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Review

Dynamics of surface-localised electronic excitations studied with the scanning tunnelling microscope

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Abstract

The decay rates of electron and hole excitations at metal surfaces as determined by a scanning tunnelling microscope are presented and discussed. Surface-localised electron states as diverse as Shockley-type surface states and quantum well states confined to ultrathin alkali metal adsorption layers are covered. Recent developments in the analysis of the experimental procedures that are used to determine decay rates with the scanning tunnelling microscope, namely the analysis of line shapes and the spatial decay of standing wave patterns, are discussed.

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Contents

1. Introduction

The investigation of electronic excitations at surfaces is of great interest since they are involved in many important processes including catalytic reactions, photosynthesis, and light conversion in solar cells. The lifetime of these excitations determines the dynamics of charge and energy transfer and thus governs the effectiveness of the above mentioned processes. Consequently, substantial research effort has gone into elucidating the mechanisms which limit the lifetime of surface-localised electronic excitations.

Scanning tunnelling microscopy and spectroscopy have contributed to the determination and the understanding of the finite lifetimes of surface-localised states as diverse as Shockley-type surface states and quantum well states. Two experimental methods are used to determine the lifetime from scanning tunnelling microscopy and spectroscopy data, namely the analysis of line shapes of spectroscopic signatures and the spatial decay of standing electron wave patterns – this latter method is often referred to as the phase coherence length approach.

This article focuses on recent results based on the line shape analysis. However, we briefly touch upon some key results using the phase coherence length approach.

The article is organised as follows: In Section 2 we give a historical overview of the investigation of surface-localised electronic excitations with focus on scanning tunnelling microscopy and spectroscopy experiments. Experimental details are summarised in Section 3. Section 4 is devoted to the line shape analysis method. Here, Shockley surface states of the (1 1 1) surfaces of noble metals, confinement of surface states to artificially fabricated quantum boxes, and quantum well states hosted by ultrathin alkali metal adsorption layers are discussed, and also scattering by adatoms. The phase coherence length approach and recent developments that improve this method are presented in Section 5, and we summarise in Section 6.