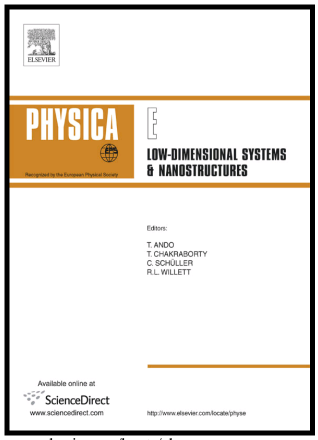

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Defect enhanced spin and valley polarizations in silicene superlattices

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We studied the effect of a defect of superlattice on the spin and valley dependent transport properties in silicene, where there is an abnormal barrier in height. It is found that the transmission resonance is greatly suppressed, because the symmetry of superlattice structure is destroyed by the defect. The spin-up and spin-down electrons near the K and K' valleys are dominated by different effective superlattices and defects. Therefore, the conductances are strongly dependent on the spin and valley of electron. By adjusting the defect strength properly, the spin and valley polarizations could be dramatically enhanced in a wide energy region. Furthermore, the result suggests an application of the structure as a defect-controlled switch.

I. INTRODUCTION

The great success on graphene inspires people to search for other two-dimensional Dirac materials, such as silicene and transition metal dichalcogenides. Recently, silicene, the graphene equivalent of silicon, has been fabricated via epitaxial growth on Ag [1, 2], ZrB_2 [3], Ir [4], and MoS_2 [5] surfaces. In particular, a silicene field-effect transistor at room temperature has been reported experimentally [6]. Silicene has the Dirac cone band structure around K and K' valleys, and the electrons near the Dirac points obey the relativistic Dirac equation [7], similar to those of graphene. However, contrary to graphene, silicene has a strong intrinsic spin-orbit coupling due to the larger atomic number, which leads not only to a gap of approximately $1.55meV$ [7, 8], but also to a coupling between the spin and valley degrees of freedom. The buckled structure of silicene allows us to control the band gap by an external electric field [8–10], which offers great advantages over the gapless graphene.

The spin and valley resolved electronic properties of silicene have received considerable attention due to its prominent application. In the presence of electric field E_z and exchange field M, Ezawa explored the phase diagram in the $E_z - M$ plane, which exhibits a rich varieties of phases due to different effects of E_z and M on the band characterized by the spin and valley indices [10]. Further considering the Rashba spin-orbit coupling, a valley-polarized quantum anomalous Hall state is predicted in silicene owing to the topological phase transition [11]. Based on the state transition, a silicene-based spin filter with nearly 100% spin polarization is proposed which is robust against weak disorder [12]. Yokoyama studied the ballistic transport through a ferromagnetic (FM) silicene junction and demonstrated a controllable spin and valley polarized current [13]. Subsequently, tunneling magnetoresistance in silicene junctions is explored [14, 15]. The spin and valley transports through double FM barriers [16] and FM superlattices [17, 18] on silicene are also extensively investigated. It is confirmed that the spin and valley polarizations could be enhanced by the superlattice structure. Furthermore, the features of the additional Dirac point and group velocity caused by the superlattice strongly depend on the spin and valley indices [19, 20]. The spin and valley degeneracy of the Landau levels could be lifted by a periodically modulated electric field in silicene [21]. Obviously, as reported in these relevant works, silicene superlattices present many novel transport properties and band structures, which are mainly determined by the periodicity structure. However, no work focuses on the effect of a defect superlattice on the transport property in silicene, where the periodicity is broken. Actually, due to the restriction of the experimental techniques, the defect of the barrier in superlattices is unavoidable. Therefore, the study on a defect superlattice is necessary and it would be helpful for understanding the transport mechanism in experiment.

Inspired by finding a high spin and valley polarization, in this paper, we discuss the spin and valley dependent transports through a defect superlattice in silicene. It is shown that the transmission resonances are dramatically suppressed by the defect. Previous studies [17, 18] indicate that in the symmetric superlattices, the polarization platform in energy region presents many dips due to the resonance effect, where the fully valley and spin polarized current cannot be achieved. Nevertheless, the present results manifest that with the presence and increase of the defect, the conductance resonance with specific spin and valley indices could be forbidden, and the dips fade away. The spin and valley polarizations could be greatly enhanced via a proper tuning of the defect.

The paper is organized as follows. In Sec. II, we present the model and the theoretical formalism. The numerical results for the defect superlattice are shown in Sec. III. Finally, we conclude with a summary in Sec. IV.

II. THEORETICAL FORMULATION

We consider a defect FM superlattice in silicene with metallic gates above it, and there is an abnormal barrier