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Ballistic charge transport by polarokinks and polarobreathers

Juan FR. Archilla†, Jānis Bajārs‡, Yusuke Doi§, Masayuki Kimura§§

† Group of Nonlinear Physics, Department of Applied Physics I
Universidad de Sevilla, ETSII, Avda Reina Mercedes s/n, 41012-Sevilla, Spain
‡ Faculty of Physics, Mathematics and Optometry
University of Latvia, Jelgavas Street 3, Riga, LV-1004, Latvia
§ Laboratory of Microdynamics, Department of Mechanical Engineering, Graduate School of Engineering
Osaka University 2-1 Yamadaoka, Suita, Osaka 565-0871, Japan
§§ Department of Electrical and Electronic Engineering, Faculty of Science and Engineering
Setsunan University, 17-8 Ikeda-Nakamachi, Neyagawa, Osaka 572-8508, Japan
Email: archilla@us.es, janis.bajars@lu.lv, doi@mech.eng.osaka-u.ac.jp, masayuki.kimura@setsunan.ac.jp

Abstract—Some materials of the mica group experience hyperconductivity, the transport of electric charge without an electric field. The charge transport is stimulated by ion bombardment that produces nonlinear waves that transport charge. We have developed a semiclassical model using physical principles and empiric potentials and found nonlinear waves that are able to transport charge.

1. Introduction

It has been observed in fossil tracks and experiments in layered silicates the transport of charge through the cation layers [1]. Kinks or crowdions imply the movement of a cation in the K+ layer and therefore the transport of charge. Single crowdions and double crowdions with no radiation have been found in [2]. The energy of single crowdions is large, about 26 eV and could be a good candidate for primary tracks in muscovite. There are however fainter tracks, called secondary tracks, scattered from the primary tracks that should have much smaller energies of the order of tenths of eV. Moving exact breathers with such energies have also been found in [3]. However, they do not transport charge.

If a K+ ion loses an electron, for example by beta- decay of the nuclei, a positive hole is created. Within an insulator, the probability of the hole to be transferred to another ion is very low but large vibrations enhance enormously the probability of transmission [4]. In this way a travelling anharmonic vibration with charge can appear. It can be a polarokink, that is, a kink or crowdion trapping an extra hole. A crowdion is basically a moving interstitial, which in an ionic crystal implies a moving charge. Therefore, a polarokink transports two units of charge. It should be noted that an electric current needs this extra charge because electrons have to move through the metal contacts and wires. The anharmonic vibration can also be a breather trapping a hole, that is a polarobreather.

ORCID iDs JFR Archilla: 0000-0001-6583-6114,
J Bajars: 0000-0001-7601-8694, Y Doi: 0000-0003-3749-5353,
M Kimura: 0000-0002-1445-6266

To refine the model we have used recent results on the spectra of moving nonlinear waves [3] to estimate the values of the transfer integral and developed improved methods for semiclassical sytems that conserve the charge probability in each integrating step and are also symplectic.

2. Summary and Conclusions

A semiclassical model for charge transport in silicates using new numerical methods provides nonlinear excitations that travel along the lattice without an electric field as observed in experiments. The best carriers are kinks which have brought about the reflection that although kinks transport charge by themselves in ionic crystals, the need to attach to an extra electron or hole that could be transported from and to the wires that close the circuit where the currents are measured.

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References

[1] F.M. Russell, J.F.R. Archilla, Phys. Status Solidi RLL **16**(3), 2100420 (2022)

[2] J.F.R. Archilla, Y. Zolotaryuk, Yu. A. Kosevich, Y. Doi, Chaos **28**(8), 083119 (2018)

[3] J.F.R. Archilla, Y. Doi, M. Kimura, Phys. Rev. E **100**(2), 022206 (2019)

[4] V.I. Dubinko, P.A. Selyshchev, J.F.R. Archilla, Phys. Rev. E **83**, 041124 (2011)

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