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Diamond-like carbon charge state conversion surfaces for low-energy neutral atom imaging instruments on future space missions

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Abstract

The technique of surface ionisation for mapping low-energy neutral atoms in space plasmas was successfully applied in several instruments onboard space missions in the past. We investigated diamond-like carbon surfaces regarding their eligibility as a charge state conversion surface material for future space missions, where improved characteristics of the conversion surfaces are required. Measurements on CVD (chemical vapour deposition) diamond surfaces, which are from stock available, show that the material has high potential to be used in neutral atom imaging detectors on future space missions.

1. Introduction

Measurements of energetic neutral atom (ENA) populations and directions in space plasmas offer clues to ENA formation and interactions and therefore enlarge our understanding of global plasma processes in the magnetosphere or heliosphere [1]. For measuring the mass and velocity of neutral atoms, these atoms have to be ionised. For ENAs with energies below 1 keV, surface ionisation was identified as the only viable technique, complying with all specification and limitations of a space mission. Charge state conversion surfaces were successfully flown in neutral atom imaging instruments on several past missions. Building on the success of the IBEX mission, a follow up mission concept to further explore the boundaries of the heliosphere, already exists: The objective of the Interstellar MApping Probe (IMAP) is to map ENAs in a larger energy range with a perceptible improvement in both sensitivity and angular resolution [3]. A charge state conversion surface will also be part of the JNA (Jovian Neutral Analyzer) sensor in the PEP (Particle Environment Package) instrument onboard the JUICE mission [2] and the NPA (Neutral Particle Analyser) sensor onboard the MarcoPolo-R mission [4]. The aspired performance of these sensors requires charge state conversion surfaces with improved characteristics.

2. Measurements

We investigated from stock samples of CVD diamond regarding their ionisation efficiency, scattering and reflection properties, which are the key parameters of charge state conversion surfaces. In Fig.1 one of the samples is shown. AFM images (Fig.2) were taken to measure the surface roughness of the samples.

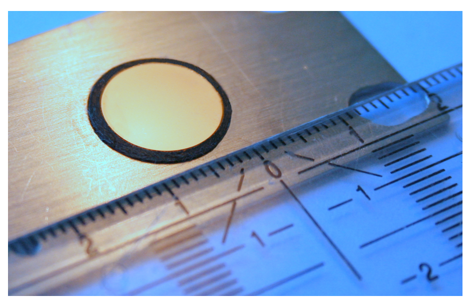

Figure 1: CVD sample on ILENA sample holder [9].

Experiments were carried out at the ILENA facility [5] at the University of Bern, a calibration facility that was used to select conversion surfaces for several past space missions. In ILENA, atoms of a selected test gas are scattered from a conversion surface sample. Angle of incidence and atom energy can be selected. The scattered atoms are imaged by a microchannelplate imaging detector. We measured the ionisation efficiency and the angular scattering of the CVD surfaces for oxygen and hydrogen atoms in the energy range 100 eV to 1 keV for different angles of incidence. In

Fig.3 the angular scattering of 250 eV oxygen atoms for one of the CVD samples, is displayed. For characterisation of the angular scattering, we investigate the full width half maximum, which is indicated by a bold line in the contour plot (Fig. 3, left panel).

The results of the CVD surfaces were compared to data of the conversion surfaces of the IBEX-Lo sensor and to a diamond-like carbon surfaces investigated in [6].

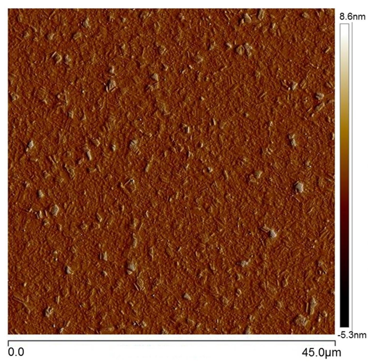

Figure 2: AFM image of a CVD surface [9]. The surface roughness was found to be 1 nm$< rms >$ in agreement with specifications from the manufacturer [8].

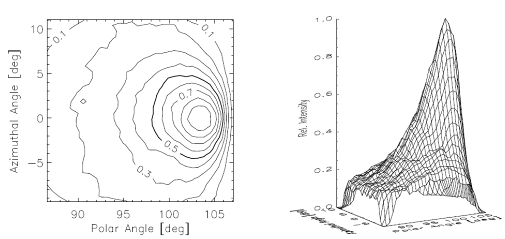

Figure 3: Angular scattering distribution of 250 eV oxygen atoms off a CVD conversion surface, measured in the ILENA facility [9].

3. Results

In comparison to the reference surfaces from the IBEX mission [7] and [6], we measured very narrow scattering cones and sufficient high ionisation efficiencies on the CVD surfaces. Both, angular scattering and ionisation efficiency, are crucial parameters to maximise the transmission through a neutral atom imaging instrument, hence to increase sensitivity. Small and symmetrical angular scattering, as we measured for the CVD surfaces, is favourable for guiding and focussing ion-optics and improves the conditions for neutral atom imaging with high spatial resolution.

Our results demonstrate that diamond-like carbon still is the preferred material for charge state conversion surfaces. But our measurements show that new surface technologies offer improved diamond conversion surfaces with the possibility for improvement of the performance of neutral atom imaging instruments onboard future space missions.

Acknowledgments

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