MAR10-2009-020048

Abstract for an Invited Paper
for the MAR10 Meeting of
the American Physical Society

Regular metal cluster arrays on graphene/Ir(111)

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Clusters represent a distinct state of matter. Due to their size, they exhibit a broad range of new properties, such as magnetism for normally non magnetic materials, a highly increased catalytic activity, or size effects in the electronic spectrum. These properties are of relevance for information technology or energy efficiency. The controlled growth of clusters on a surface is still a challenge. We have grown regular arrays of various metal clusters (Ir, Pt, W, Re, Au, IrFe, IrAu) on a self organized graphene/Ir(111) moiré template by physical vapor deposition in ultra high vacuum and studied them with scanning tunneling microscopy. The template epitaxial graphene grown by the thermal decomposition of ethene (C_2H_4) on Ir(111). This yields a moiré superstructure with a periodicity of 25.3Å. Upon physical vapor deposition of metals, clusters nucleate in the cells of moiré superstructure. The clusters are perfectly ordered in a hexagonal array with an nearest neighbour distance given by the 25.3Å periodicity of the moiré. Clusters bind to the graphene layer via a local rehybridization of the carbon from sp^2 to sp^3 underneath the cluster. The average number of atoms in a cluster can be tuned by the amount of deposited metal, which is for Ir from 4.5 – 130 atoms. Despite their small size, the clusters possess a high temperature stability. While small Au clusters are only stable at temperatures around 100 K Ir, clusters are stable above 500 K. The decay of the areal density of clusters can be described by an Boltzmann law with a very low effective attempt frequency below 1000 Hz and energy barriers between 0.4 – 0.8 eV. The coalescence occurs through two different types of atomic process: complete coalescence for two small clusters results in one cluster occupying a single moiré cell, while for large clusters a sintering takes place. The resulting cluster spans multiple moiré cells. For some materials, which do not form ordered cluster arrays at room temperature, the formation of regular cluster superlattices can be enhanced by a lower substrate temperature. This method is demonstrated for Au and Re. The obtained Re clusters remain stable at room temperature. A second method, to form clusters containing materials, which do not form clusters at room temperature which is demonstrated for Fe and Au at room temperature. We seeded the superlattice with small Ir clusters and in a second step used these well ordered array of Ir clusters to anchor additional Fe or Au. The graphene/Ir(111) moiré is a versatile template for the growth of regular metal cluster arrays.