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GRAPHENE NEMS TECHNOLOGY FOR EXTREME SENSING AND NANO THERMAL ENGINEERING

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An overview is presented for our recent study of novel graphene nano-electro-mechanical (GNEM) devices. We first present GNEM devices for low-power switching and ultra-sensitive chemical gas sensing applications. Three-terminal GNEM switches with heterogeneously stacked graphene/h-BN layers are developed, which achieves low-voltage and sub-thermal switching (S<<60 mV/decade). We then present GNEM chemical gas sensors, which detect either resistance or mass changes due to a small number of gas molecules physisorbed onto suspended graphene at room temperature. With the resistance detection method, we show quantized increments in the temporal resistance, signifying single CO_2 molecule adsorption. As for the mass detection method, we demonstrate the resonance frequency shift of a doubly-clamped graphene resonator with the mass resolution of hundreds zeotpgram (10^{-21} g) order. We also show our recent attempt of patterning single-nanometer-size nanopores in suspended graphene by using state-of-the-art atomic-size focused helium ion beam. Arrays of pores of 3-4 nm in diameter spanning a complete suspended ribbon were successfully patterned with a pitch down to ~14 nm. Thanks to a very high Young's modulus and therefore a high Debye temperature of graphene, the phononic bandgaps are expected to be formed in the bandwidth of a few THz with such single-nanometer pore arrays. This enables us to control thermal transport dominated by heat phonons for relatively low temperature (<200°C). We will discuss the possibility of GNEM-based heat phonon engineering applications

Biography

Hiroshi Mizuta (C Phys FInst P) is currently Distinguished Professor at School of Materials Science, Japan Advanced Institute of Science and Technology (JAIST). He holds a joint appointment, as Visiting Chief Scientist with the Hitachi Cambridge Laboratory. He has a strong research interest in silicon- and graphene-based nanoelectronic devices and nano-electro-mechanical-systems (NEMS) and has led a number of large research projects in the UK and Japan, including PI of the UKRC EPSRC project SISSQIT (2010-2013) on electron spins in Si quantum dots, the EPSRC-JST UK-Japan project NOVTLOS (2011-2014) in which his team developed a new Si-based NEMS nonvolatile switch, and PI of the Japan MEXT grant-in-aid for scientific research projects, Development of Graphene NEMS Hybrid Functional Devices for Autonomous and Ultrasensitive Integrated Sensors (2013-2018) and Single-Nanometer-Scale Graphene Nems Technology for Heat Phonon Engineering (2019- 2023). He has published more than 530 peer-reviewed scientific papers and filed over 50 patents.

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