MONOLAYERED C_{60} ON Au NANO-PARTICLES PLACED IN LINES ON SAPPHIRE

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We have aimed to fabricate a nano-scaled structure with monolayered C_{60} molecules and to place them one- and/or two-dimensionally by the re-evaporation technique which was newly developed in this work. The important aspect is that the binding between C_{60} and metals is stronger than that among the C_{60} molecules. We expect that only C_{60} monolayers remain on Au surfaces after deposition and re-evaporation of C_{60}, whereas the C_{60} molecules bound with a weak Van der Waals interaction are re-evaporated. As the first step we investigated the process conditions for the preparation of nano-structured Au particles aligned on atomically flat of single crystal surfaces with the step-terrace structure[1].

Films were deposited by using an MBE system which was evacuated by a diffusion pump and a turbo-molecular pump. The sapphire Al_2O_3 substrates cleaned by acetone or HF treatments were annealed at 1000°C for 12 h in air. The pre-bake at 400°C for 30 min in vacuum was done prior to the film deposition. Au with 99.99% purity and C_{60} powder with 99.95% purity were evaporated from pyrolytic boron nitride (PBN) crucibles in Knudsen cells. The Au deposition was usually completed after the appearance of additional RHEED rings from Au. During the deposition the temperature of the C_{60} K-Cell was controlled in order to maintain a constant flux rate by a crystal thickness monitor. The surface morphology of the film was observed by AFM (Seiko Instruments Inc. SII: SPI3800) and the chemical binding energy of C_{60} was analized by XPS (SHIMADZU Co.：ESCA-850, X-ray: MgKα).

The sapphire (0001) surface showed uniform parallel steps and atomically flat terraces with ca. 0.2 nm height and ca. 80 nm width. The sapphire ($1\bar{1}02$) surface showed jagged step edges and atomically flat terraces with ca. 0.3 nm height and ca.100 nm width. Those steps function as a potential barrier for migration of Au atoms. The uniform parallel steps are suitable for an electric conduction measurement of Au particles one-dimensionally aligned along the steps.

The substrate temperature *T*s was changed from 300°C to 620°C. The Au flux was fixed during deposition at the equilibrium vapor pressure of 0.820 - 1.64 mTorr. After the Au deposition the spotted pattern of RHEED from the substrate disappeared and/or faint diffraction rings from Au were observed, which suggested the growth of polycrystalline Au films.

The Au particles deposited on the annealed sapphire substrates become spherical as a general tendency because of the large difference in surface energy between Au and the oxide substrate[2]. The Au particles with diameters of approximately 10 nm were distributed without alignment at the *T*s lower than 500°C. Under the conditions of *T*s lower than 300°C the surfaces of the Au film obtained were atomically flat and their AFM images were similar to those of the substrates. At the *T*s of 620°C, particles had the diameter of ca.20 nm and were aligned partially along the edges of the steps. At the conditions of *T*s =620°C and the Au flux =0.820 mTorr, comparatively small Au particles with diameters of ca.13 nm aligned around the steps. The diameter of the Au particles became smaller and the probability of the adherence of Au particles at the steps became higher with decreasing the Au flux.

Figure 1 shows the typical AFM images of the surfaces of Au//Al_2O_3. In the case of ($1\bar{1}02$) planes the probability of adherence of Au particles around the edges was almost two times as large as that on the terraces. The Au particles apparently placed in lines along the steps.

Figure 2 shows the typical XPS spectrum of C_{60}/Au// Al_2O_3. Then the C_{60} film was prepared on the Au//Al_2O_3 (0001) at *T*s of 190°C and successively re-evaporated at *T*s of 350°C for 30 min. The XPS C1s peak observed revealed the tail extended to the higher binding energy side. This is interpreted as the result of the charge transfer from Au to C_{60}. This kind of the phenomenon was observed only in ultrathin C_{60} films thinner than a monolayer[3)] The observed asymmetric peak of the C_{60} film strongly suggested that the prepared C_{60} film was a monolayer.

As a summary the nano-structured 1-dimensional alignment of Au particles appeared partially along the steps of sapphire ($1\bar{1}02$) surfaces at *T*s of approximately 600°C with comparatively low Au flux. Atomically flat 2-dimensional Au thin films were deposited at *T*s less than 300°C. After the C_{60} deposition at 190°C and the successive re-evaporation at 350°C, C_{60} monolayers were synthesized on Au// Al_2O_3. It was demonstrated that the newly developed re-evaporation technique of C_{60} is a hopeful bottom-up process for the preparation of nano-devices of monolayered C_{60}.

References:

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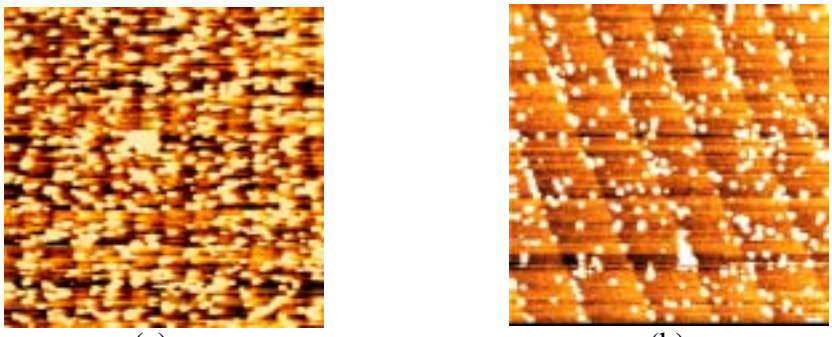

(a) (b)

Fig. 1. AFM images (1 μ m^2) of Au films deposited on Al_2O_3 (0001) (a), and ($1\bar{1}02$) substrates (b). Au films were deposited at *T*s of 600°C.

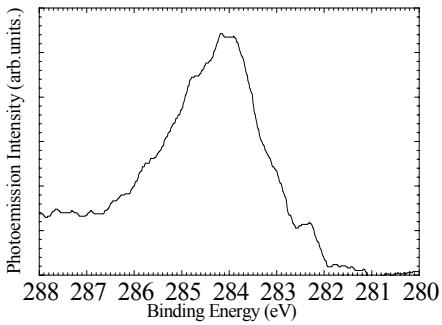

Fig. 2. XPS spectrum of C1s peak of C_{60}/Au// Al_2O_3 (0001). The C_{60} film was deposited at *T*s of 190°C and successively was re-evaporated at 350°C.