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Enhanced desorption from solid deuterium driven by charging with keVelectrons

Films of solid deuterium at a temperature around 3 K have been irradiated by 1.5 or 2 keV electrons. The films were deposited on the silver electrode of a quartz crystal microbalance (QCM) suspended below a pumped liquid helium cryostat [1,2]. The thickness of the films ranged from 10 nm to up to 5 m. The initial film thickness and the mass loss as result of desorption were monitored by the QCM. The electron beam current was kept at about or below 100 nA to avoid beam-induced evaporation.

Key words: desorption of solid deuterium, the surface potential of the film cryocrystals.

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Улучшенная десорбция твердого дейтерия, обусловленная зарядкой электронами

Пленки твердого дейтерия при температуре около 3 К облучались электронами 1,5 или 2 кэВ. Пленки осаждались на серебряный электрод микровесов с кристаллом кварца (МКК), свободно подвешенный ниже откачиваемого гелиевого криостата. Толщина пленок варьировалась в пределах от 10 нм до 5 мкм. Поверхностный потенциал вызван накоплением электронного заряда в пленках большой толщины, откуда электроны более не способны мигрировать к проводящей подложке с достаточно высокой скоростью. Линейное увеличение поверхностного потенциала может быть объяснено только поведением конденсатора.

Ключевые слова: десорбция, твердый дейтерий, поверхностный потенциал, пленки криокристаллов.

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кэВ-электрондармен зарядталуға негізделген қатты дейтерийдің жақсартылған десорбциясы

3К температурада қатты дейтерийдің қабықшасы 1,5 немесе 2 кэВ электрондармен сәулеленген. Қабықшалар кварц кристалды микросалмақты күміс (КМК) жинақталатын гелий криостаттан төмен ілінген электродқа отырғызылған. Қабықшаның қалыңдығы 10 нм-ден 5 мкм-ге дейін түрлендірілген. Беттік потенциал қабықшадан электрондар өткізгіш төсемеге жеткілікті жоғары жылдамдықпен өте алмайтын қалың қабықшаға электр зарядының жинақталуынан туындаған. Беттік потенциалдың сызықтық артуы тек конденсатордың әрекетімен түсіндірілуі мүмкін.

Түйін сөздер: десорбция, қатты дейтерий, беттік потенциал, криокристалдардың қабықшалары.

Films of solid deuterium at a temperature around 3 K have been irradiated by 1.5 or 2 keV electrons. The films were deposited on the silver electrode of a quartz crystal microbalance (QCM) suspended below a pumped liquid helium cryostat [1,2]. The thickness of the films ranged from 10 nm to up to 5 μm. The initial film thickness and the mass loss as result of desorption were monitored by the QCM. The electron beam current was kept at about or below 100 nA to avoid beam-induced evaporation.

Secondary electron emission was suppressed to a value below 0.01-0.03 electrons/electron by a repeller ring at a bias of – 90 V. However, for films thicker than 3-4 times the range of the bombarding electrons, the electron yield suddenly rose to a value close to 0.40. From this secondary electron yield the

voltage potential could be determined unambiguously from secondary electron emission curves obtained by short pulse measurements on fresh films. For the thickest films the charging induced a surface potential of more than 1.0 kV, i.e. one-half of the energy of the bombarding electron. For these thick films the desorption yield increased from the minimum value of 6-10 D2/electron up to 380 D2/electron at 1.5 keV and 960 D2/electron at 2 keV.

The surface potential is induced by electron charge accumulation in the film at large thicknesses from where the electrons no longer are able to migrate to the conductive substrate with a sufficiently high rate. The interesting point is that the surface potential increases linearly with film thickness and that the increase corresponds to 600 MV/m for both bombardment by 1. 5 keV electrons and 2 keV electrons. This internal field is very high, even though one has to consider that solid deuterium is an extremely bad conductor. The electron-induced field starts at a thickness of 1.9 μm, which should be compared with an average penetration depth for 1.5 keV electrons of 350 nm. For 2 keV electrons the field (as well as the charging) starts at 2.3 μm, which reflects the larger penetration depth of a 2 keV electron. The linear increase of the surface potential can only be explained by a capacitor behavior: the accumulated electrons are located close to the surface within a limited thickness while the space between the charges close to the surface and the metal substrate (the electrode of the QCM) is essentially free of any charge.

It is not clear how the electrons are trapped. As discussed by R. L. Brooks and coauthors [3] the electrons can be trapped in existing vacancies as «bubbles» or by polarons, which are somewhat more mobile. The density of these more and less immobile electrons is 1017 electrons/cm3. This density could actually provide an intrinsic field of the magnitude that has been measured experimentally, provided that the accumulated electrons are located within 0.5 μm from the surface.

References

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