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Michaelis–Menten kinetics during chemical etching of germanium

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A R T I C L E I N F O

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A B S T R A C T

The chemical etching of germanium in Br_2 environment is investigated theoretically. The steady-state etching rate is described by the Michaelis-Menten equation. It shown that Michaelis constant is the ratio of desorption rate constant to reaction rate constant. The activation energies of elementary processes are evaluated using the transition state theory. It is found that the activation energy of Ge(s) + Br_2(g) → $GeBr_2$(a) reaction is equal to (1.168 ± 0.173) eV, and the desorption activation energy of $GeBr_2$ molecules is equal to (1.404 ± 0.077) eV. The Michaelis constant depends on temperature because the reaction activation energy differs from the desorption activation energy. Surface passivation by GeBr radicals is not observed under the investigated experimental conditions.

Video to this article can be found online at https://doi.org/10.1016/j.sctalk.2022.100079.

Figures and table

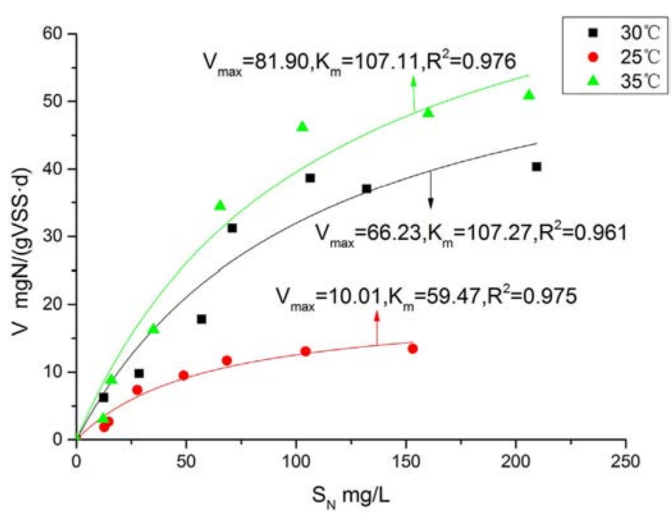

Fig. 1. Typical nonlinear regression analysis of the Michaelis-Menten saturation curves [1].

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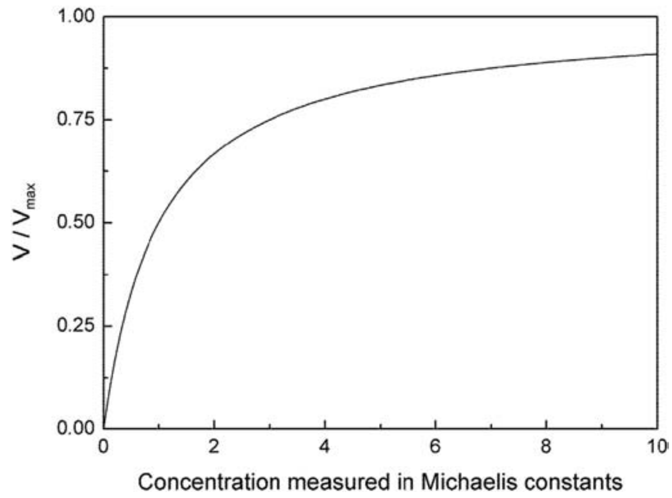

Fig. 2. The dependence of V / V_{max} on the concentration measured in the Michaelis constants.

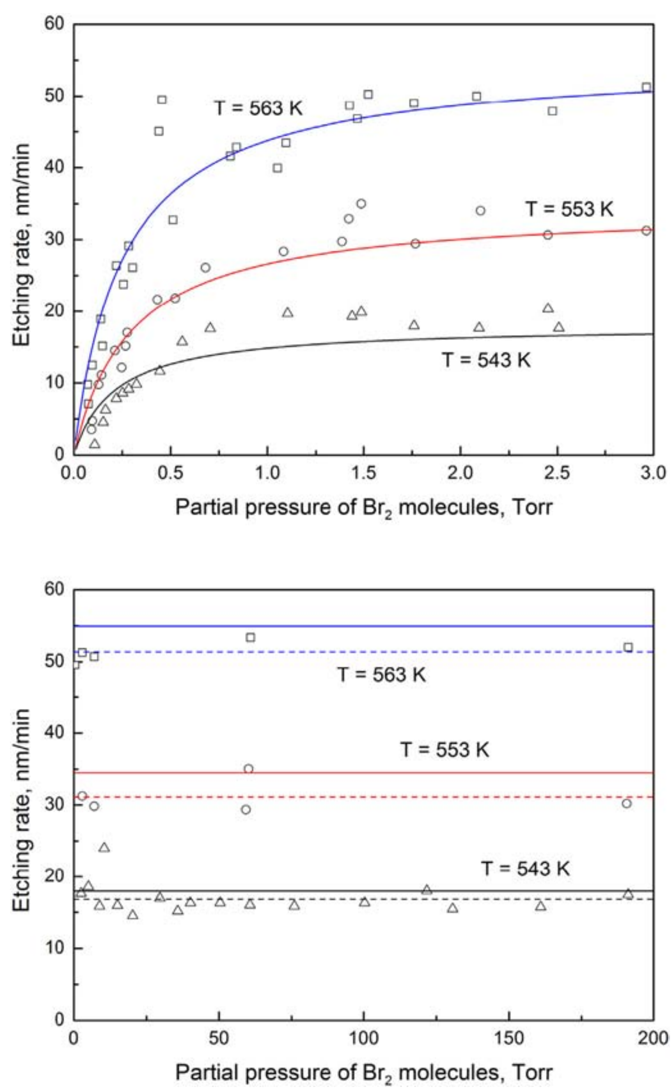

Fig. 3. The experimental [2] and theoretical dependences of germanium etching rate on the partial pressure of Br_2 molecules.

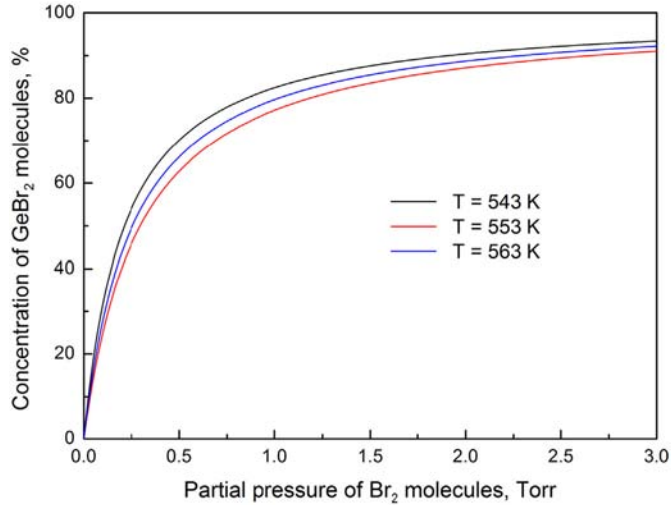

Fig. 4. Theoretical dependences of the surface coverage on the partial pressure of Br_2 molecules.

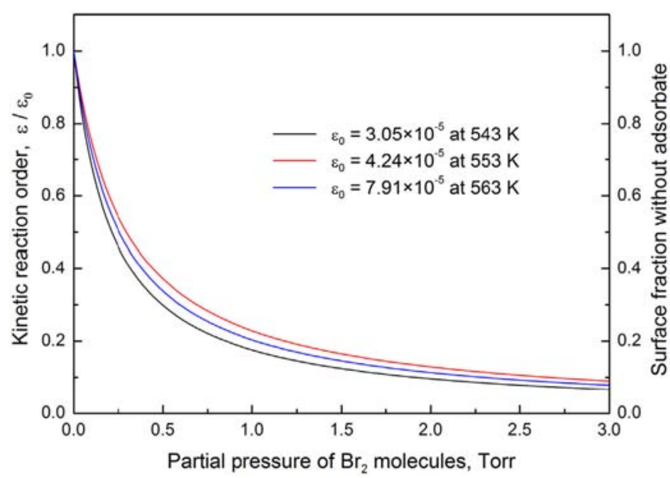

Fig. 5. The theoretical dependences of kinetic reaction order, ratio $\varepsilon/\varepsilon_0$, and surface area not covered with adsorbate on the partial pressure of Br_2 molecules.

Table 1
The kinetic parameters determined during nonlinear regression and graphical analysis of the experimental data. Activation energies of the elementary processes are calculated using the transition state theory. The average kinetic transmission coefficient $A = 1\ Pa^{-1}$.

$T,\ K$	$k_r \pm \Delta k_r,\ Torr^{-1}s^{-1}$	$\omega \pm \Delta\omega,\ s^{-1}$	$E_r \pm \Delta E_r,\ eV$	$E_d \pm \Delta E_d,\ eV$
		Nonlinear regression analysis		
543	4.975 ± 1.045	1.060 ± 0.038	1.166 ± 0.245	1.404 ± 0.050
553	6.859 ± 0.839	2.032 ± 0.070	1.173 ± 0.143	1.399 ± 0.048
563	12.670 ± 1.433	3.237 ± 0.107	1.164 ± 0.132	1.403 ± 0.046
		Michaelis-Menten plot		
543		0.992 ± 0.125		1.408 ± 0.177
553		1.834 ± 0.134		1.404 ± 0.103
563		3.025 ± 0.085		1.406 ± 0.040

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CRediT authorship contribution statement

Rimantas Knizikevičius: Conceptualization, Methodology, Formal analysis, Investigation, Validation, Resources, Writing – review & editing.

Declaration of interests

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Rimantas Knizikevičius received PhD degree in Physics from Kaunas University of Technology in 2000. His research interests include dry etching processes and surface inhibition mechanisms. From 2002 until 2006 he appeared as a clear winner of The Young Scientists Research Competition organized by Kaunas University of Technology. In 2003, he won The Young Scientists Research Competition in the field of mathematics, physics, and chemistry organized by The Lithuanian Academy of Sciences. Afterwards, he served as the editor of Dataset Papers in Science, Hindawi Publishing Corporation. In 2019, he was granted a Latvian state research fellowship at Riga Technical University. As theoretical scientist, he has published over 30 articles in Web of Science journals as single author. Since receiving PhD degree, he is reading lectures of physics at Kaunas University of Technology, Lithuania.