. Moreover, the devices exhibit current rectification characteristics at room temperature.

In the January issue of *Nano Letters* (p. 64; DOI: 10.1021/nl071905e), the researchers report the fabrication of SWCNT-FETs with a channel length of ~90 nm. The researchers started with a highly boron-doped silicon wafer, which was capped by thermal oxide of 500 nm. Their interdigital electrode of Au 90 nm/Ti 10 nm thickness was patterned on this thermal oxide. SWCNTs were placed across these electrodes by a dielectrophoresis technique. They specifically kept the concentration of the SWCNT suspension very low in order to have only a few SWCNTs bridged between these interdigital electrodes. The Al (source) was deposited in a way so that one end of the SWNT-channel was attached to the sidewall of the Au (drain) electrodes and the other end was buried beneath the deposited Al layer in order to create a shallow gap between the Al and Au electrodes. At room temperature, they found that the device shows diode-like characteristics with a maximum current rectification ratio of ~10^4. But at 25 K, they found a diamond-shaped current suppression region in the contour plot of the drain–source current mapped in a plane as a function of the drain–source bias voltage (on one axis) and the gate-source voltage bias (on the other axis), which they identified as the Coulomb blockade effect that is usually found in single electron transistors. With increasing temperature, the thermal energy becomes comparable to or even larger than the Coulomb charging energy. As a result, the oscillation peaks broaden and fade away when the temperature is ~100 K.

The researchers concluded that due to the unequal thermionic emission current in the asymmetric contacts (as a result of their different barrier heights), they saw asymmetric current amplitudes under positive and negative drain–source voltage bias. The barrier height for electrons at the Au/SWCNT contact is larger than that at the Al/SWCNT contact by a factor of >2 for all gate voltages. In an atmosphere environment, the device shows significant diode-like effects with maximum current rectification ratios of >10000.

M. GOWTHAM

Slithering of Shear Bands Can Improve Plasticity in Bulk Metallic Glasses

Glasses have evolved through many developments, starting from Obsidian (a natural glass) to metallic glasses and bulk metallic glasses (BMGs). BMGs have been developed since the 1990s as a new class of engineering materials, which offer an opportunity to revolutionize the field of structural materials with an excellent combination of ductility, strength, and toughness.

Failure of BMGs under extensive deformation through the formation of shear bands at room temperature has been well documented for Pt-, Cu-, Pd, Ti-, and Zr-based glassy alloys. However, this disadvantage has been overcome by the recent development of unique ductile BMGs.

As described in the January issue of the

Journal of Materials Research (p.6; DOI: 10.1557/JMR.2008.0025), K.B. Kim of Sejong University, J. Das of the Institute for Complex Materials, Dresden, S. Yi of Kyungpook National University, E. Fleury of the Korea Institute of Sciences and Technology, Z.F. Zhang of the Chinese Academy of Sciences, and colleagues reported "slither propagation of shear bands" on the fracture surface of $Cu_{47.5}$ $Zr_{47.5}$ Al_5.

The research group was able to prepare such a composition by arc melting the pure elements in argon atmosphere, followed by direct casting into cylindrical rods. The group made structural investigations of the as-cast and deformed samples using high-resolution transmission electron microscopy (HRTEM) coupled with energy-dispersive x-ray analysis (EDX).

The researchers carried out structural investigations on as-cast alloy and with the help of transmission electron microscopy (TEM) bright-field imaging, they observed that alloy microstructure consists of 5–15 nm size spherical regions, homogeneously distributed in the matrix. The group did a chemical analysis using conversion nanobeam EDX with a spot size of ~7 nm and demonstrated that spherical regions are enriched with Cu with poor Zr content and HRTEM images revealed the absence of lattice fringes confirming the formation of amorphous structure in the glassy alloy.

Previous investigations report the mechanically induced nanocrystallization, agglomeration, and phase separation during the propagation of shear bands. However, researchers made microscopic observations using HRTEM and TEM to demonstrate the slithering of shear bands on the fracture surface of the deformed alloy with nanoscale heterogeneous regions locally aligned along the shear bands. Through selected area diffraction (SAD), they demonstrated that these agglomerated regions reveal halo diffraction intensities, similar to those in undeformed alloys. The researchers said that an interesting finding from this result is that there is no mechanically induced phase transformation, that is, nanocrystallization.

The research group concluded that "slither shear band propagation is considered to be due to local stress-strain differences caused by the interaction of the shear band with a nanoscale heterogeneity, which as a result leads to aggregation of heterogeneous areas along the shear bands." This work has shown that during propagation of shear bands, nanoscale chemical inhomogeneities are generated, which helps in the improvement in toughness, the researchers said.

The researchers said that this finding can serve to elucidate the emerging plasticity and "work hardening-like" behavior of BMGs, and can also be incorporated into a model system to understand the mechanical behavior of ductile $Cu_{47.5}Zr_{47.5}Al_5$ BMGs.

ROHIT KHANNA