Construction of an apparatus for production of size-selected clusters, characterisation of magnetic and optical properties of cluster films and studies of the photostability of sunscreens

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Abstract

A laser vaporisation source with a continuous flow of He gas has been used to produce metal clusters from a few up to hundreds of atoms. A quadrupole mass spectrometer (QMS), with an upper mass limit of 4000 amu, has been connected to select clusters with a desired mass. The design of a deposition and characterisation chamber is also presented. This chamber can be placed so that either the total distribution of clusters from the cluster source, or just a size selection of clusters, is deposited. In the deposition chamber an evaporation source is also placed for evaporation of atoms, which can grow into small islands on a substrate. The characteristics of films grown by deposition of atoms evaporated from a rod can be compared with films of deposited clusters. We have compared these two production methods for Ti by an apparatus for optical absorption spectroscopy, where a grating spectrometer and a charge-coupled device (CCD) camera make it possible to study changes of the optical properties of the deposited films during growth as well as responses to gases that are let in.

The magnetic properties of iron cluster films on highly oriented pyrolytic graphite (HOPG) have been studied, by using an alternating gradient magnetometer (AGM) and Mössbauer spectroscopy. The Mössbauer spectra reveal the presence of the characteristic sextet of α-iron, constituting about 1/3 of the signal, a closely related satellite at 10% intensity and a "non-magnetic" component. The Mössbauer spectra show that the films are primarily superparamagnetic at room temperature, which is typical for small mono-domain particles. The temperature dependence of the coercivity, B_C, and remanence, M_R, determined from hysteresis loops measured with the AGM is also typical for mono-domain particles that become thermally blocked at lower temperatures. Thermal blocking was also observed in Mössbauer spectra measured at low temperatures.

As protection against the sun for soldiers in the US Navy fighting in the Pacific Ocean during the Second World War, sunscreens were developed. The protection consisted of photoabsorbing molecules. Nowadays, many sunscreens contain nanoparticles of TiO_2 or ZnO, which scatter and absorb the sunlight. The photostability of some of these molecules has been investigated by exposing them to a dose of UVA (320-400 nm) and UVB (290-320 nm) radiation that corresponds to one day in the sun. The compounds that initially protect against both UVA and UVB light lose a significant amount of their UVA protection, whereas those that protect only against UVB light, were much more stable. The photostability of commercial sunscreens when exposed to sunlight or to the UV lamps has also been studied. We chose sunscreens that contain photoactive molecules which have been studied previously, as well as some containing small TiO_2 and ZnO particles. The photostability of sunscreens containing photoactive molecules varied, while the sunscreens with TiO_2 and ZnO particles were more stable. The degradation rate seemed to be higher when exposed to the sun compared to the UV lamps.

Keywords: clusters, deposited, size-selected, optical properties, Ti, oxidation, magnetism, Mössbauer, Fe, sunscreens, photostability