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**INVESTIGATIONS OF THE DYNAMICS AND GROWTH OF INSULATOR FILMS BY
HIGH RESOLUTION HELIUM ATOM SCATTERING**

Final Report
for the Project Period from
May 1, 1985 to April 30, 1997

from
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I. Aims

Over the twelve years of this grant from the U. S. Department of Energy, DE-FG05-85ER45208, the over-reaching aims of this work have been to explore and to attempt to understand the fundamental physics and chemistry of surfaces and interfaces. The *instrument* we have employed in this work is high-resolution helium atom scattering (HAS) which we have become even more convinced is an exceptionally powerful and useful tool for surface science.

One can follow the evolution of the development and progress of the experiments that we have carried out by the evolution of the proposal titles for each of the four three-year periods. At first, in 1985-1988, the main objective of this grant was to construct the HAS instrument so that we could begin work on the surface vibrational dynamics of crystalline materials; the title was "Helium Atom-Surface Scattering Apparatus for Studies of Crystalline Surface Dynamics". Then, as we became more interested in the growth of films and interfaces the title in 1988-1991 became "Helium Atom Surface Spectroscopy: Surface Lattice Dynamics of Insulators, Metal and Metal Overlayers". In 1991-1994, we headed even more in this direction, and also recognized that we should focus more on insulator materials as very few techniques other than helium atom scattering could be applied to insulators without causing surface damage. Thus, the proposal title became "Helium Atom- Surface Scattering: Surface Dynamics of Insulators, Overlayers and Crystal Growth". In the final period of this grant the title ended up "Investigations of the Dynamics and Growth of Insulator Films by High Resolution Helium Atom Scattering" in 1994-1997.

As one can see, the real focus of the grant has never changed.

II. Work Accomplished

As indicated in Section I, the principal objective at the beginning was to construct a state-of-the-art helium scattering instrument which is capable of measuring Bragg diffraction from the surface to provide information about the surface structure and time-of-flight (TOF) spectra from which the surface lattice dynamics could be inferred. This was accomplished. We should note that the instrument is very adaptable so that it could easily be modified for the growth studies which came later. We list below all of the systems which have been studied in this laboratory:

Alkali Halide (001) Surfaces: LiF, NaCl, NaI, KBr, RbCl, RbBr, RbI, CsF.

Rocksalt-Structured Oxide (001) Surfaces: MgO, NiO, CoO.

Other Material Surfaces: mica, KCN.

Thin Film Growth, Structure and Dynamics: NaCl/NaCl(001), KBr/NaCl(001), KBr/RbCl(001), KCN/KBr(001), bromohexane/KBr(001), alkyl halides/alkali halides.

Perovskite Surfaces: $\text{KTaO}_3(001)$.

A list of significant accomplishments include:

1. Tests of the Shell Model. The Shell Model has been the standard model for describing the physical behavior of bulk ionic insulator materials of which the alkali halides are the archetypes. The experiments that we carried out on the alkali halides were primarily to compare the surface dynamics with that predicted by Shell Model calculations. In general, the agreement has been very good. We have been able to confirm many predictions of the

calculations, including shifts in energy of the phonon dispersion branches because of surface relaxation. However, we found several effects which turn out to be important that were not recognized by the theorists at first, most notably in the strength of the interaction of the helium probe with "crossing" modes. In addition, in the growth studies of KBr/NaCl and KBr/RbCl we have provided theorists detailed information about the layer-by-layer growth which is not available by other techniques and in treating these results by the Shell Model, a more systematic method of selecting parameters for the model had to be developed.

2. Multiphonon Scattering. In addition to single-phonon scattering events which provide data for calculating the phonon dispersion curves, HAS TOF experiments also yield data on the multiphonon scattering. Recent theoretical treatment of these scattering events has opened up a method to extract the surface Debye temperature and parameters of the helium-surface interaction potential. Our experiments with NaCl(001), LiF(001) and KCN(001) are now standards with which other multiphonon experiments can be compared.

3. Physisorbed Monolayer Films. We have found that alkyl halides can assemble from solution or by vapor deposition as physisorbed monolayers on alkali halide surfaces. While these adlayers are very weakly bound to the substrate, they have long-range order as indicated by Bragg diffraction of the elastically scattered helium beam. In addition, these films undergo a phase transition as the substrate changes temperature. For bromohexane there appears to be a small temperature range, from about 170 K to 180 K where the film can "anneal" without desorbing; *i. e.*, in this temperature range the molecules seem to be able to rearrange themselves into a more ordered surface structure, but above 180 K the ad molecules rapidly desorb.

4. Other Surface Phase Transitions. We have been able to observe phase transitions at surfaces, both in cleaved bulk crystals as in KTaO_3 and in monolayer films such as KCN/KBr(001). In the latter, it was found that the monolayer film of KCN undergoes an anti-ferroelectric transition from (1x1) to (2x1) structure with respect to the KBr(001) substrate lattice at about 100 K. This behavior somewhat follows the bulk properties except that the bulk has three phases while the monolayer film apparently can exist in only two phases. It should be noted that the (001) surface obtained by cleaving single crystal KCN appears disordered in HAS, whereas the monolayer film on KBr does have the characteristic Bragg diffraction spots which indicate long-range order. It may be possible to study other materials in this way, *i.e.*, by growing the material onto a suitable substrate layer-by-layer through vapor deposition. For the perovskite KTaO_3 , there are no bulk phase transitions although when doped to only a few percent by Nb atoms, it undergoes a ferroelectric transition. The surface phase transition, from (1x1) to (2x1), appears to require a thermal cycle to activate, going from room temperature (~300 K) to around 60 K and back. The (1x1) structure can be restored by heating to about 365 K. Considerable hysteresis is also observed in the intensities of the Bragg diffraction peaks as one cycles in temperature between 60 K and 300 K.

5. Surface Magnetic Effects. The oxides NiO and CoO undergo antiferromagnetic to paramagnetic phase transitions as the temperature is raised. We attempted to observe changes in the surface phonons of the (001) surfaces of cleaved single crystals of these materials as the temperatures were raised through their respective Néel temperatures. However, no effects were observed. We also attempted to use ^3He scattering to see if we

could observe Bragg diffraction from the magnetic lattice (the magnetic unit cell is (2×1) compared to the chemical unit cell), but were not able to observe any half order spots.

We note also that in the period of this grant we have collaborated extensively with the group of Prof. J. P. Toennies at the Max-Planck-Institut für Strömungsforschung, Göttingen, Germany, and made considerable use of the helium atom scattering facilities there. We have also collaborated with Prof. J. R. Manson of Clemson University, Prof. G. Benedek of the University of Milan, Prof. U. Schröder of the University of Regensburg, Prof. Ch. Wöll of the University of Bochum, Dr. L. Boatner of the Oak Ridge National Laboratory and Dr. S. Miret-Artes of the University of Madrid. These collaborations are amply reflected in the lists below of publications and presentations.

III. Estimate of Unexpended Funds

All of the funds from this grant should have been spent or obligated by the end of the last budget period, April 30, 1997.

IV. Scientific Staff

The scientific personnel during the grant period from May 1, 1985, to April 30, 1997, consisted of the co-principal investigators, JGS (Physics Department) and SAS (Chemistry Department), and the following graduate and undergraduate students:

Gung Chern, Ph. D. Physics, 1990, post-doctorate 1991-92 MARTECH- currently an Assistant Professor at the Chang Kai Shek University, Taiwan.

W. Patrick Brug, Ph. D. Chemistry, 1991- currently at Los Alamos National Laboratory, New Mexico.

Jun Duan, Ph. D. Physics, 1993- completed a medical physics program in Gainesville, Florida; currently practicing in Panama City, Florida.

Edward S Gillman, Ph. D. Physics, 1994- currently a postdoctorate at FSU in the Chemistry Department.

Gregory G. Bishop, Ph. D. Physics, 1994- currently a postdoctorate at Rutgers University, New Jersey.

Juan J. Hernández, Ph. D. Physics, 1995- currently with Hewlett-Packard in Corvallis, Oregon.

Jeffrey R. Baker, Ph. D. Physics, 1996-currently a postdoctorate at the National Research Laboratory, Risø, Denmark.

Jaime A. Li- current Physics graduate student.

Thomas W. Trelenberg- current Physics graduate student.

Elshan A. Akhadov- current Physics special student.

1986: Melissa Reeves, summer research assistant- completed her Ph. D. in Physical Chemistry at the University of Indiana.

1987: Jane Davis, summer NSF fellow- currently at the University of West Florida.

1988: Shawn Seat, summer NSF fellow- started Ph. D. in engineering at Georgia Tech.

1989: Tim Wheland, summer NSF fellow.

- 1990: Robert Stewart, Chemistry honors student, Spring term.
 1991: Chris Immer, summer research assistant.
 Ben Barnes, Directed Individual Study student.
 Brian Bright, Chemistry honors student, Spring term.
 1992: Chris Banbury, summer NSF fellow.
 Ben Barnes, Directed Individual Study student.
 1993: Scott Murphy, summer NSF fellow.
 Jim Matthies, research assistant.
 Albert Richardson, Chemistry honors student, Spring term.
 Chris Libbey, Chemistry honors student, Spring term.
 1994: Adam Pierce, summer NSF fellow.
 Jim Matthies, research assistant.
 Nicole Odell, Chemistry honors student, Spring term, summer research assistant, won third prize for a student poster she presented on work in our laboratory at the Florida Chapter of the American Vacuum Society February, 1995, meeting in Clearwater.
 1995: Mitzi Robinson, summer NSF fellow, research assistant, Fall term.
 Sara Kelly, Chemistry honors student, Spring term.
 David Mozzoni, Chemistry honors student, Spring term, research assistant, Fall term.
 David Byrd, summer Directed Individual Study student, research assistant, Fall term.
 1996: Jackie Menchaca, summer NSF fellow.
 Mark Chandler, Chemistry honors student, Spring term.
 David Mozzoni, research assistant Spring term.
 Gary Conner, Directed Individual Study student, Spring and Summer terms.
 Lance Culver, Directed Individual Study student, Summer and Fall terms.
 1997: Lance Culver, Directed Individual Study student, Spring term.
 David Edwards, Chemistry Honors student, Spring term.
 Paul Benschoter, Chemistry Honors student, Spring term.

In addition, Professor M. E. "Betty" Derrick, Chemistry Department, Valdosta State University, Valdosta, Georgia, spent nine months in our laboratory as a Visiting Professor in our laboratory in 1991-2. This stay at FSU was sponsored by a grant from the NSF.

V. All Publications: May, 1985-April, 1997

1. "Surface Optical Phonons in NaF (001) <100> by Inelastic He atoms Scattering", G. Benedek, G. Brusdeylins, L. Miglio, R. Rechsteiner, J.G. Skofronick and J.P. Toennies. Phys. Rev. Letters 54, 446 (1985).
2. "Temperature Dependent Surface Structure and Dynamics of 2H-TaSe₂ (0001) Studied by He-Atom Diffraction", G. Brusdeylins, C. Heimlich, J. G. Skofronick, J.P. Toennies, R. Vollmer, G. Benedek and L. Miglio, Vuoto XVI, 202 (1986).
3. "New Evidence for the Folding of Surface Phonon Modes in Quasimonatomic Crystals from He Time-of-Flight Measurements in NaF", G. Benedek, L. Miglio, G. Brusdeylins, J. G. Skofronick and J. P. Toennies, Phys. Rev. B35, 6593 (1987).

4. "Determination of the potential for Simultaneous Rotational Excitation and Diffraction in Scattering of D_2 from LiF", G. Brusdeylins, G. Drolshagen, A. Kaufhold, J. G. Skofronick and J. P. Toennies, *Surf. Sci.* 189/190, 972 (1987).
5. "Surface Phonon Dynamics in 2H-TaSe₂ (001)", G. Benedek, L. Miglio, J.G. Skofronick, G. Brusdeylins, C. Heimlich and J. P. Toennies, *J. Vac. Sci. Technol.*, A5, 1093 (1987).
6. "Surface Phonon Dynamics in 2H-TaSe₂(001)", G. Benedek, L. Miglio, G. Brusdeylins, C. Heimlich, J. G. Skofronick and J. P. Toennies, *Europhys. Lett.* 5, 253 (1988).
7. "Shifted Surface Phonon Anomaly on 2H-TaSe₂", G. Benedek, G. Brusdeylins, C. Heimlich, L. Miglio, J.G. Skofronick, J. P. Toennies and R. Vollmer, *Phys. Rev. Lett.* 60, 1037 (1988).
8. "Surface Phonon Dispersion Curves via Thermal Energy Atom Scattering: He Atoms on RbCl (001) Surface", G. Chern, W. P. Brug, S. A. Safron and J. G. Skofronick, *J. Vac. Sci. Technol. A* 7, 2094 (1989).
9. "Surface Phonon Dispersion Curves of KBr (001) via Helium Atom Scattering: Comparison with Calculations", G. Chern, J. G. Skofronick, W. P. Brug and S. A. Safron, *Phys. Rev. B* 39, 12828 (1989).
10. "Surface Phonon Modes of the RbBr (001) Crystal Surface by Inelastic He Atom Scattering", G. Chern, J. G. Skofronick, W. P. Brug and S. A. Safron, *Phys. Rev. B* 39, 12838 (1989).
11. "Determination of the Critical Exponent for a Charge Density Wave Transition in 2H-TaSe₂ by Helium Atom Scattering", G. Brusdeylins, C. Heimlich, J. G. Skofronick, J. P. Toennies, R. Vollmer and G. Benedek, *Europhys. Lett.* 9, 563 (1989).
12. "A Search for Cold Fusion using X-ray Detection", M. R. Deakin, J. D. Fox, K. W. Kemper, E. G. Myers, W. N. Shelton and J. G. Skofronick, *Phys. Rev. C* 40, R1851 (1989).
13. "Surface Dynamics of NaCl (001) by Inelastic He Atom Scattering", S. A. Safron, W. P. Brug, G. Chern, J. Duan, J. G. Skofronick and J. R. Manson, *J. Vac. Sci. Technol. A* 8, 2627 (1990).
14. "Surface Phonon Modes of the NaI (001) Crystal Surface by Inelastic He Atom Scattering", W. P. Brug, G. Chern, J. Duan, S. A. Safron, J. G. Skofronick and G. Benedek, *J. Vac. Sci. Technol. A* 8, 2632 (1990).
15. "Elastic and Inelastic He Atom Scattering on NaI (001)<110>", J. G. Skofronick, G. Chern, W. P. Brug, J. Duan, S. A. Safron and J. R. Manson, in *PHONONS 89*, S. Hunklinger, W. Ludwig and G. Weiss, eds., World Scientific, Singapore, 1990, pp 889-891.
16. "Interpretation of Features in the Surface Vibrational Modes of KBr and RbBr", S. A. Safron, G. Chern, W. P. Brug, J. G. Skofronick and G. Benedek, in *PHONONS 89*, S. Hunklinger, W. Ludwig and G. Weiss, eds., World Scientific, Singapore, 1990, pp 949-951.
17. "Interpretation of Features in the Surface-Phonon Dispersion Curves of KBr(001) and RbBr(001)", S. A. Safron, G. Chern, W. P. Brug, J. G. Skofronick and G. Benedek, *Phys. Rev. B* 41, 10146 (1990).

18. "Temperature Dependence of He Atom Scattering from NaCl(001)", J. G. Skofronick, G. G. Bishop, W. P. Brug, G. Chern, J. Duan, S. A. Safron and J. R. Manson, *Superlattices and Microstructures* **7**, 239 (1990).
19. "Surface Lattice Dynamics of the RbI(001) Crystal Surface via Inelastic He Atom Scattering", S. A. Safron, W. P. Brug, G. G. Bishop, J. Duan, G. Chern, and J. G. Skofronick, *J. Electron Spectrosc. Relat. Phenom.* **54/55**, 343 (1990).
20. "He-Atom Scattering Study of the Temperature-Dependent Charge-Density-Wave Surface Structure and Lattice Dynamics of 2H-TaSe₂(001)", G. Brusdeylins, C. Heimlich, J. G. Skofronick, J. P. Toennies, R. Vollmer, G. Benedek and L. Miglio. *Phys. Rev. B* **41**, 5707 (1990).
21. "Surface and Bulk Phonon-Assisted Resonances with Surface Bound States in the Inelastic Scattering of He Atoms on NaCl(001)", S. A. Safron, W. P. Brug, G. G. Bishop, G. Chern, M. E. Derrick, J. Duan, M. E. Deweese and J. G. Skofronick, *J. Vac. Sci. Technol. A* **9**, 1657 (1991).
22. "Surface Dynamics of CsF by He Atom Scattering", J. G. Skofronick, J. Duan, G. Chern, W. P. Brug, G. G. Bishop and S. A. Safron, *Surf. Sci.* **251/252**, 782 (1991).
23. "Study of the Epitaxial Growth of Single Crystal C₆₀ on Mica by Helium Atom Scattering", D. Schmicker, S. Schmidt, J. G. Skofronick, J. P. Toennies and R. Vollmer, *Phys. Rev. B* **44**, 10995 (1991).
24. "Homoepitaxial Growth Investigated by High-Resolution He Atom Scattering: NaCl onto NaCl(001)", J. Duan, G. G. Bishop, E. S. Gillman, G. Chern, S. A. Safron and J. G. Skofronick, *J. Vac. Sci. Technol. A* **10**, 1999 (1992).
25. "Epitaxial Growth of KBr onto NaCl(001) by High Resolution He Atom Scattering", J. Duan, G. G. Bishop, E. S. Gillman, G. Chern, S. A. Safron and J. G. Skofronick, *Surf. Sci.* **272**, 220 (1992).
26. "Surface Lattice Dynamics of NiO(001) by Inelastic He Atom Scattering", W. P. Brug, G. Chern, J. Duan, G. G. Bishop, S. A. Safron and J. G. Skofronick, *J. Vac. Sci. Technol. A* **10**, 2222 (1992).
27. "Helium Atom Scattering Studies of the Surface Phonons of Layered Materials", J. G. Skofronick and J. P. Toennies, in *Surface Properties of Layered Structures*, (Kluwer Academic Publishers, The Netherlands, 1992), pp.151-218.
28. "Multiphonon Effects in Thin Organic Films", J. R. Manson and J. G. Skofronick, *Phys. Rev. B* **47**, 12890 (1993).
29. "Multiphonon Inelastic Scattering of Helium Atoms from Crystal Surfaces", G. G. Bishop, W. P. Brug, G. Chern, J. Duan, S. A. Safron, J. G. Skofronick and J. R. Manson, *Phys. Rev. B* **47**, 3966 (1993).
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32. "Measurement of the Surface Dynamics of RbCl (001) via High Resolution He Atom Scattering", G. G. Bishop, J. Duan, E. S. Gillman, S. A. Safron and J. G. Skofronick,

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33. "He Atom Scattering Study of the Surface Dynamics of an Epitaxial One Monolayer KBr Film on RbCl(001): A Shell Model Analysis", J. G. Skofronick, G. G. Bishop, J. Duan, E. S. Gillman, S. A. Safron, D. Bonart and U. Schröder, J. Electron Spectrosc. Relat. Phenom. 64/65 747 (1993).
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 35. "Multiphonon Scattering of Thermal Energy Helium Atoms from the LiF(001) Surface", G. G. Bishop, E. S. Gillman, J. J. Hernández, J. Baker, J. G. Skofronick and S. A. Safron, J. Vac. Sci. Technol. A 12, 2124 (1994).
 36. "Inelastic Scattering of He Atoms from NaCl(001): Search for Surface Shear Horizontal Modes", G. Benedek, R. Gerlach, G. Lange, W. Silvestri, J. G. Skofronick and J. P. Toennies, Il Vuoto, (1995).
 37. "Scattering of ³He from the NiO(001) Surface", G. G. Bishop, J. Baker, E. S. Gillman, J. J. Hernández, S. A. Safron and J. G. Skofronick, J. Vac. Sci. Technol. A 13, 1416-1420 (1995).
 38. "Helium Atom Scattering Study of the Multiphonon Processes in LiF(001)<100> with Temperature Variation for Specular and Off-Specular Angles", G. G. Bishop, E. S. Gillman, J. Baker, J. J. Hernández, S. A. Safron, J. G. Skofronick, S. M. Weera and J. R. Manson, Phys. Rev. B 52, 13229 (1995).
 39. "Scattering of Helium Atoms from KCN: Analysis of the Energy Exchange", S. M. Weera, J. R. Manson, J. Baker, E. S. Gillman, J. J. Hernández, G. G. Bishop, S. A. Safron and J. G. Skofronick, Phys. Rev. B 52, 14185 (1995).
 40. "Focussed Inelastic Resonances in the Scattering of He Atoms from NaCl(001)", G. Benedek, R. Gerlach, A. Glebov, G. Lange, S. Miret-Artes, J. G. Skofronick and J. P. Toennies, Phys. Rev. B 53, 11211 (1996).
 41. "Surface Lattice Dynamics of KBr Epitaxially Grown on RbCl(001)", E. S. Gillman, J. Baker, J. J. Hernández, G. G. Bishop, J. A. Li, S. A. Safron, J. G. Skofronick, D. Bonart and U. Schröder, Physica B 219, 428 (1996).
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 43. "High Resolution Helium Atom Scattering as a Probe of Surface Vibrations", S. A. Safron, in *Advances in Chemical Physics, Volume XCV*, I. Prigogine and S. A. Rice, eds. (John Wiley and Sons, New York, 1996) pp. 129-212.
 44. "High Resolution Helium Atom Scattering from an Epitaxially Grown One-Monolayer Film of KCN on KBr(001)", J. Baker, J. J. Hernández, J. A. Li, J. G. Skofronick, S. A. Safron and E. S. Gillman, Surf. Sci. 357/358, 639 (1996).
 45. "Self-Assembled Films of Alkyl Halides on Alkali Halides", J. J. Hernández, J. A. Li, J. Baker, S. A. Safron and J. G. Skofronick, J. Vac. Sci. Technol. A 14, 1788 (1996).
 46. "Evidence for a Surface Optical Phonon Mode on NaCl(001)", G. Benedek, A. Glebov, W. Silvestri and J. G. Skofronick, J. Vac. Sci. Technol., A 14, 1522 (1996).
 47. "Evidence for the Shear Horizontal Phonon Mode on the NaCl(001) Surface", G.

- Benedek, A. Glebov, W. Silvestri, J. G. Skofronick and J. P. Toennies, Phys. Rev. B 54, 17886 (1996).
48. "Surface Phonon Dispersion Curves for a Hexagonally Close Packed Metal Surface: Ru(0001)", J. Braun, K. L. Kostov, G. Witte, L. Surnev, J. G. Skofronick, S. A. Safron and Ch. Wöll, Surf. Sci. 372, 132-144 (1997).
 49. "Defect-Mediated Diffraction Resonances in Surface Scattering", A. Glebov, J. R. Manson, J. G. Skofronick and J. P. Toennies, Phys. Rev. Lett. 78, 1508 (1997).
 50. "Structure of KCN Monolayer Films Vapor-Deposited onto Cleaved KBr(001) by Helium Atom Scattering", S. A. Safron, J. R. Baker, J. A. Li, E. A. Akhadov, T. W. Trelenberg and J. G. Skofronick, Mat. Res. Soc. Proc. (In press).

VI. Abstracts and Papers Presented at Meetings: May 1, 1985-April 30, 1997

1. "Surface Acoustic and Optical Phonon Dispersion Relations for GaSe", J. G. Skofronick, G. Brusdeylins, J. P. Toennies, G. Benedek and L. Miglio, Bull. Am. Phys. Soc. 31, 608 (1986).
2. "Surface Phonon Dynamics of 2H-TaSe₂ (001)", G. Benedek, L. Miglio, J. G. Skofronick, G. Brusdeylins, C. Heimlich, and J. P. Toennies, 33rd National Symposium, American Vacuum Society, Oct. 27-31, 1986, Baltimore, Maryland.
3. "Folding of Surface Phonon Dispersion Curves in Nearly Isobaric Alkali Halide Crystals", J. G. Skofronick, G. Benedek, L. Miglio, G. Brusdeylins, and J. P. Toennies, Workshop on Interactions of Molecular Beams and Surfaces, The Netherlands, Sept. 22-25, 1986.
4. "Helium Diffraction Studies of Charge-Density Wave Reconstruction in Tantalum Disulfide (1T-TaS₂)", G. Benedek, G. Brusdeylins, C. Heimlich, J. G. Skofronick and J. P. Toennies, Workshop on Interactions of Molecular Beams and Surfaces, The Netherlands, Sept. 22-25, 1986.
5. "Temperature Dependent Surface Structure and Dynamics of 2H-TaSe₂ (0001) Studied by He-Atom Scattering", G. Benedek, G. Brusdeylins, C. Heimlich, J. G. Skofronick and J. P. Toennies, Workshop on Interactions of Molecular Beams and Surfaces, The Netherlands, Sept. 22-25, 1986.
6. "Elastische und Inelastische Heliumstreuung an den Schicht-Einkristallen 1T-TaS₂ und 2H-TaSe₂ (Charge-Density-Waves)", G. Brusdeylins, C. Heimlich, J. P. Toennies and J. G. Skofronick, DPG - Fruejahrstagung Freudenstadt, Germany, 7-11 April, 1986.
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