Introduction

Since their discovery in 1984 [1], quasicrystals (QCs) have become an interesting topic for theoretical and experimental investigations because of their intriguing structure and fascinating properties. Quasicrystals possess long range order without translational symmetry and often show conventionally forbidden rotational symmetries such as 5-fold, 8-fold, 10-fold, and 12-fold, distinguishing them from other known forms of solid matter. In addition to their unique structural features, QCs exhibit many unusual physical properties compared with their metallic constituents and alloys such as a very low electrical conductivity and negative temperature coefficient of electrical resistivity [2].

Although the quasicrystalline structure first observed in a rapidly solidified Al-Mn alloy was metastable, there has been a rapid success to grow many different types of QCs in thermodynamically stable phases [3, and find references therein]. Many binary and ternary alloys of metals possess quasicrystalline phases in very narrow regions of their phase diagram. The polygonal and icosahedral are the two main types of quasicrystals discovered so far. The polygonal QCs are two-dimensional QCs exhibiting a periodicity only along the third dimension, while icosahedral QCs show quasicrystalline structure in all three dimensions. In addition, a few 1D QCs have been found which exhibit a quasiperiodic arrangement of diffraction spots along one direction and periodic arrangements of spots on the planes perpendicular to the quasiperiodic direction [4].

While significant progress has been made in the determination of physical properties of QCs [2], the problem of determining their atomic structure has not been completely solved yet. Questions regarding the physical origin of quasicrystalline structure and the cause behind the unusual physical properties are also still under debate. Atomic clusters are believed to be the main structural building blocks of the QCs [5] and many physical properties have been described in terms of this cluster approach.

There are several reasons motivating the study of QC surfaces. First of all, it is important to determine how the surface features observed on QC will differ from those of periodic crystals. Secondly, it would be interesting to learn whether or not the aperiodic long range order of the bulk is extended up to the surface preserving bulk structural properties. Thirdly, QC surfaces possess interesting properties like a low coefficient of friction and a non-sticking behavior [6] and the potential applications of quasicrystals as coating materials, thin films etc., are related to these surface phenomena.

With the availability of mm-size single-grain samples, surface investigations by various experimental techniques have become possible. There is an increasing number of studies on the structure and physical properties of the surfaces. So far, the clean surface of decagonal (d) Al-Ni-Co and icosahedral (i) Al-Pd-Mn has been studied intensively by employing different experimental techniques, mainly low energy electron diffraction (LEED) [7-10], scanning tunneling microscopy (STM) [11-20], and X-ray photoelectron diffraction (XPD) [21].

Almost all investigations reported so far show that surfaces prepared by sputtering and annealing are bulk terminated. However, the surface termination is extremely sensitive to the preparation conditions due to the preferential sputtering of light atoms and different diffusion rates of the atomic constituents [6, 22-27]. Nevertheless, sputter-annealing is the most established method to clean the surface as in the case of normal metal surfaces. Surfaces obtained by UHV (ultra high vacuum) cleavage were found not to be sufficiently smooth for most studies. STM measurements on the cleaved 5-fold and 2-fold surfaces of i-Al-Pd-Mn show a very rough termination with an aggregation of atomic clusters in agreement with the bulk structure [14, 15].

In addition to these clean surface studies, there has been a great effort to grow a single element quasicrystalline thin film [28-33], which may be helpful to separate the influence of alloy composition and quasicrystalline structure on their intriguing characteristics.

The present work involves experimental investigations on the structure, morphology, and dynamics of high symmetry surface(s) of d-$Al_{71.8}Ni_{14.8}Co_{13.4}$ and i-$Al_{71.5}Pd_{21}Mn_{8.5}$ with the application of highly surface-sensitive He atom scattering (HAS), high resolution spot profile low energy electron diffraction (SPA-LEED), and low temperature scanning tunneling microscopy (LT-STM). The main focus of the investigation is on the high symmetry surfaces of d-Al-Ni-Co, while only a few measurements on i-Al-Pd-Mn are included.

He diffraction from the surfaces prepared by sputtering and annealing has been successfully measured. Due to the extreme sensitivity of He diffraction to all kinds of defects (adatoms, vacancies, steps, etc), the fact that diffraction is observed at all from the quasicrystals is evidence that their surfaces have high structural quality and contain only a modest amount of defects. The observed diffraction patterns reveal that the topmost surface layer maintains a long range, quasicrystalline order compatible with bulk terminated surfaces. In agreement with bulk models, a rhombic tiling has been identified in STM images of the 10-fold *d*-Al-Ni-Co surface.

In addition to these structural investigations, surface phonons (Rayleigh mode) of the 10-fold surface of *d*-Al-Ni-Co and the 5-fold surface of *i*-Al-Pd-Mn have been measured and constitute the first surface phonon dispersions measured on quasicrystal surfaces. The sound velocities of the Rayleigh modes are found to be in excellent agreement with bulk phonons data.

This dissertation is organized as follows: Basic concepts of QCs as well as a theoretical structure model of *d*-Al-Ni-Co are discussed in Chapter 1. Chapter 2 reports details about experimental techniques. Experimental results on the structure and morphology of the 10-fold and 2-fold surfaces of *d*-Al-Ni-Co are presented in Chapter 3 and 4, respectively, while surface phonons of the 10-fold *d*-Al-Ni-Co are described in Chapter 5. Chapter 6 contains results from the 5-fold *i*-Al-Pd-Mn surface. Finally, a summary and conclusions of the present investigation are given.