Accurate *in situ* measurements of dielectric constants obtained in THz range

Dielectric constants give significant information on how materials behave and relax under the influence of electromagnetic fields. N. Matsumoto and T. Hosokura from the Murata Manufacturing Co. Ltd. and T. Nagashima and M. Hangyo from Osaka University have developed reflection-type time-domain terahertz spectrosopic ellipsometry (THz-TDSE). Reflection-type spectroscopy is a contactless technique used for high-absorption materials and thin films deposited on opaque substrates, and time-domain spectroscopy provides transmittance/reflectance as well as phase shift information. The accuracy of time-domain spectroscopy is limited by phase shift phenomena. The researchers implemented THz-TDSE, eliminating previous reference and phase shift problems, thus allowing for accurate, contactless, and nondestructive *in situ* measurements of complex dielectric constants in the THz range.

In the January 15th issue of *Optics Letters* (DOI: 10.1364/OL.36.000265; p. 265), the researchers report development of a setup that allows accurate measurements of the dielectric constants in the THz range of different materials, namely GaAs thin films and $SrTiO_3$ on Pt substrate. In the setup, THz waves are generated by irradiation of a photoconductive antenna (on low-*T* grown GaAs) by a pulsed 800 nm laser, and focused on the sample on a ~20 mm^2 area.

The polarizations of incident and emerging THz waves are controlled precisely in order to detect *p*- and *s*-waves independently. The detection of the reflected wave is done by another photoconductive antenna irradiated by the delayed probe laser beam. The photocurrent of the antenna is measured through a lock-in amplifier. The time domain waveforms of *p*- and *s*-polarized reflected waves are measured independently, and Fourier-transformed into complex reflection coefficients.

Since the optical path lengths of the *s*- and *p*-polarized waves are strictly equal, the phase shift information between the *p*- and *s*-polarization can be obtained precisely. Reflection coefficients are used to compute real and imaginary parts of the dielectric constant. Interferences arising from the different interfaces were taken into account and this technique permitted measurement of the dielectric constant for GaAs thin film, as well as soft-mode phonon dispersion spectra in $SrTiO_3$ thin films.

Elsa Couderc

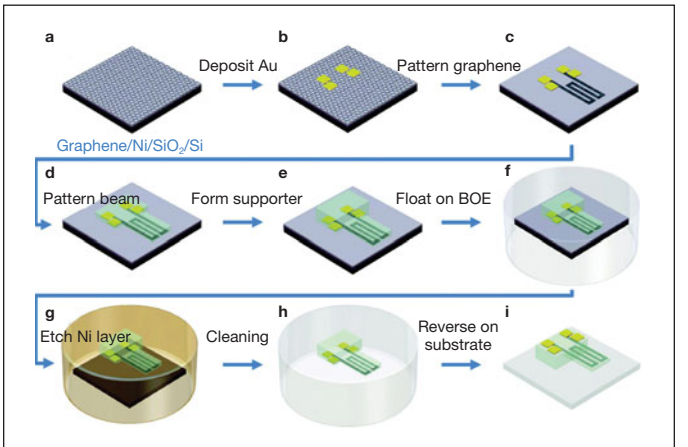
Nano Focus

Novel method developed to fabricate graphene-on-organic film

Researchers H.J. Cho of the University of Central Florida, J.H.Ahn of Sungkyunkwan University, and their colleagues have developed a method to fabricate graphene-on-organic film. This method stems out of the significant challenges in developing a compatible fabrication method of actuator materials for a large displacement and a rapid response at low voltages. Most work on actuators has focused on shape memory alloys, piezoelectric ceramics, and polymer-based materials; however, these materials require postprocessing steps that are not compatible with conventional batch microfabrication steps. The graphene-based organic film is compatible with microfabrication processes and used for electromechanically driven micro-actuators.

As reported in the January 31st online edition of *Nano Letters* (DOI: 10.1021/nl103618e), the researchers used a hybrid material of graphene/epoxy to fabricate the actuator using a series of steps as shown in the Figure. In the first steps (a, b), graphene films are grown by chemical vapor deposition (CVD) on a 4 in. SiO_2/Si wafer coated with a Ni catalyst. The photolithography process is used to fabricate gold contact pads; additionally the process is coupled with O_2 plasma reactive ion etching (RIE) to produce a serpentine micro heater pattern. A sequential photolithography two-step process is used to fabricate a thin graphene/epoxy cantilever beam and support body. The researchers used a buffer echant oxide and Fe_3Cl to remove the nickel and SiO_2 layer and used deionized water to clean the cantilever to be used for testing.

After the fabrication process, the researchers used four arrays of the graphene-epoxy hybrid and a field emission scanning electron microscope (FE-SEM) to confirm the structure of the graphene seropentine pattern. For biomorph actuation, graphene films were directly heated, and the organic epoxy film was warmed up by the diffused heat upon applying the electric power. The researchers report a resistance of graphene ranging 50–60 kΩ



Schematic diagram of the fabrication process for graphene and epoxy hybrid cantilever system. Reproduced with permission from *Nano Lett.* (DOI: 10.1021/nl103618e). © 2011 American Chemical Society.

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and a transfer yield approaching 99%.

The team also constructed a finite element theoretical model of the graphene actuator and calculated a coefficient of thermal expansion of $(-6.9 \pm 0.6) \times 10^{-6}$ per °C.

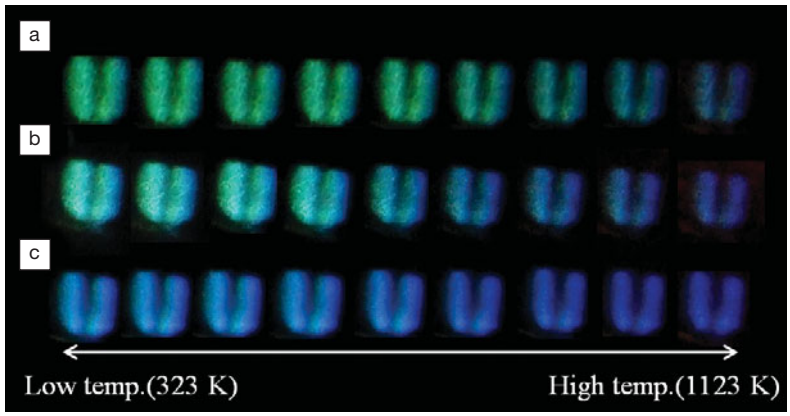
To compare both theoretical and experimental results, the researchers investigated the effect of temperature as a function of input power. The team determined that the temperature of the cantilever changed linearly to 36°C with a supplied power up to 1.26 mW. The deflection of the cantilever increased linearly with temperature or the electrical input power resulting to conversion factors of 0.17 μm/°C and 2.58 μm/mW. These values are in agreement with theoretical values. The oscillation of the beam with a frequency of 0.91 Hz are observed.

Jean L. Njoroge

Y_2O_3:Tb^{3+}/Tm^{3+} phosphors: New materials for thermometry

Phosphor thermometry provides noncontact temperature measurements by analyzing the changes of photoluminescence (lifetime decay or intensity ratios) with temperature. Compared with other noncontact temperature measurements, phosphor thermometry is a low-cost technique and provides simple diagnostics, enabling its use in nonplane geometries and in fluids. N. Ishiwada, S. Fujioka, T. Ueda, and T. Yokomori from the Keio University, Japan have investigated the photoluminescence response to the temperature of Tb^{3+}/Tm^{3+} co-doped Y_2O_3 phosphors, finding that these materials show a clear intensity ratio response even at high temperatures, not suffering from strong thermal quenching. The researchers have shown that these materials present intensities of two emission lines with different responses to temperature, an emission intensity strong enough to avoid optical noise, and emission of blue or green light, where black-body radiation is relatively weak. The results of this study appeared in the March 1st issue of *Optics Letters* (DOI: 10.1364/OL.36.000760; p. 760).

The researchers prepared Y_2O_3:Tb^{3+}, Y_2O_3:Tm^{3+}, and Y_2O_3:Tb^{3+}/Tm^{3+} phosphors by a flame spray synthesis method. They dissolved $Y(NO_3)_6 \times 6H_2O$, $Tb(NO_3)_3 \times 6H_2O$ and $Tm(NO_3)_3 \times 6H_2O$ in distilled water to prepare a 0.3 M precursor solution that was supplied, together with methane and oxygen gases, to the co-axial burner to form a high-temperature diffusion flame where monoclinic Y_2O_3 could be crystallized.



Temperature-sensitive visible photoluminescence images of Yb_2O_3:Tb^{3+}/Tm^{3+} depending on the concentration of the dopants (Tb^{3+} mol% / Tm^{3+} mol%): (a) 2/1, (b) 1/1 and (c) 0.6/1. Reproduced with permission from *Opt. Lett*. **36** (2011) DOI: 10.1364/OL.36.000760; p. 760. © 2011 Optical Society of America.

The researchers investigated the thermal dependence of photoluminescence by placing the phosphors in a 30 mm diameter ceramic vessel, surrounded by a wire heater, and by monitoring and controlling their temperature with a K-type sheath thermocouple connected to a PID temperature control unit within an accuracy of ±2 K. The researchers excited the phosphors with 355 nm UV light and recorded their emissions with a spectroscope in front of which they used a long-pass filter (>430 nm) to remove any remaining excitation light.

The researchers chose the concentrations of Tb^{3+} (1 mol%) and Tm^{3+} (1 mol%) to obtain the optimum intensity difference between the two dopants. The results demonstrate that the peak line at ~456 nm generated by Tm^{3+} was still strong at more than 1000 K whereas the other peak lines at 489, 543, 588, and 624 nm due to Tb^{3+} decreased due to the thermal quenching effect. By monitoring the intensity ratio between the 543 nm and 456 nm emissions with temperature, the researchers observed that this ratio presented a high gradient with temperature change and linearity over a wide temperature range, representing the most appropriate intensity ratio to be used for thermometry, offering the opportunity for measurement of temperature over a wide range and with high sensitivity.

The researchers also investigated the temperature-sensitive visible photoluminescence of Yb_2O_3:Tb^{3+}/Tm^{3+} as a function of dopant concentration. They observed visible photoluminescence color changes from green to blue with increasing temperature for specific dopant concentration (see Figure). The researchers said this property suggests the possibility of measuring the temperature not only by analyzing the intensity ratio but also by observing the color change visually through a visual thermo-sensor (VTS).

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