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Alexander A. Balandin, Sergei V. Zaitsev-Zotov and George Grüner

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Alexander A. Balandin,[1,a)] Sergei V. Zaitsev-Zotov,[2] and George Grüner[3]

AFFILIATIONS

[1]Department of Electrical and Computer Engineering, University of California, Riverside, California 92521, USA
[2]Kotelnikov Institute of Radioengineering and Electronics, Moscow 125009, Russia
[3]Department of Physics, University of California, Los Angeles, California 90095, USA

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[a)]**Author to whom correspondence should be addressed:** balandin@ece.ucr.edu

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A charge-density-wave (CDW) phase is a macroscopic quantum state consisting of a periodic modulation of the electronic charge density accompanied by a periodic distortion of the atomic lattice.[1–5] Unconventional forms of superconductivity frequently emerge from the CDW phase—hence, the fundamental interest. Early works on CDW effects were performed with bulk samples, which have quasi-one-dimensional (1D) crystal structures of strongly bound 1D atomic chains that are weakly bound together by van der Waals forces. Many spectacular observations were made—nonlinear transport, oscillating electric current for time-independent voltages, effects analogous to the Josephson effect observed in superconductors, giant dielectric response, multi-stable conducting states, just to mention a few.[1–8]

As more of a rule than an exception, new properties, associated with the broken-symmetry ground state of materials, offer application opportunities. The most prominent examples are superconductivity and various forms of magnetism. This will be the case for CDWs as well. Novel properties, such as giant dielectric constants, and nonlinear conductivity at low applied voltages—consequences of incommensurate CDWs—are just two attributes.[8] Additional ingredients for applications will emerge due to the low-dimensional character of the materials involved. It is known that two-dimensional (2D)—or quasi-2D—materials, following graphene, are, in general, emerging as fertile hosts of application opportunities. This, coupled with the enhanced response function associated with reduced dimensions, will ensure that the broken symmetry states will be in the mix of application opportunities. Another ingredient is the large variety of the ground states, 1D, 2D, commensurate, incommensurate, eventually various symmetries: the myriad of electron states, generating myriad of potentially useful attributes. The need to operate at reduced temperatures—where most of these broken symmetry states occur at present—makes the application more cumbersome. However, just as in the case of superconductors, eventually, we will possess a variety of materials where such states will occur above room temperature (RT). The spin density waves, the magnetic states closely related to CDWs, contribute an additional exciting element to the physics and applications of density waves in solids.[9]

Recent years witnessed a rebirth of the CDW field driven by research on layered quasi-2D van der Waals materials, where CDW phases can manifest themselves at RT and above.[10–18] The size and geometry of quasi-2D CDW films provide new opportunities for device fabrication. The interest in quasi-1D CDW materials has also reemerged due to the possibility of investigating CDW effects in nanowires with small diameters, CDW effects above RT, photoconduction and photo-controlled CDW transport, and recent findings of topological nontriviality of many of such materials.[19,20] The first reports of depinning and sliding of CDWs in quasi-2D materials have emerged suggesting some common features among CDW phenomena in quasi-1D and quasi-2D systems.[21,22] However, there is also an understanding of differences in physics governing CDW phases in material systems of different dimensionalities and crystal structures.[23,24] The rebirth of the field of CDW materials and devices can also be viewed in the context of 2D and 1D van der Waals materials research, which has a broad base in physics and engineering communities.

An example of a new CDW material that recently attracted a lot of attention is the 1T polymorph of TaS_2—one of the quasi-2D van der Waals materials of the transition-metal dichalcogenide group that reveals several CDW phase transitions in the form of resistivity changes and hysteresis.[10–18] The transitions can be induced by temperature, electric bias, and other stimuli. Two of the phase transitions in 1T-TaS_2 are above RT—a feature, which opens the prospects of practical applications. Despite numerous open physics questions, the field of CDW quantum materials is now evolving toward applied physics and engineering domains with application potential for amplifiers, detectors, memory, optoelectronic devices, information processing, and radiation-hard electronics.[18,25–27]

The above-mentioned developments motivated this Special Topic issue on the CDW quantum materials and devices.[28–45] The topics covered in the issue include synthesis and characterization of novel low-dimensional quasi-2D and quasi-1D CDW materials; physics of the CDW phase transitions and electron transport in nearly commensurate and incommensurate CDW materials; topologically nontrivial CDW states, effects of low-dimensionality, and stress; new developments in CDW pinning; optical and electric switching of CDW phases, photoconduction in CDW materials; "broad-band" and "narrow-band" electronic noise in CDW materials; CDW phase interaction with light and other stimuli; advancements in the CDW theory; as well as device applications of CDW materials.

This Special Topic issue includes a perspective on collective states and CDWs in the transition metal trichalcogenides[28] and original papers that address the new developments in the theory of CDWs;[29,30] physical properties of CDWs in quasi-2D and quasi-1D van der Waals materials and the methods of CDW control with external perturbations;[31–38] the effects of mechanical stress on the CDW state;[39–41] the light and radio frequency radiation interaction with CDWs;[42,43] memory and information processing applications of 1T-TaS_2 CDW devices.[44,45] The Special Topic invited and contributed papers emphasize the applied physics aspect of the CDW field. One should keep in mind that when the study describes the effect of external perturbations on the CDW state—there is an application in mind. Multiple CDW phases discovered in both quasi-1D and quasi-2D van der Waals materials make practical applications of the CDW switching and hysteresis much more feasible.

In conclusion, this Special Topic issue provides an opportunity for the readers to get a glimpse on the ongoing CDW research in terms of a better understanding of fundamental physics and prospects of practical electronic applications. While the research in the CDW field is progressing fast, it is important to look back on the last few years and summarize the most important findings. We hope this Special Topic will be relevant and interesting for researchers both in and outside the field.

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