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High contrast elliptic operators in honeycomb structures

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In this talk, we analyse the propagation of Transverse Electric (TE) waves in a two dimensional honeycomb photonic medium. This medium consists of an homogeneous bulk of fixed permittivity and an array of high permittivity dielectric inclusions centered at the vertices of a honeycomb lattice. In the high contrast regime, we perform a mathematical study of the band structure of the photonic crystal. Using a combination of rigorous analytical methods, supported by numerical simulations, we obtain detailed local information about the conical crossings of dispersion surfaces (Dirac points) as well as global information about the high contrast behavior of dispersion surfaces.
The results presented here are based on the article [1] and are summarized in the conference paper [2]. In particular, we prove under a non-degeneracy condition (verified numerically) that the first two dispersion surfaces touch at conical singularities, called Dirac points, over the vertices of the Brillouin zone. We also provide asymptotic expansion with respect to the contrast parameter of the Bloch eigenelements associated to the "Dirac energy".
For the particular case of circular inclusions, we prove that all these properties hold for an infinite number of bands arbitrarily high in the spectrum. Finally, we will contrast the E&M setting [1] and the quantum model of graphene analyzed in [3].

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\noindent [1] M. Cassier and M. I. Weinstein, High contrast elliptic operators in honeycomb structures, Multiscale Modeling & Simulation 19 (4), 1784-1856, 2021, available on Arxiv (https://arxiv.org/abs/2103.16682).

\noindent [2] M. Cassier and M.I. Weinstein, TE Band Structure for High Contrast Honeycomb Media, 2020 Fourteenth International Congress on Artificial Materials for Novel Wave Phenomena (Metamaterials), IEEE, 2020. p. 479-481.

\noindent [3] C.L. Fefferman, J.P. Lee-Thorp, and M.I. Weinstein, "Honeycomb Schrödinger operators in the strong binding regime ‘’, Comm. in Pure and Appl. Math., vol. 71 (6), p. 178, 2018.

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