

Quench switching of Mn_2As

Kamil Olejník¹, Zdeněk Kašpar^{1,2}, Jan Zubáč^{1,2}, Sjoerd Telkamp³, Andrej Farkaš^{1,2}, Dominik Kriegner¹, Karel Výborný¹, Jakub Železný¹, Zbyněk Šobán¹, Peng Zeng⁴, Tomáš Jungwirth¹, Vít Novák¹, and Filip Krizek^{1,*}

¹*Institute of Physics, Czech Academy of Sciences, 162 00 Prague, Czech Republic*

²*Faculty of Mathematics and Physics, Charles University, 121 16 Prague, Czech Republic*

³*Solid State Physics Laboratory, ETH Zurich, 8093 Zurich, Switzerland*

⁴*ScopeM, ETH Zurich, 8093 Zurich, Switzerland*



(Received 4 November 2024; revised 6 June 2025; accepted 5 August 2025; published 1 October 2025)

We demonstrate that epitaxial thin film antiferromagnet Mn_2As exhibits the quench-switching effect, which was previously reported only in crystallographically similar antiferromagnetic CuMnAs thin films. Quench switching in Mn_2As shows a stronger increase in resistivity, reaching hundreds of percent at 5 K, and significantly longer retention time of the metastable high-resistive state before relaxation towards the low-resistive uniform magnetic state. Qualitatively, Mn_2As and CuMnAs show analogous parametric dependence of the magnitude and relaxation of the quench-switching signal. Quantitatively, relaxation dynamics in both materials show direct proportionality to the Néel temperature. This confirms that the quench switching has a magnetic origin in both materials. The presented results suggest that the antiferromagnets crystalizing in the Cu_2Sb structure are well suited for exploring and exploiting the intriguing physics of highly nonuniform magnetic states associated with the quench switching.

DOI: [10.1103/1c81-tnzw](https://doi.org/10.1103/1c81-tnzw)

I. INTRODUCTION

In the past decade, the unique properties of antiferromagnetism inspired new research directions in condensed matter, especially with a focus on manipulation of their Néel vector [1–4]. Its orientation can be detected electrically, e.g., via anisotropic magnetoresistance [5,6], spin-Hall magnetoresistance [7], or second-harmonic magnetoresistance [8]. However, because of the relativistic nature of these phenomena, the corresponding signals are weak, typically below 1%.

We have previously demonstrated a strong and reproducible nonrelativistic mechanism of manipulation of magnetic order in CuMnAs —the quench switching [9–11]. This effect is induced by electrical or optical pulses of length ranging from ms to fs, which temporarily heat the material above its Néel temperature (475 K in CuMnAs [12]) and allow it to rapidly cool down. As a result, the antiferromagnet remains frozen (quenched) in a metastable state, associated with a strong fragmentation of the antiferromagnetic order by the formation of nanoscale magnetic textures [5,6,7,9], which only slowly relaxes back towards the uniform equilibrium state of the antiferromagnet. The metastable state features a significant increase in resistivity, which can be measured in

a straightforward two-point or four-point in-plane resistor geometry. The quench-switching effect in CuMnAs has several intriguing aspects: (i) the high-resistive metastable states are multilevel, controllable by magnitude, length, delay, or order of switching pulses; (ii) switching times can match characteristic $\mu\text{s}/\text{ns}$ scales [5] of microcontrollers/microprocessors, as well as ps-scales [5,7] of THz or optical technologies; (iii) the change in resistivity at room temperature can reach 10% (100% at low temperature) with very low energy cost of $\approx \text{aJ}/\text{nm}^3$ required for switching [6]; (iv) the (sub)ps attempt rates and activation barriers $E/k_B \approx 30 \times 300$ K result in temperature-dependent relaxation times spanning many orders of magnitude (from seconds at 300 K to hours at 230 K [9]); and (v) combination of the above features conforms to the requirements of analog time-dependent logic-in-memory (spiking neuromorphic) circuits [11]. However, up to now, the observation of the above phenomenology of the quench switching remained constrained to a single antiferromagnetic material—the epitaxial thin film of tetragonal CuMnAs .

In this paper, we report on epitaxial thin film Mn_2As grown on GaAs substrate, which exhibits a qualitatively analogous phenomenology of the quench-switching effect as in CuMnAs . Quantitatively, the magnitude and retention time of the switching signal is larger, in proportion to the hundred degrees higher Néel temperature in Mn_2As .

Mn_2As was selected from an in this context virtually unexplored material family of tetragonal 3d-metal pnictides [13], which belong to the Cu_2Sb -like $P4/nmm$ space group and stabilize in a wide range of accessible magnetic orders [14]. The previously synthesized bulk form of Mn_2As is known to be isomorphic to tetragonal CuMnAs , with Cu_2Sb -type $P4/nmm$ crystal structure and lattice parameters $a = 3.78 \text{ \AA}$

*Contact author: krizekfi@fzu.cz

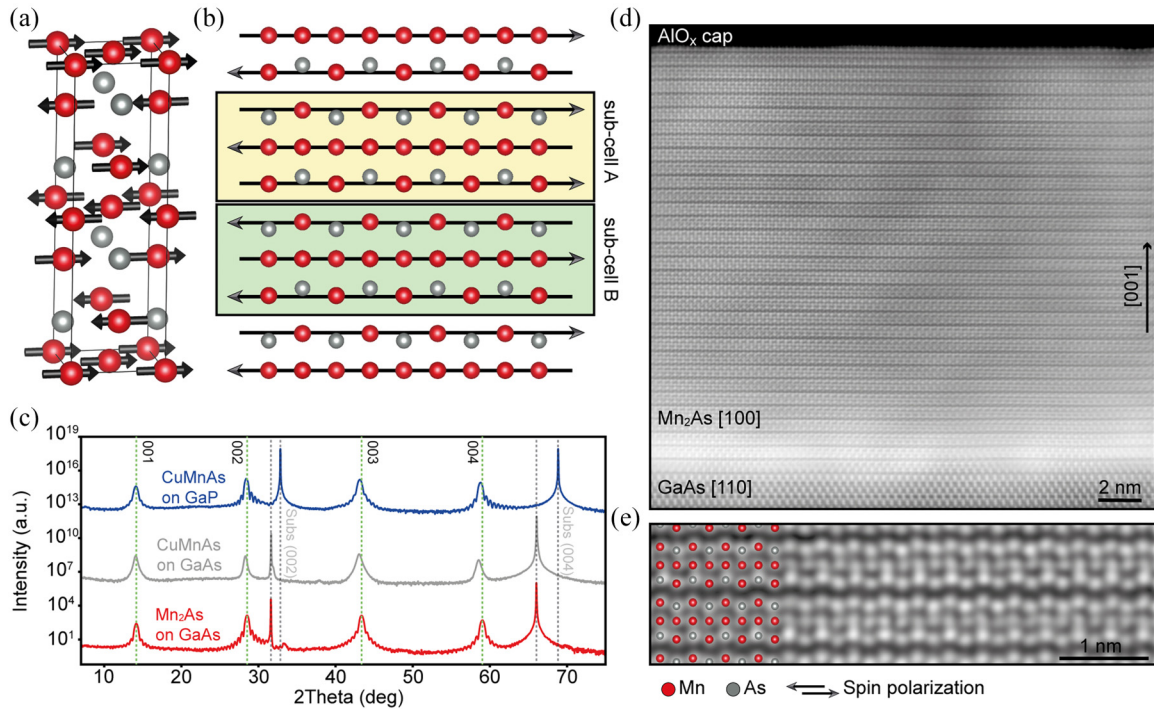


FIG. 1. (a) Unit cell model of Mn_2As (Mn in red, As in gray), where the arrows highlight the expected local moment orientation. (b) $[110]$ projection model of a portion of Mn_2As where the antiferromagnetic compensation between magnetic subcells A and B is highlighted within the yellow and green rectangle. (c) XRD radial scan, demonstrating the high quality of a 20 nm thick Mn_2As (red) film grown on GaAs together with comparison with CuMnAs grown on GaAs (gray) and GaP (blue) substrates. The green dashed lines highlight positions corresponding to the 00L Bragg peaks of Mn_2As and gray dashed lines the 002 and 004 Bragg peaks of the substrate. (d) HAADF-STEM projection along $[100]$ direction of a 20 nm film of Mn_2As grown on a GaAs substrate. (e) HAADF-STEM close-up on a portion of the Mn_2As , with an overlay indicating the Mn (red) and As (gray) atoms [15].

and $c = 6.28 \text{ \AA}$ [16], very close to $a = 3.85 \text{ \AA}$ and $c = 6.28 \text{ \AA}$ of CuMnAs. The antiferromagnetic magnetic structure of Mn_2As belongs to P_nma magnetic space group, which has doubled unit-cell along the $[100]$ direction, as illustrated in Fig. 1(a).

Besides the structural similarity between CuMnAs and Mn_2As and the fact that both are compensated collinear in-plane antiferromagnets, there are also important differences which are highly relevant for the comparison of the quench switching process in the two materials: (i) Mn_2As has a higher Néel temperature of 570 K–573 K [16,17], approximately by 100 K higher than CuMnAs; (ii) both materials have a different magnetic symmetry: CuMnAs is PT symmetric but the P symmetry is broken by the magnetic order, while Mn_2As is both P symmetric and PT symmetric; (iii) in Mn_2As , Mn/Cu antisite defects do not exist, which in CuMnAs represent the most likely low-energy point defects [18].

II. MATERIAL GROWTH AND PROPERTIES

The Mn_2As samples were grown on GaAs (001) substrates by molecular beam epitaxy (MBE). After desorption of the native oxide the GaAs wafer was cooled to 570°C and a 100 nm thick GaAs buffer layer was grown. After growth of the buffer, the sample was cooled down to 220°C (measured by band edge spectroscopy [19]) and 20 (Sample A), 50 (Sample B), or 78 nm (Sample C) thick Mn_2As films were grown at $0.024 \text{ \AA/s}$. Finally, the Mn_2As film was capped

with a 3 nm thick layer of Al (at substrate temperature below 10°C) which, after oxidation at ambient conditions, forms a protective AlO_x layer. To suppress a possible current leakage to the GaAs substrate in electrical measurements, a 500 nm thick $\text{Al}_{0.4}\text{Ga}_{0.6}\text{As}$ was grown as a second buffer layer in Sample D below the 20 nm Mn_2As film and Al cap.

Maintaining the 2:1 ratio of the Mn and As fluxes turns out to be crucial for successful growth, since only a slight deviation from the correct stoichiometry results in surface roughening and/or formation of ferromagnetic MnAs. In our case, the nonuniformity of Mn and/or As fluxes result in a gradient of stoichiometry across the wafer, and Mn_2As with ideal stoichiometry grows only in a few-millimeter wide annular area of the 2" wafer (see SEM and RHEED images in Supplemental Material [20]). Reference CuMnAs samples were grown under conditions given in Ref. [21].

From XRD radial measurements we extract $c = 6.25 \text{ \AA}$ and $a = 3.80 \text{ \AA}$. Rotated by 45° with respect to the substrate, Mn_2As is coincidence-site lattice matched to GaAs, which means that the $[100]$ direction of Mn_2As aligns with the $[110]$ direction of GaAs, in analogy to CuMnAs deposited on III-V substrates. The remaining mismatch is approximately 5%.

To assess the crystallographic structure and quality, in Fig. 1(c) we show the XRD radial scans of the Mn_2As film grown on GaAs substrate, together with data for the reference CuMnAs grown on GaAs and GaP. For both Mn_2As and CuMnAs, XRD confirms the formation of pure tetragonal phase with similar lattice constants. Our Mn_2As epilayers are of high

quality, which is apparent from clear thickness fringes around all the 001, 002, 003, and 004 peaks. The XRD reciprocal maps and STEM measurements further reveal that the Mn_2As films have superior quality compared to the CuMnAs films in terms of mosaicity and that they are fully relaxed. The relaxation occurs via the formation of pairs of misfit dislocations of opposite Burgers vectors at the interface with the GaAs substrate [22]. The overall high quality of the Mn_2As films, corroborated by scanning transmission electron microscopy (STEM) measurements in Fig. 1(d) and Supplemental Material [20,23], is mainly due to the absence of point and extended crystallographic defects, which commonly form in CuMnAs [21]. Remarkably, even though Mn_2As bulk lattice constant is closer to GaP than to GaAs, we found that growth on GaP results in the formation of extended defects and chemical intermixing at the interface. In the rest of the paper we, therefore, focus on Mn_2As films grown on GaAs (more detailed STEM comparison and reciprocal map analysis are given in Supplemental Material [20,24]).

In order to confirm the expected compensated antiferromagnetic ordering of Mn_2As thin films [16,17,25], we performed SQUID measurements and compared the results to ferromagnetic MnAs thin film of equal thickness, as shown in Fig. 2(a). At 10 K the Mn_2As films show only a negligible magnetic moment, in spite of approximately 50% higher density of Mn atoms compared to MnAs . However, the presence of the diamagnetic substrate did not allow us to draw more quantitative conclusions from the magnetization measurements (see Supplemental Material [20]). We note, that the attempts for exact determination of the Néel temperature of our Mn_2As thin films failed due to the relatively high expected temperature range. Yet, considering the fully relaxed state and high quality of our films we expect that it is close to the bulk value [16,17]. This was previously found for the crystallographically lower quality CuMnAs thin films [11,12].

Similarly to CuMnAs [10,26], the AFM order strongly influences magneto-transport properties of our Mn_2As films. Magnetoresistance (MR) of the order of 0.1% is observed, see Fig. 2(b), which depends on the direction of applied in-plane magnetic field. Saturation of a spin-flop-like reorientation in field above ≈ 6 T marks the upper limit of a range where the MR is dominated by magnetic moments changing their direction. For stronger fields, the longitudinal and transversal MR (i.e., blue and green curves) run nearly parallel to each other and they are dominantly of orbital origin [27]. The difference between the two values of R_{xx} (approximately 0.5%) is then the anisotropic MR (AMR), which is of similar magnitude [28] as in transition metals. The sign of the AMR in Mn_2As films is opposite to that in CuMnAs thin films [10], and the same as in CuMnAs bulk [29]. Higher spin-flop field in Mn_2As is consistent with the higher Néel temperature.

As seen in Fig. 2(b), the reorientation of the magnetic moments is accompanied by a noticeable hysteresis in the MR curves. The hysteretic behavior and its relation to quench switching was studied in detail in CuMnAs [10].

III. QUENCH SWITCHING

To perform the quench-switching experiments selected Mn_2As samples were patterned into bars with one-square

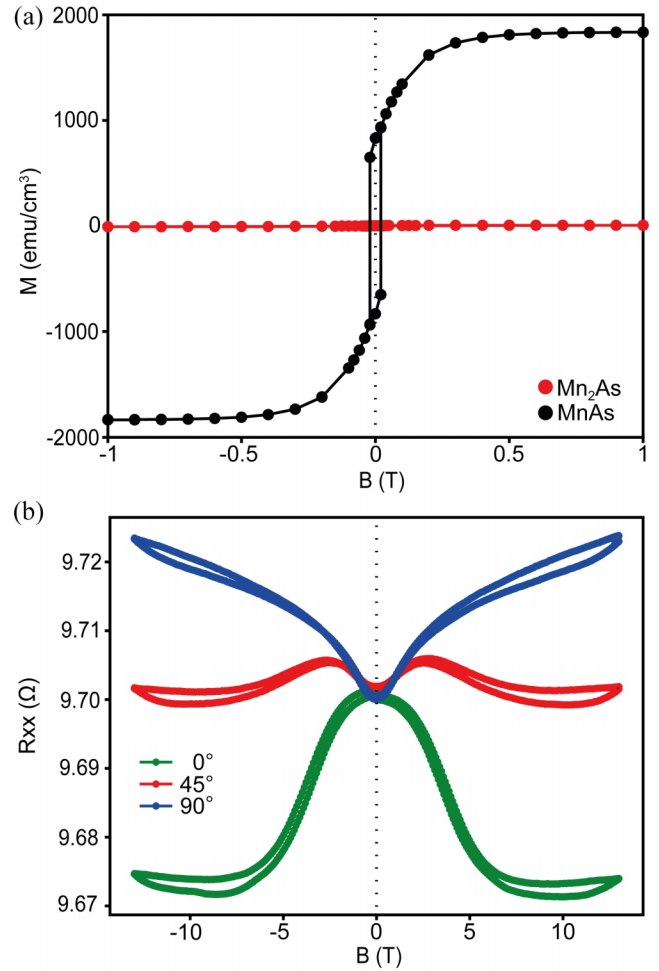


FIG. 2. (a) Out-of-plane magnetization of Mn_2As (Sample A) and, for comparison, ferromagnetic MnAs thin films; the measurements were performed at 10 K. Data are shown after subtraction of the diamagnetic contribution of the substrate. (b) Dependency of longitudinal resistance of Mn_2As in a Hall-bar geometry on the in-plane external magnetic field. 0° , 45° , and 90° indicate angles between the magnetic field and the current direction; the Hall bar was oriented along the [100] direction of Mn_2As , the measurements were performed at 80 K.

($40 \times 40 \mu\text{m}$) channel constriction in the middle. The design of the devices was optimized with respect to the presence of spurious parallel conductivity of the GaAs substrate occurring at elevated temperature during the pulse (for more details see Supplemental Material [20]).

Electrical pulses of 10 to 20 V amplitude and $100 \mu\text{s}$ duration were applied to induce the quench-switched state. The four-probe resistance was recorded after each pulse, exhibiting a characteristic and reproducible relaxation shown in Fig. 3(a) as the relative change ΔR . We note, that the heat generated by the switching pulses dissipates into the substrate and the sample holder significantly faster than the shortest time resolution used within this study [11]. In the case of a single $100 \mu\text{s}$ pulse used in this study about half of the heat dissipates within the first microsecond after the pulse, and 90% of the heat is dissipated within 10 microseconds (see Supplemental Material of [9] for experimental measurement of resistivity

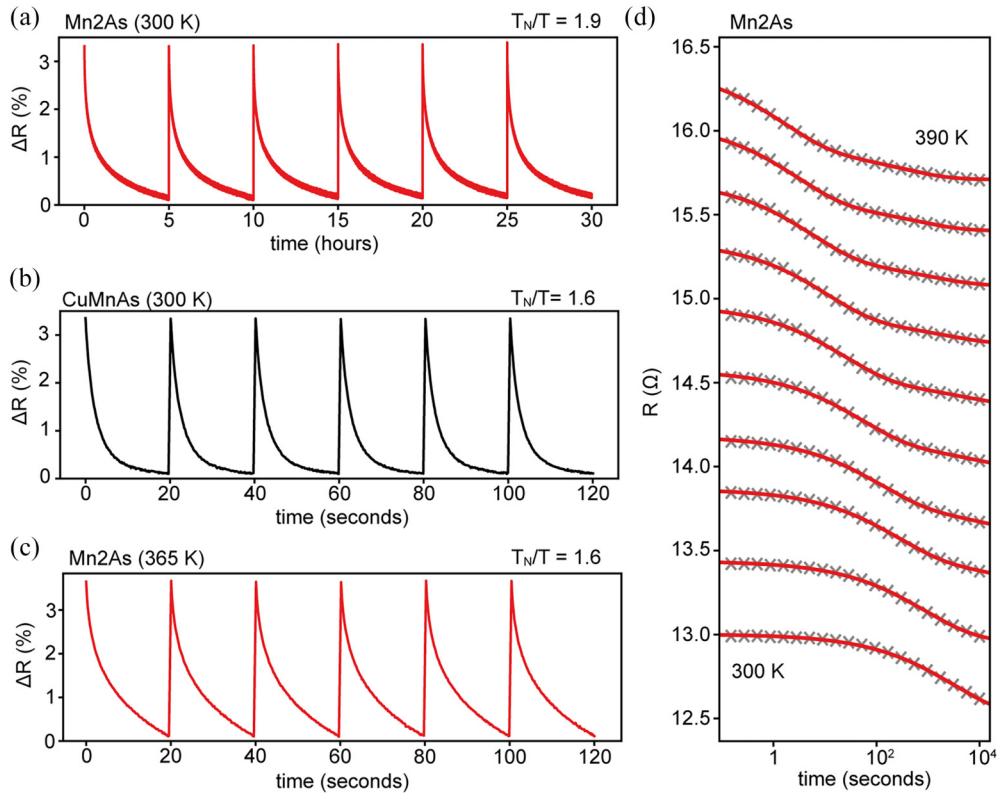


FIG. 3. (a) Time-dependent resistance change induced by the quench-switching of Mn_2As (Sample C) by a sequence of six $100\ \mu\text{s}$ voltage pulses, showing a characteristic resistance relaxation lasting for hours at 300 K (corresponding to $T_N/T = 1.9$). (b) The same for CuMnAs , showing a characteristic relaxation lasting for tens of seconds at 300 K (corresponding to $T_N/T = 1.6$). (c) The same for Mn_2As , showing a characteristic relaxation lasting for tens of seconds at 365 K (corresponding to $T_N/T = 1.6$). Pulse amplitudes of 20.0 V, 33.9 V, and 20.8 V were used for a, b, and c, respectively. (d) Time-dependent resistance change induced by the quench-switching of Mn_2As at temperatures ranging from 300 to 390 K in steps of 10 K, highlighting the temperature dependency of the relaxation process. The red lines correspond to fit to the data by stretch-exponential functions.

during the pulse and Comsol simulation of temperature of a CuMnAs device).

In Figs. 3(a) and 3(b) we compare the quench-switching characteristics of Mn_2As and CuMnAs at room temperature. For each material we adjusted the pulse amplitude so that it lead to $\Delta R \sim 3\%$. The device response to pulsing is in both cases qualitatively similar. An important difference is that at the base temperature of 300 K we observe relaxation on the time scales of hours in the case of Mn_2As and seconds in the case of CuMnAs .

The relaxation time of the quench-switched resistance in Mn_2As strongly depends on the base temperature, similarly to CuMnAs [9]. In Fig. 3(c) we show results of a measurement of the same Mn_2As device as in Fig. 3(a), but at the base temperature of 365 K. The magnitude of the quench-switched signal is set to be the same as at 300 K by adjusting (decreasing) the pulse amplitude. The character of the relaxation remains the same as at 300 K, but the relaxation time shifts to the order of tens of seconds. This matches the relaxation time in CuMnAs at 300 K.

In Fig. 3(d) we plot the recorded relaxations of the quench-switched signal in Mn_2As on the logarithmic time-scale for different base temperatures ranging from 300 K to 390 K. Similarly to CuMnAs , in the measured time-window of 10^{-1} – 10^4 s the data can be fitted with two Kohlraush

stretched exponential functions [9],

$$\Delta R(t) = A_{\text{main}} \cdot e^{-\left(\frac{t}{\tau_{\text{main}}}\right)^\beta} + A_{\text{slow}} \cdot e^{-\left(\frac{t}{\tau_{\text{slow}}}\right)^\beta},$$

where β is the stretching parameter. The best fits were obtained with $\beta = 0.5$. The two exponentials reflect the presence of two relaxation components with different characteristic relaxation times τ_{main} and τ_{slow} and amplitudes A_{main} and A_{slow} . Although the physical origin of these components remains unclear, their amplitudes depend in a threshold-like manner on the amplitude of the heating pulse. This is shown in Fig. 4(a), where an earlier onset of the main component and its prevalence over the slow component can be seen. To allow for comparison between Mn_2As and CuMnAs , in further text we focus our analysis only on the main component which dominates the relaxation process in both cases.

In both materials the onset of the quench switching occurs at currents corresponding to approximately $1 \times 10^7\ \text{A}/\text{cm}^2$ for the pulse length of $100\ \mu\text{s}$, considering the nominal cross section of the current channel. Note, that in the case of Mn_2As on GaAs the actual cross section is significantly larger due to the current leakage to the substrate during the pulse. The keypoint, however, is that in both materials the total amount of energy delivered to the device is consistent with the heat needed to exceed the Néel temperature, which is necessary

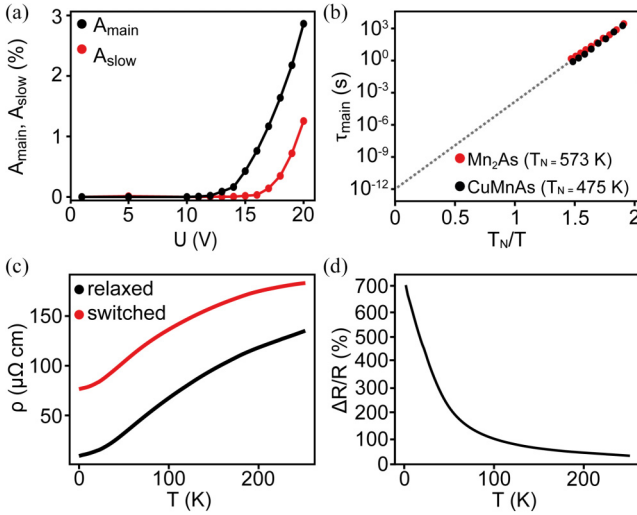


FIG. 4. (a) Fitted amplitudes of the main and the slow components of the resistance relaxation of Mn_2As recorded at the base temperature of 370 K, Sample C. (b) Relaxation times of the main component in Mn_2As and CuMnAs plotted as a function of inverse temperature normalized to T_N , from fits in Fig. 3(c). (c) Temperature dependence of resistance of a Mn_2As device in the maximally quench-switched state and in the relaxed state; above ~ 250 K the quench-switched state starts to relax (not shown in the figure), sample D. (d) The same data as in (c) plotted as the relative change in the resistance (with respect to the relaxed value).

to induce the quench switching effect (see Supplemental Material for the detailed discussion and quantitative estimates [20]).

In Fig. 4(b) we show the relaxation times of the main component for both Mn_2As and CuMnAs plotted against the inverse temperature. Their temperature dependencies can be fitted by an Arrhenius-like relation $\tau = \tau_0 \cdot \exp(E_b/k_B T)$ [30], where τ_0 reflects the characteristic attempt rate and E_b is the energy barrier governing the thermally activated relaxation. Both dependencies yield τ_0 in the picosecond range which agrees with the value expected for THz antiferromagnetic spin dynamics governing the attempt rate of the relaxation process.

Moreover, the dependencies for Mn_2As and CuMnAs clearly overlap, when the inverse temperatures in the Arrhenius plot are normalized by the respective Néel temperatures. The overlap implies that the energy barriers E_b of the two materials also scale with the Néel temperature.

Both materials can be also compared in terms of the maximum achievable magnitude of the quench-switching signal. To suppress the current leakage of the high-amplitude (~ 30 V) heating pulse into the GaAs substrate, the 20 nm thick Mn_2As film was grown on top of an AlGaAs buffer layer (Sample D). Analogously to CuMnAs [9], we measured the temperature dependency of the resistance in the quench-switched state and in the fully relaxed state. The Mn_2As device was quench-switched at 250 K to $\Delta R/R \approx 35\%$, which for the particular sample was close to the maximum at which still no structural damage was induced to the material. At 250 K (i.e., at $T_N/T \approx 2.3$) the relaxation is practically inhibited and temperature dependence of the device resistance

can be recorded down to 5 K while remaining in the fully quench-switched state [red curve in Fig. 4(c)]. Subsequently, the device was heated to 390 K, which triggered a relatively fast relaxation. After four hours at this temperature, the fully relaxed resistance was again recorded during the cool down back to 5 K [black curve in Fig. 4(c)]. The corresponding relative change in resistance is shown in Fig. 4(d) and approaches 700% in Mn_2As at 5 K, compared to 100% previously reported in CuMnAs . Part of this difference comes from different residual resistivity ratios (RRR) of CuMnAs and Mn_2As . The highest RRR achieved in CuMnAs reaches about 6, in Mn_2As we observed RRR as high as 24. We attribute the difference in RRR of the two materials to the absence of Mn/Cu antisite defects in Mn_2As . In the case of the device shown in Fig. 4(c) RRR reaches approximately 16.

IV. DISCUSSION

Previous microscopic investigations of quench switching in CuMnAs [9] revealed, that the resistance increase is associated with fragmentation of the magnetic state into domains with size less than ≈ 10 nm. Later works connected the fragmentation to the presence of atomically sharp domain walls [10,31], which would allow for the existence of magnetic domains with nm size that may remain unresolved by standard magnetic imaging methods. Formation and long-term stability of such domain walls seem to fall out of the framework of effective micromagnetic modeling, which predicts relatively wide (tens of nanometers) domain walls for the considered antiferromagnets. In the micromagnetic framework the domain wall width is given by an energy minimum associated with balance of competing exchange and anisotropy energies. In contrast to the micromagnetic approach, atomistic *ab-initio* simulations in CuMnAs revealed that a local minimum in the domain wall energy exists for the case of a 180° atom-to-atom spin rotation, i.e., for the atomically sharp domain wall [31]. Energy barrier for the formation of such atomically sharp domain wall is directly related to the atom-to-atom exchange interaction.

In this work, we show by comparing the relaxation times in Mn_2As and CuMnAs that the energy barrier governing the quench-switching relaxation is proportional to the Néel temperature [see Fig. 4(b)]. Importantly, the scaling to the Néel temperature confirms the magnetic origin of the effect. Furthermore, since the Neel temperature is directly proportional to the exchange interaction, the scaling also represents additional support for the microscopic mechanism of quench switching based on atomically sharp domain walls whose energy is related solely to the strength of exchange interaction in contrast to the traditional micromagnetic domain mechanism sensitive also to the strength of magnetic anisotropy.

The stretching parameter of the relaxation relates to the dimensionality of the problem [32]. Interestingly, $\beta = 0.5$ was found in Mn_2As while for CuMnAs the value 0.6 was observed, indicating 2D and 3D diffusion, respectively. This may be related to different spin stiffness along the c -axis in the two materials which affects the domain fragmentation in the c -direction. The difference of magnetic interactions along the c -direction is, in fact, of qualitative character: in CuMnAs the strongly antiferromagnetically coupled planes of Mn

atoms are separated by nonmagnetic planes of Cu atoms, whereas in Mn_2As the Cu planes are occupied by magnetically oriented Mn atoms and the magnetic unit cell is doubled. The difference in β can also be related to differences in characteristic defects.

In both materials the main relaxation component is accompanied by additional distinguishable components. In the case of slow component in Mn_2As films, the analysis is less reliable due to its relative weakness and only partial degree of relaxation achieved within the studied 10^4 s window. Nevertheless, the data suggest that, similarly to CuMnAs , its relaxation time has similar temperature dependency as the main component. Within the picture of resistivity of the quench-switched state originating in the presence of atomically sharp domain walls, the origin of the additional component could be related, e.g., to the presence of atomically sharp domain walls oriented along different crystallographic directions, their diffusion along different directions, or their pinning on particular characteristic crystallographic defects. Alternatively, formation and metastability of other, possibly topologically more complex, spin textures could be involved.

Mn_2As is of particular interest due to its high T_N . The associated temperature dependence of the quench-switching signal opens the possibility of performing a wider range of experiments aiming to characterize the quench-switched state such as the use of complex magnetic imaging techniques and even experiments studying relaxation dynamics at room temperature, where the slow relaxation process takes tens of hours. This is in contrast to CuMnAs , where lower T_N results in impractically short relaxation times at room temperature for most microscopy techniques.

The relaxation time scale of quench switching in both materials is determined by T/T_N . Therefore, setting the correct

base temperature range is essential for testing the presence of quench switching in other antiferromagnetic materials and for its separation from other effects. Changing the T/T_N ratio also allows for precise tuning of the relaxation properties of quench-switching-based spintronic devices and tailoring their neuron-like long and short-term memory properties [11].

V. CONCLUSION

We have shown that the recently reported intriguing quench-switching phenomenology is not limited solely to CuMnAs , but is a universal mechanism present in more antiferromagnetic materials, as demonstrated in this work in epitaxial Mn_2As . The comparison of quench switching in Mn_2As and CuMnAs shows clear scaling of the relaxation dynamics with the Néel temperature and confirms the magnetic origin of the effect. The experimental observation of the quench switching of resistivity in another material provides the evidence needed to establish and validate the theoretical description of the microscopic origin of the effect and its further refinement.

ACKNOWLEDGMENTS

We thank M. Sousa (IBM) and IBM Research Zurich for the access to the TEM facility. The authors also acknowledge ScopeM for their support and assistance. The authors also acknowledge the support of GACR Grant No. 21-28876J, MEYS Grants No. LM2023051 and No. CZ.02.01.01/00/22_008/0004594 and the Dioscuri Program LV23025 funded by MPG and MEYS. D.K. acknowledges the support from the Czech Academy of Sciences (Project No. LQ100102201).

-
- [1] T. Jungwirth, X. Marti, P. Wadley, and J. Wunderlich, Antiferromagnetic spintronics, *Nat. Nanotechnol.* **11**, 231 (2016).
 - [2] V. Baltz, A. Manchon, M. Tsoi, T. Moriyama, T. Ono, and Y. Tserkovnyak, Antiferromagnetic spintronics, *Rev. Mod. Phys.* **90**, 015005 (2018).
 - [3] D. Xiong, Y. Jiang, K. Shi, A. Du, Y. Yao, Z. Guo, D. Zhu, K. Cao, S. Peng, W. Cai *et al.*, Antiferromagnetic spintronics: An overview and outlook, *Fundam. Res.* **2**, 522 (2022).
 - [4] H. Chen, L. Liu, X. Zhou, Z. Meng, X. Wang, Z. Duan, G. Zhao, H. Yan, P. Qin, and Z. Liu, Emerging antiferromagnets for spintronics, *Adv. Mater.* **36**, 2310379 (2024).
 - [5] X. Marti, I. Fina, C. Frontera, J. Liu, P. Wadley, Q. He, R. Paull, J. Clarkson, J. Kudrnovský, I. Turek *et al.*, Room-temperature antiferromagnetic memory resistor, *Nat. Mater.* **13**, 367 (2014).
 - [6] P. Wadley, B. Howells, J. Železný, C. Andrews, V. Hills, R. P. Campion, V. Novák, K. Olejník, F. Maccherozzi, S. Dhesi *et al.*, Electrical switching of an antiferromagnet, *Science* **351**, 587 (2016).
 - [7] J. Han, Y. Wang, F. Pan, and C. Song, Spin-Hall-effect-assisted electroresistance in antiferromagnets via 10^5 A/cm² dc current, *Sci. Rep.* **6**, 31966 (2016).
 - [8] J. Godinho, H. Reichlová, D. Kriegner, V. Novák, K. Olejník, Z. Kašpar, Z. Šobáň, P. Wadley, R. P. Campion, R. M. Otxoa, P. E. Roy, J. Železný, T. Jungwirth, and J. Wunderlich, Electrically induced and detected Néel vector reversal in a collinear antiferromagnet, *Nat. Commun.* **9**, 4686 (2018).
 - [9] Z. Kašpar, M. Surynek, J. Zubáč, F. Krizek, V. Novák, R. P. Campion, M. S. Wörnle, P. Gambardella, X. Marti, P. Němec *et al.*, Quenching of an antiferromagnet into high resistivity states using electrical or ultrashort optical pulses, *Nat. Electron.* **4**, 30 (2021).
 - [10] J. Zubáč, Z. Kašpar, F. Krizek, T. Förster, R. P. Campion, V. Novák, T. Jungwirth, and K. Olejník, Hysteretic effects and magnetotransport of electrically switched CuMnAs , *Phys. Rev. B* **104**, 184424 (2021).
 - [11] M. Surynek, J. Zubac, K. Olejnik, A. Farkas, F. Krizek, L. Nadvornik, P. Kubascik, F. Trojanek, R. Campion, V. Novak *et al.*, Picosecond transfer from short-term to long-term memory in analog antiferromagnetic memory device, *Newton* **1**, 100034 (2025).
 - [12] P. Wadley, V. Hills, M. Shahedkhah, K. Edmonds, R. Campion, V. Novák, B. Ouladdiaf, D. Khalyavin, S. Langridge, V. Saidl *et al.*, Antiferromagnetic structure in tetragonal CuMnAs thin films, *Sci. Rep.* **5**, 17079 (2015).

- [13] K. Motizuki, H. Ido, T. Itoh, and M. Morifuji, *Electronic Structure and Magnetism of 3d-Transition Metal Pnictides* (Springer, Berlin, Heidelberg, 2010).
- [14] Y. Zhang, J. Brgoch, and G. J. Miller, Magnetic ordering in tetragonal 3D metal arsenides M_2As ($\text{M} = \text{Cr}, \text{Mn}, \text{Fe}$): An *ab initio* investigation, *Inorg. Chem.* **52**, 3013 (2013).
- [15] K. Momma and F. Izumi, VESTA: A three-dimensional visualization system for electronic and structural analysis, *J. Appl. Crystallogr.* **41**, 653 (2008).
- [16] A. Austin, E. Adelson, and W. Cloud, Magnetic structures of Mn_2As and $\text{Mn}_2\text{Sb}_{0.7}\text{As}_{0.3}$, in *Proceedings of the Seventh Conference on Magnetism and Magnetic Materials* (Springer, New York, NY, 1962), pp. 1356–1357.
- [17] M. Yuzuri and M. Yamada, On the magnetic properties of the compound Mn_2As , *J. Phys. Soc. Jpn.* **15**, 1845 (1960).
- [18] F. Máca, J. Kudrnovský, P. Baláž, V. Drchal, K. Carva, and I. Turek, Tetragonal CuMnAs alloy: Role of defects, *J. Magn. Magn. Mater.* **474**, 467 (2019).
- [19] V. Novák, K. Olejník, M. Cukr, L. Smrčka, Z. Remeš, and J. Oswald, Substrate temperature changes during molecular beam epitaxy growth of GaMnAs , *J. Appl. Phys.* **102**, 083536 (2007).
- [20] See Supplemental Material at <http://link.aps.org/supplemental/10.1103/1c81-tnzw> for detailed description of experimental methods, additional XRD and TEM data and analysis, measurement setup, RHEED images and magnetometry.
- [21] F. Krizek, Z. Kašpar, A. Vetushka, D. Kriegner, E. M. Fiordaliso, J. Michalicka, O. Man, J. Zubáč, M. Brajer, V. A. Hills *et al.*, Molecular beam epitaxy of CuMnAs , *Phys. Rev. Mater.* **4**, 014409 (2020).
- [22] J. Narayan and S. Oktyabrsky, Formation of misfit dislocations in thin film heterostructures, *J. Appl. Phys.* **92**, 7122 (2002).
- [23] J. Schindelin, I. Arganda-Carreras, E. Frise, V. Kaynig, M. Longair, T. Pietzsch, S. Preibisch, C. Rueden, S. Saalfeld, B. Schmid *et al.*, Fiji: An open-source platform for biological-image analysis, *Nat. Methods* **9**, 676 (2012).
- [24] D. Kriegner, E. Wintersberger, and J. Stangl, xrayutilities: A versatile tool for reciprocal space conversion of scattering data recorded with linear and area detectors, *J. Appl. Crystallogr.* **46**, 1162 (2013).
- [25] Z. Yang, K. Zhang, and X. Xie, Electronic structure and magnetic properties of Mn_2As , *Phys. Rev. B* **58**, 339 (1998).
- [26] M. Wang, C. Andrews, S. Reimers, O. J. Amin, P. Wadley, R. P. Campion, S. F. Poole, J. Felton, K. W. Edmonds, B. L. Gallagher *et al.*, Spin flop and crystalline anisotropic magnetoresistance in CuMnAs , *Phys. Rev. B* **101**, 094429 (2020).
- [27] S. N. Zhang, Q. S. Wu, Y. Liu, and O. V. Yazyev, Magnetoresistance from Fermi surface topology, *Phys. Rev. B* **99**, 035142 (2019).
- [28] P. Ritzinger and K. Výborný, Anisotropic magnetoresistance: Materials, models and applications, *R. Soc. Open Sci.* **10**, 230564 (2023).
- [29] J. Volný, D. Wagenknecht, J. Železný, P. Hrcuba, E. Duverger–Nedellec, R. H. Colman, J. Kudrnovský, I. Turek, K. Uhlířová, and K. Výborný, Electrical transport properties of bulk tetragonal CuMnAs , *Phys. Rev. Mater.* **4**, 064403 (2020).
- [30] M. Meinert, D. Graulich, and T. Matalla-Wagner, Electrical switching of antiferromagnetic Mn_2Au and the role of thermal activation, *Phys. Rev. Appl.* **9**, 064040 (2018).
- [31] F. Krizek, S. Reimers, Z. Kašpar, A. Marmodoro, J. Michalicka, O. Man, A. Edström, O. J. Amin, K. W. Edmonds, R. P. Campion *et al.*, Atomically sharp domain walls in an antiferromagnet, *Sci. Adv.* **8**, eabn3535 (2022).
- [32] J. C. Phillips, Axiomatic theories of ideal stretched exponential relaxation, *J. Non-Cryst. Solids* **352**, 4490 (2006).