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Reflection of Condensed Molecular Beams of Helium at Solid Surfaces

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Reflection of condensed molecular beams of helium at solid surfaces

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The reflection of condensed molecular beams of helium at polished stainless steel was measured using time-of-flight methods. At an angle of incidence of 85°, *measured from the surface normal, cooling the target from* 310 °K to 130 °K *caused the direction of the reflected beam to shift from* 69° to 82° *angle of reflection, thereby increasing the maximum reflected flux from* 1 % to 11 % *of the incident flux. The velocity of the reflected clusters was always higher than that of the incident ones, the factor being* 1.12 at 310 °K *and* 1.02 at 130 °K *target temperature. Sizes of both incident and reflected clusters were found to be in the order of magnitude of* 10^5 atoms/cluster.

La réflexion de jets moléculaires condensés d'hélium sur l'acier poli inoxydable a été étudiée à l'aide de mesure de temps de vol. Pour un angle d'incidence de 85° *rapporté à la normale de surface, l'angle de réflexion a augmenté de* 69° à 82° *à condition que le réflecteur fût refroidi de* 310 °K à 130 °K. *En même temps le maximum de l'intensité réfléchie a augmenté de* 1 % à 11 % *de l'intensité incidente. La vitesse des agglomérés réfléchis fut toujours plus grande que celle des agglomérés incidents, le facteur étant de* 1,12 *à une température de surface de* 310 °K *et de* 1,02 à 130 °K. *Le nombre d'atomes présents dans les agglomérés incidents et réfléchis fut de l'ordre de* 10^5.

Condensed molecular beams formed by skimming condensing supersonic jets contain clusters of atoms or molecules under molecular flow conditions. Reflecting condensed molecular beams at solid surfaces provides information on cluster-surface interactions.

The first results on nitrogen cluster beams reflected at polished stainless steel were reported by Becker, Klingelhöfer and Mayer [1]. They found the maximum of the reflected flux to be always in a direction nearly tangential to the surface independent of the angle of incidence. The velocity of the reflected beam particles was approximately the same as the tangential velocity component of the incident beam, and the surface temperature had no marked influence on the reflectivity.

This paper describes the first measurements of the reflection of condensed molecular beams of helium at polished stainless steel. The experimental set-up consisting of the condensed helium beam generating system [2], the rotatable reflector, and the analysing assembly is shown schematically in figure 1.

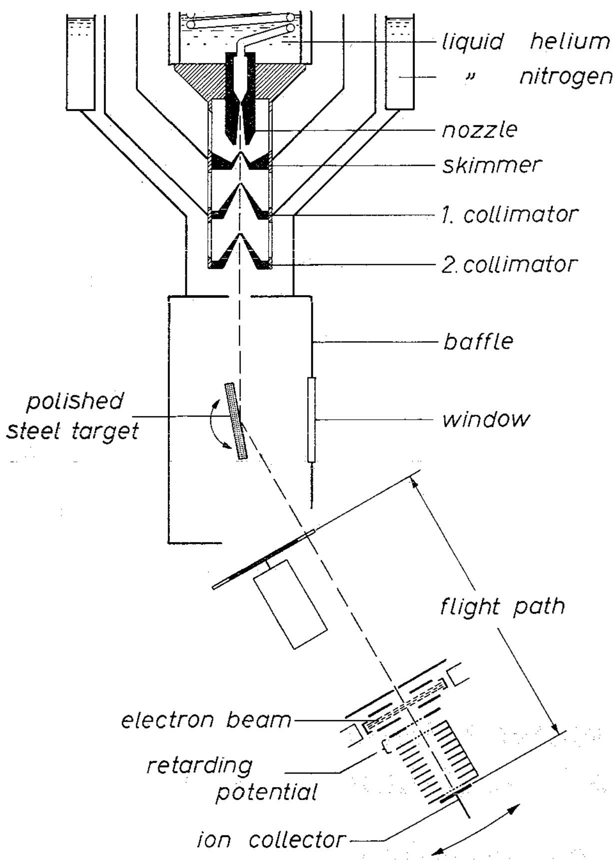

Fig. 1

The condensing supersonic jet is generated by a diverging nozzle of 0.12 mm diameter throat, 9° angular divergence, and 24 mm length of the diverging part. Nozzle, skimmer, and two collimators are mounted in a single copper block which forms the bottom part of a helium cryostat. The inlet gas is precooled by passing through a counter-current heat exchanger and the liquid helium bath. The cluster gun is surrounded by a liquid nitrogen cooled shield, which in part of the experiments was extended to enclose the reflector as well. This section of the shield serves as a baffle protecting the target from oil vapor molecules. A plexiglass window permits visual observation of the target surface.

The target consists of polycrystalline stainless steel, rotation polished with diamond abrasive paste of 1/4 µm maximum grain size. It can be rotated to change the angle of incidence or may be completely retracted from the beam position to allow measurements on the direct beam. The temperature of the target can be changed with resistive heaters or by cooling with liquid nitrogen and is measured with a copper-constantan thermocouple. The analysing assembly consisting of a single-disk beam chopper and a through-flow detector may be rotated with the same axis of rotation as the target. The angular resolution of the detector is approximately 0.5° for the reflected beam. To determine the cluster size the electron bombardement detector is provided with a retarding field section [3]. After being ionized the clusters have to overcome a potential step thereby loosing kinetic energy. As a new version of the retarding field method we measure the increase of the time-of-flight due to the deceleration of the cluster ions prior to the last 40 mm of their flight path.

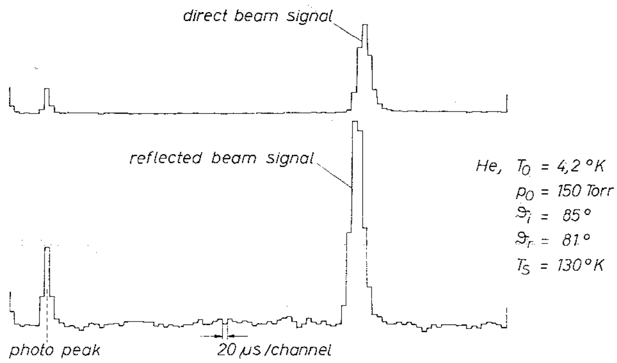

Fig. 2

Figure 2 shows typical time-of-flight signals as given by the 100-channel signal averager. The photo-peak marks the beginning of the time of flight. Since the distribution is not completely resolved even with better averager time resolution, only a lower bound of the speed ratio can be given: It must be greater than 45 for the direct beam, and greater than 34 for the reflected one. Obviously the reflected beam is faster than the direct beam. The reflected signal is further amplified by a factor of 16.

Figure 3 shows angular flux distributions, always taking the amplitude of the time-of-flight signal as a measure of the particle flux. The half-width of the direct beam at nozzle conditions $T_0 = 4.2\,°K$, $p_0 = 150$ Torr corresponds to 0.75°. The intensity i_0 measured using a stagnation ionization gauge is 2×10^{20} atoms per steradian and second. Since the retarding field measurements show that there are 2×10^5 atoms per cluster, the cluster flux is 10^{15} clusters/sr × sec.

For the reflected flux patterns the relative reflected flux is taken as radial coordinate. With unshielded target at 310 °K and 85° angle of incidence the lobe of the reflected flux centers at 69.2° angle of reflection. Cooling the target to 130 °K causes the lobe to shift to 82° and the maximum of the reflected flux to increase by nearly a factor of three. When the target is shielded by the cooled baffle the reflected flux

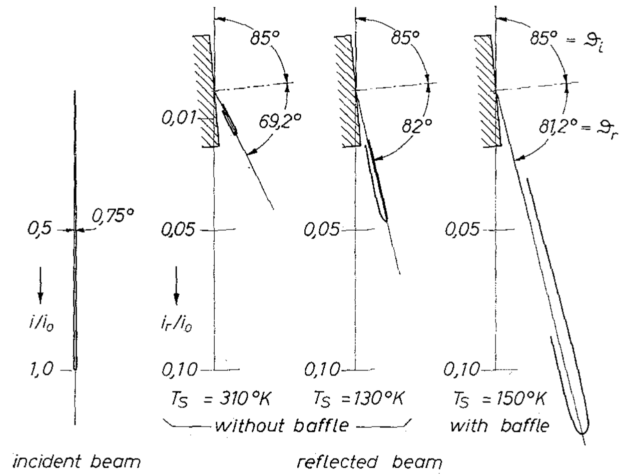

Fig. 3

increases by another factor of 2.5. The size of the reflected clusters in this case is measured to be 1×10^5 atoms/cluster. This is the same order of magnitude as in the incident beam. The width of the reflected flux patterns is approximately 7°, the reflected beams being fairly well collimated.

Figure 4 summarizes the effects of variation of temperature of the unshielded target. The reflection becomes more specular with decreasing reflector temperature T_s. The velocity of the reflected clusters, v_r, is always higher than that of the incident ones ($v_0 = 165$ m/sec) but approaches this value with decreasing T_s. The relative reflected flux increases most drastically, by nearly an order of magnitude. Its sudden decrease at the lowest temperature achieved is believed

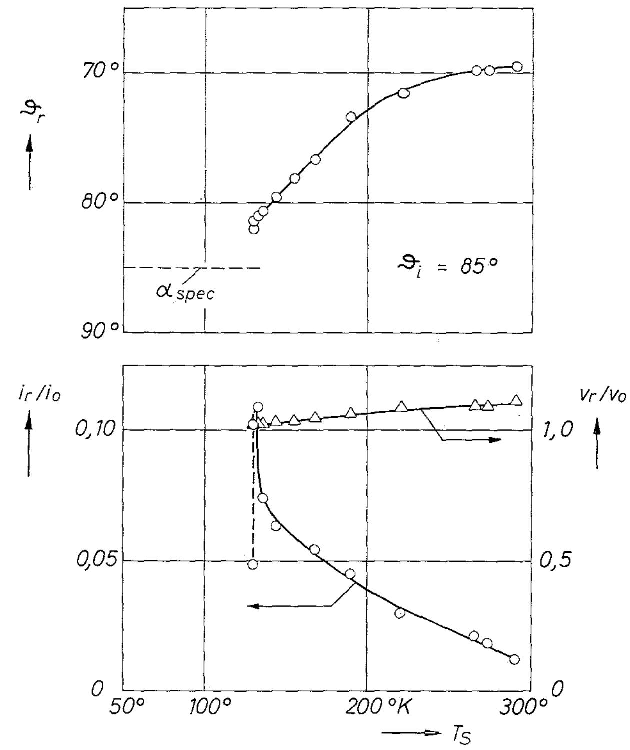

Fig. 4

to be due to contamination of the surface, as evidenced by the appearance of thin film colours. This remains to be proven by further investigation using shielded targets.

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