Referee Report on
"Observation of Shapiro Steps in the Charge Density Wave State Induced by Strain on a Piezoelectric Substrate"

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This report critically examines the claim that surface-acoustic-wave-induced strain generates Shapiro steps in a charge density wave system. While the experimental observations are technically sound, the causal interpretation relies on elimination-based reasoning, phenomenological modeling, and the absence of a variationally closed theoretical framework. As a result, the central conclusion is not demonstrated in a strict physical sense.

I. GENERAL ASSESSMENT

The manuscript reports Shapiro-step-like features observed in the current–voltage characteristics of a charge density wave (CDW) system deposited on a piezoelectric substrate under surface acoustic wave (SAW) excitation. The authors conclude that mechanical strain, rather than electromagnetic coupling, is responsible for the observed phase locking.

Although the experimental data are clearly presented, the logical structure supporting the central claim is incomplete. The conclusion is reached primarily by exclusion of alternative mechanisms rather than by a constructive derivation. In its present form, the interpretation exceeds what is strictly demonstrated by the measurements.

II. ELIMINATION-BASED CAUSALITY

The identification of strain as the driving mechanism is obtained by excluding electromagnetic wave effects and static piezoelectric fields. However, the absence of an alternative explanation does not constitute a physical proof. In driven CDW systems, mixed electromechanical couplings, non-adiabatic effects, and contact-related nonlinearities can coexist and are not exhaustively ruled out.

No explicit dynamical equation is provided that demonstrates how strain alone couples to the CDW phase to generate frequency locking. The causal chain "SAW $\rightarrow$ strain $\rightarrow$ CDW phase locking $\rightarrow$ Shapiro steps" is therefore asserted rather than derived.

III. LACK OF VARIATIONAL CLOSURE

The theoretical discussion is based on the classical washboard model for CDW dynamics (Fukuyama and Lee, Phys. Rev. B 17, 535 (1978); Grüner, Rev. Mod. Phys. 60, 1129 (1988)). However, in this framework, the driving term is an electric field acting directly on the CDW phase. Mechanical strain does not appear as an independent dynamical degree of freedom in the model.

In the present work, strain enters only phenomenologically as an effective modulation without being derived from a variational principle. No global functional is constructed whose stationarity condition selects the observed locked state. As a consequence, the proposed mechanism lacks variational closure and cannot be regarded as generative.

IV. QUANTIFICATION OF STRAIN EFFECTS

The estimated strain amplitude is of order 10^{-4}. However, the manuscript does not provide a threshold condition, scaling law, or phase-locking criterion expressed as a function of strain. Without such a quantitative relation, the connection between strain amplitude and Shapiro-step formation remains qualitative.

Moreover, the absence of a demonstrated strain-dependent locking condition prevents falsification of the proposed mechanism. This significantly weakens the physical status of the central claim.

V. INTERNAL INCONSISTENCY WITH CITED THEORY

The manuscript explicitly acknowledges that existing theoretical treatments (Mori and Maekawa, Phys. Rev. Lett. 87, 237003 (2001); Funami and Aoyama, J. Phys. Soc. Jpn. 72, 2757 (2003)) do not reproduce the reported experimental behavior. Despite this, no alternative theoretical framework is provided to replace or extend these models.

Citing theories that fail to account for the observations, without resolving the discrepancy, leaves the interpretation unsupported at the theoretical level.

VI. CONCLUSION

The reported experimental observations are interesting and may indicate nontrivial electromechanical effects in driven CDW systems. However, the identification of strain as the origin of the observed Shapiro steps is not demonstrated in a rigorous physical sense. The argument relies on elimination-based causality, phenomenological parameter assignment, and the absence of a variationally closed description.

The results should therefore be interpreted as evidence of unconventional dynamical behavior under SAW excitation, rather than as a demonstrated strain-induced Shapiro mechanism.