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# DATA ON TRAPPING AND RE-EMISSION OF ENERGETIC HYDROGEN ISOTOPES AND HELIUM IN MATERIALS, SUPPLEMENT I

May 1984

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# Data on Trapping and Re-emission of Energetic Hydrogen Isotopes and Helium in Materials Supplement 1

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This is the supplement to the data on trapping and re-emission of energetic hydrogen isotopes and helium in materials (JAERI-M 82-118). It contains 32 data up to end of 1982, dividing it into following 6 sections: 1) Dose Dependence, 2) Target Material Dependence, 3) Target Temperature Dependence, 4) Incident Energy Dependence, 5) Damage Effects and 6) Ion-Induced Release.

Key words: Fusion Reactor, Trapping, Re-emission, Ion Implantation, Hydrogen Isotopes, H-Recycling, Plasma-surface Interactions, Data Base

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This report was prepared as an account of work by the sub-working group for data-banking of particle-material interaction in the Research Committee of A&M Data of JAERI.

# 固体材料中に注入された水素同位体及び
# ヘリウムの保持・放出に関するデータ集
# サプルメント・1

日本原子力研究所東海研究所原子分子データ研究委員会

山口　貞衛*・小沢　国夫・中井　洋太
杉崎　康昭*

（1984年4月23日受理）

固体材料中に注入された水素同位体及びヘリウムの保持放出に関するデータ集　JAERI－M 82－118の増補版である。本報告は1982年迄の関連文献を調査収集し，AMSTORシステムによる計算機作図化を行って，32図のデータを増補し収録した。構成は次の6章に分類整理した。

1）イオン照射量依存性　　2）試料物質依存性
3）標的温度依存性　　4）入射イオンエネルギー依存性
5）照射損傷の影響　　6）イオン誘起脱離

＊　東北大学

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# 1. Introduction

Data on trapping and re-emission of hydrogen isotopes and helium are needed for controlled fusion research. Re-emission refers to the emission of gas from target is being bombarded by the projectile ions; the re-emission rate is generally measured by the rise in partial pressure of the projectile species as monitored in the vessel which contains target. And, trapping refers to the fraction of the incident flux which is retained in the target; this is generally determined by a direct measure of the retained projectile density. The experimental data as a function of fluence is typically given as the re-emission rate(R), expressed as a fraction of the incident flux($J_i$), or as trapping coefficient($\eta$), where $\eta \equiv 1 - R$, or as total retention(n), where $n = \int \eta(J_i)dJ_i$.

A survey has been made of the literatures upto end of 1982, by dividing it into following 6 sections: 1) Dose Dependence, 2) Target Material Dependence, 3) Target Temperature Dependence, 4) Incident Energy Dependence, 5) Damage Effects and 6) Ion-Induced Release.

The experimental data compiled in the present report are stored in the AMSTOR system of JAERI, and further addition of new data is in progress. The references for each experimental data are shown in the figures, and all the literatures concerning trapping and re-emission of hydrogen isotopes and helium are listed chronologically and alphabetically in each year at the end of the report.

The authors are grate ful to Dr. T. Shirai for his cooperation on the AMSTOR system.

# 2. Data

## 2.1 Dose Dependence

Retention studies in Be, Ni, Mo and Ta exposed to energetic deuteron are shown in Figs. 1, 2, 3, 4 and 5. The rate of re-emission in Ni and Ta are shown in Figs. 6 and 7. In these figures, the both quantities are plotted as a function of incident fluences.

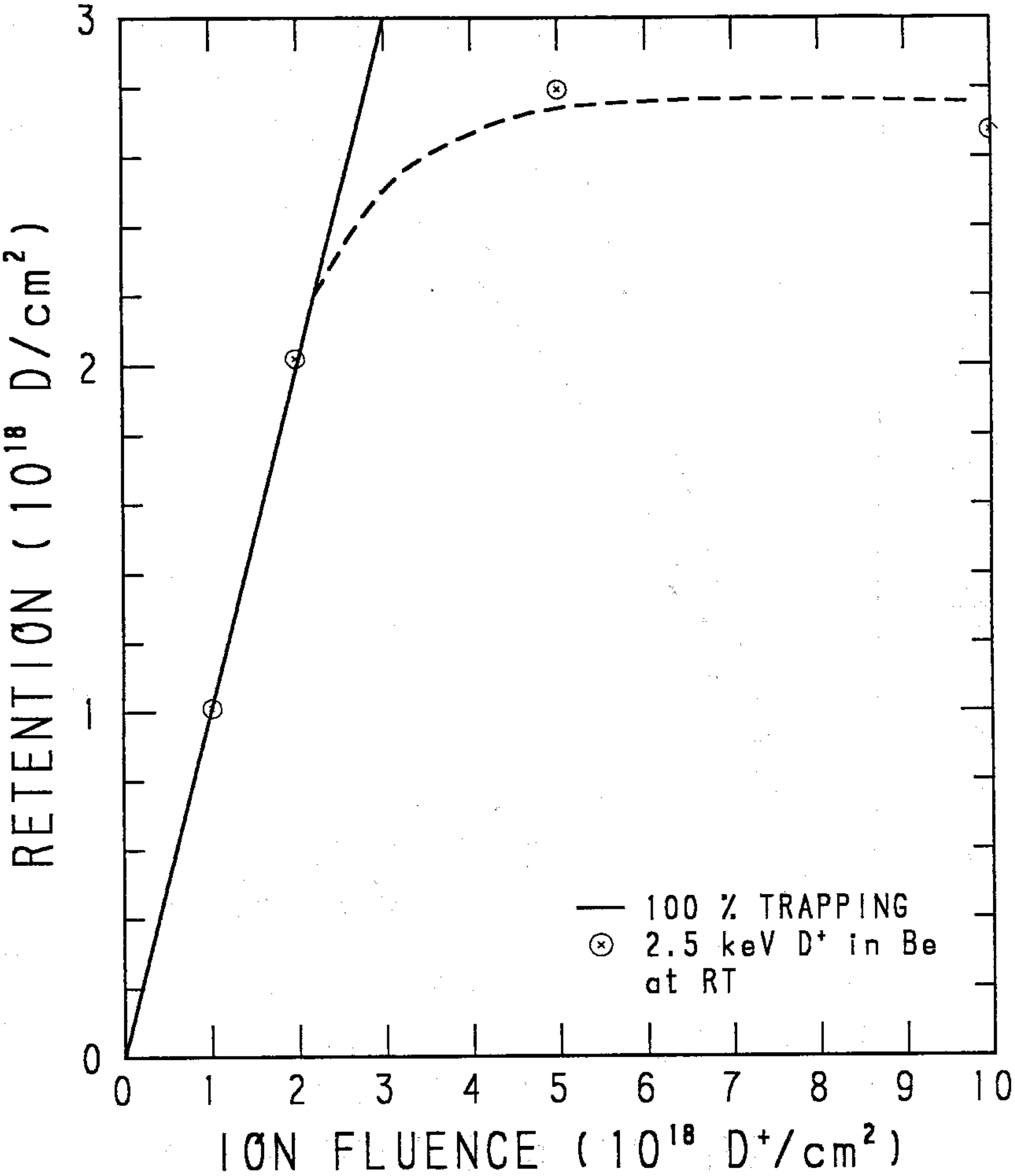


Fig. 1 Amount of deuterium trapped in surface layer of Be as a function of primary ion fluence. (ref. 46)

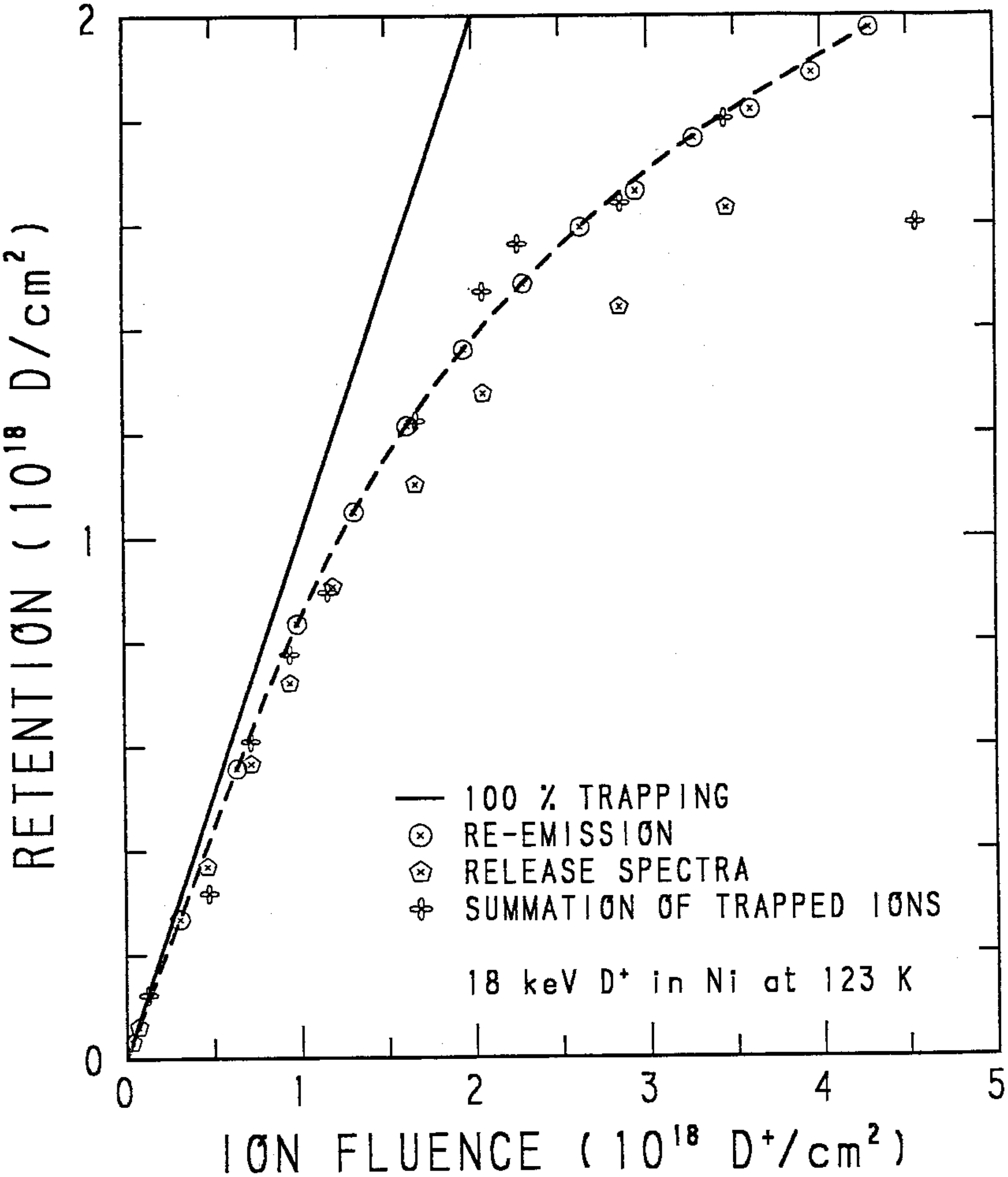


Fig. 2 Comparison of results for deuterium trapped in Ni from re-emission during bombardment, and from thermal release spectra. (ref. 4)

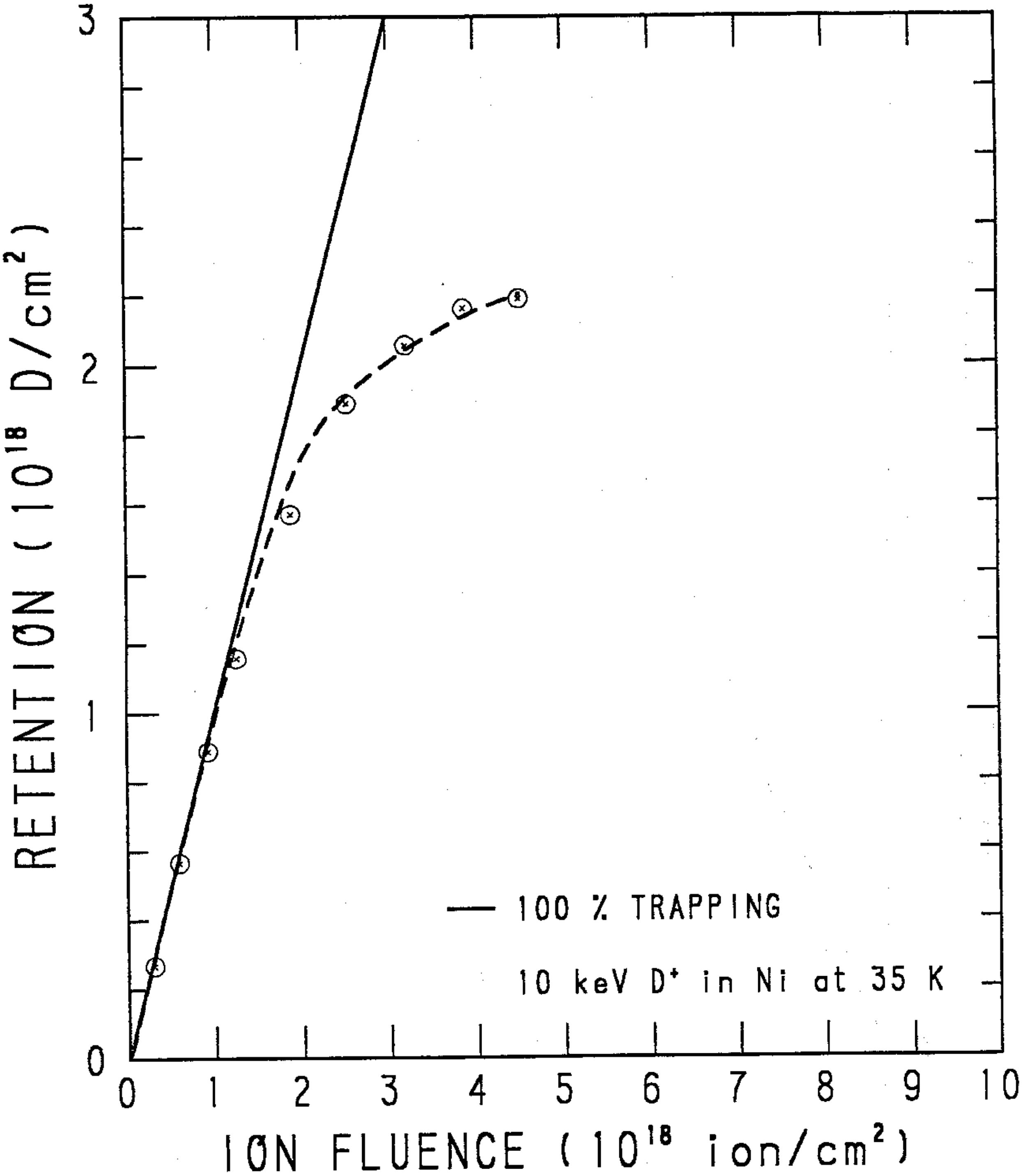


Fig. 3 Retention curve for deuteron bombardment of Ni. (ref. 94)

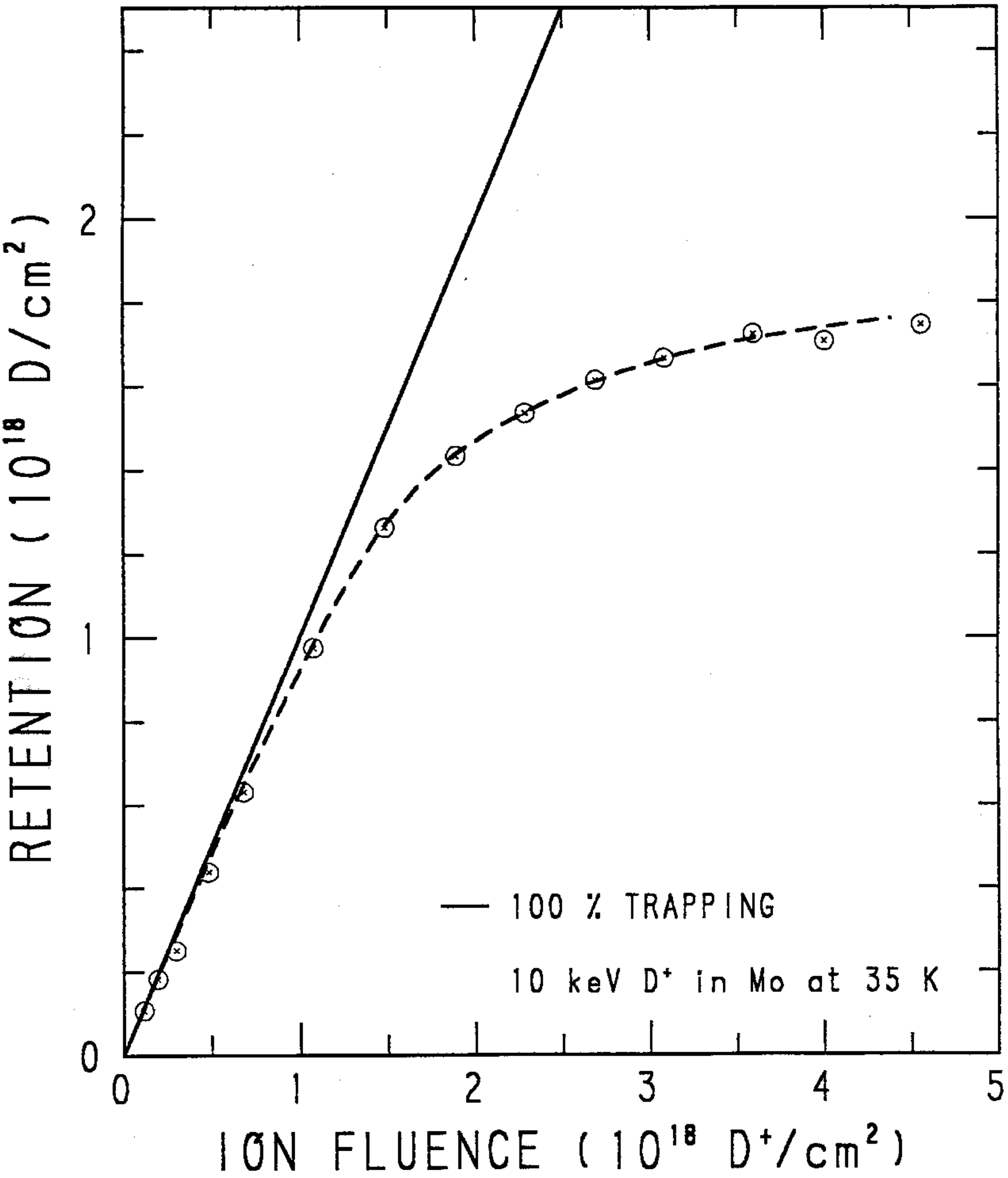


Fig. 4 Retention curve for deuteron bombardment of Mo. (ref. 94)

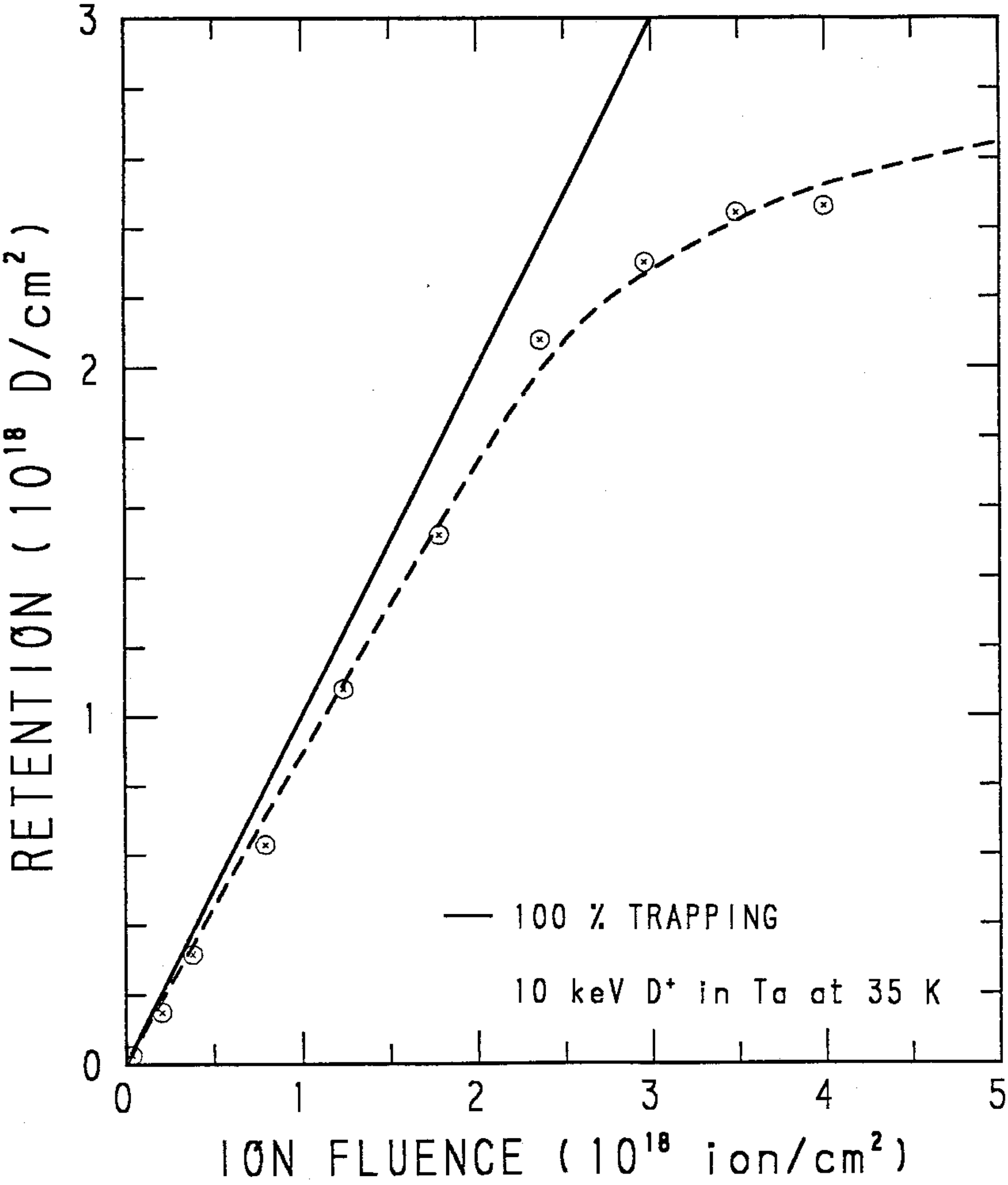


Fig. 5 Retention curve for deuteron bombardment of Ta. (ref. 94)

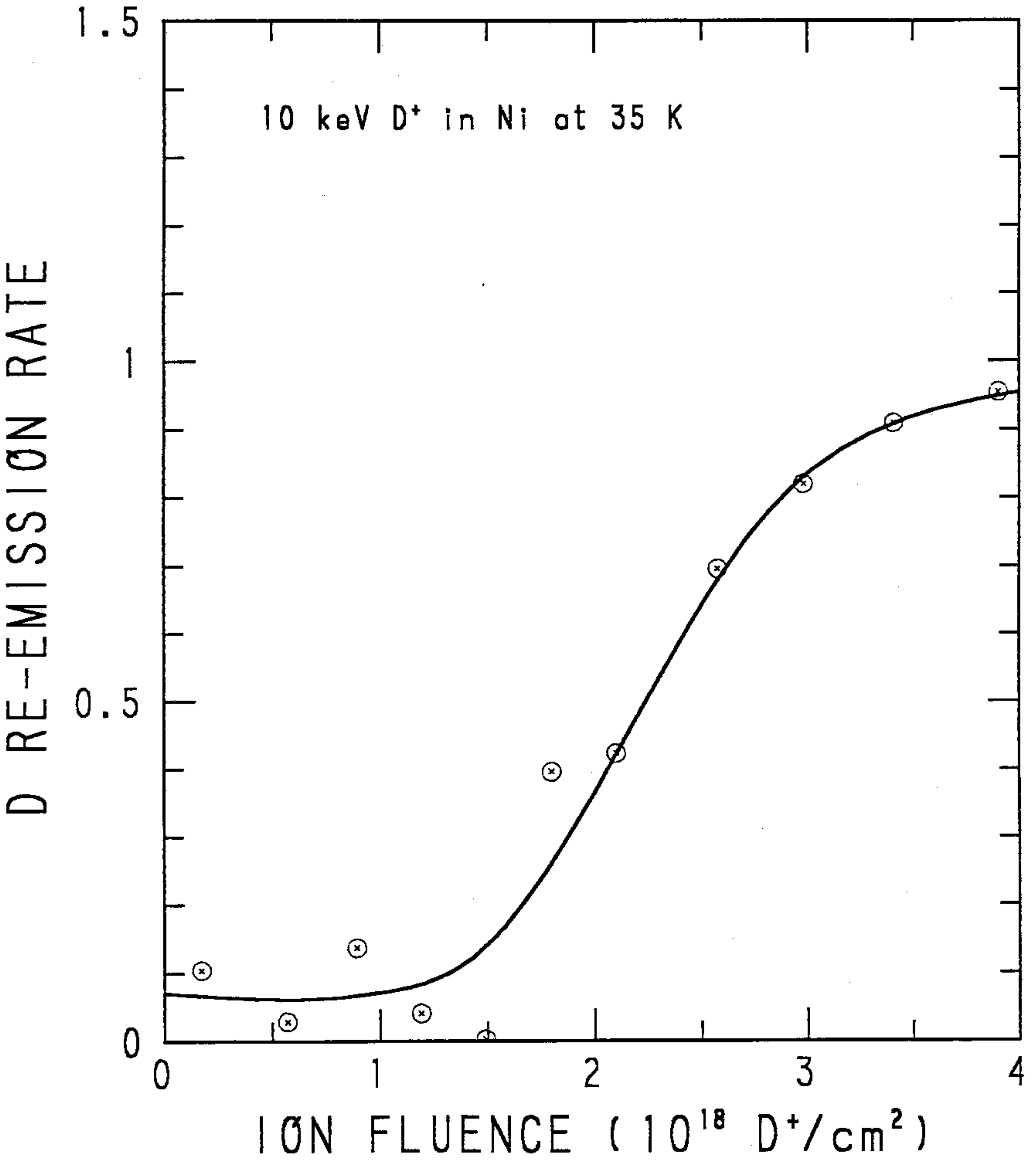


Fig. 6 Re-emission rate for Ni bombarded with 10 keV $D^+$. (ref. 63)

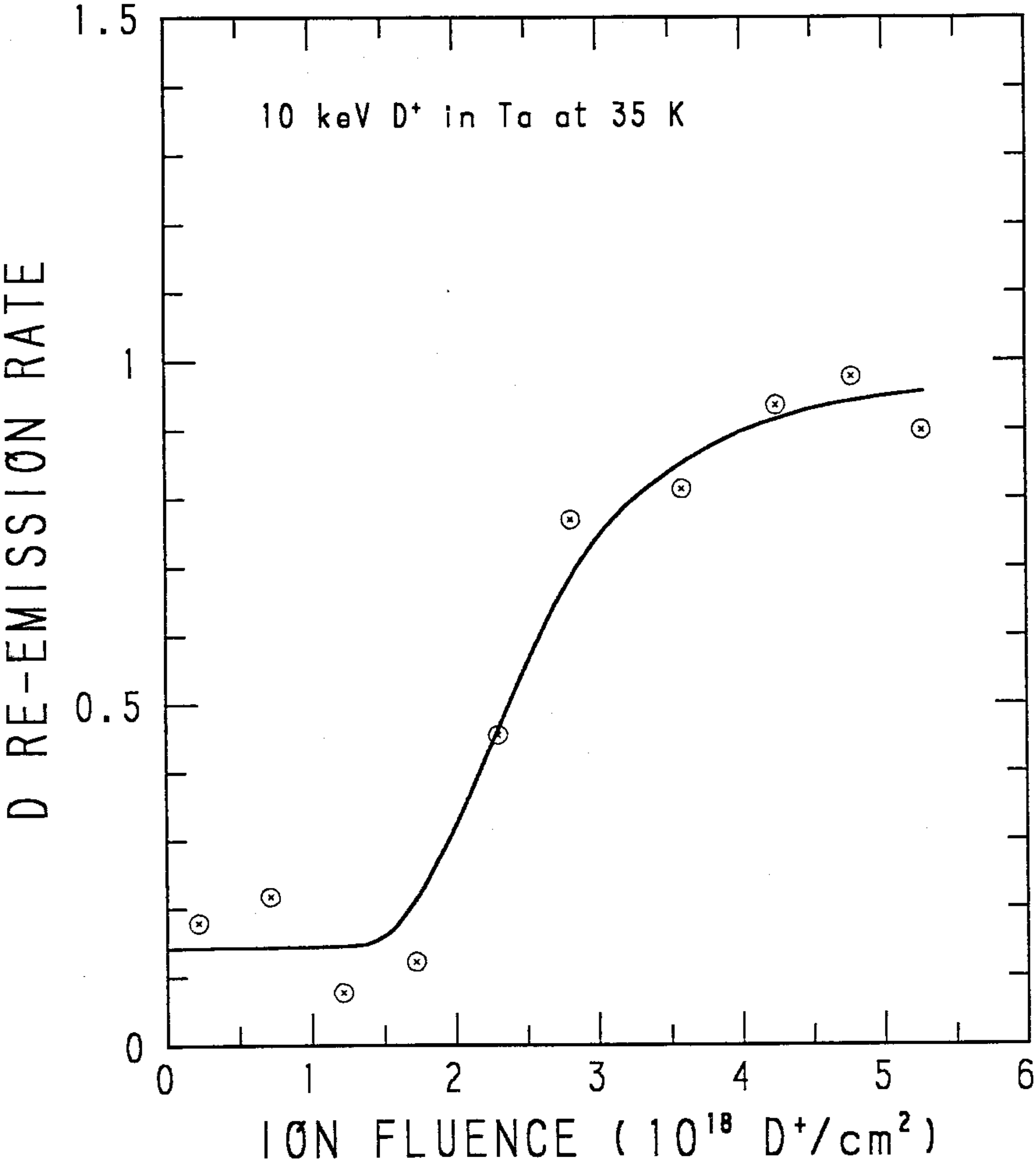


Fig. 7 Re-emission rate for Ta bombarded with 10 keV $D^+$. (ref. 63)

## 2.2 Target Material Dependence

The rate of re-emission from various stainless steels and low-Z materials are shown in Figs. 8 and 9 as a function of incident fluence, respectively.

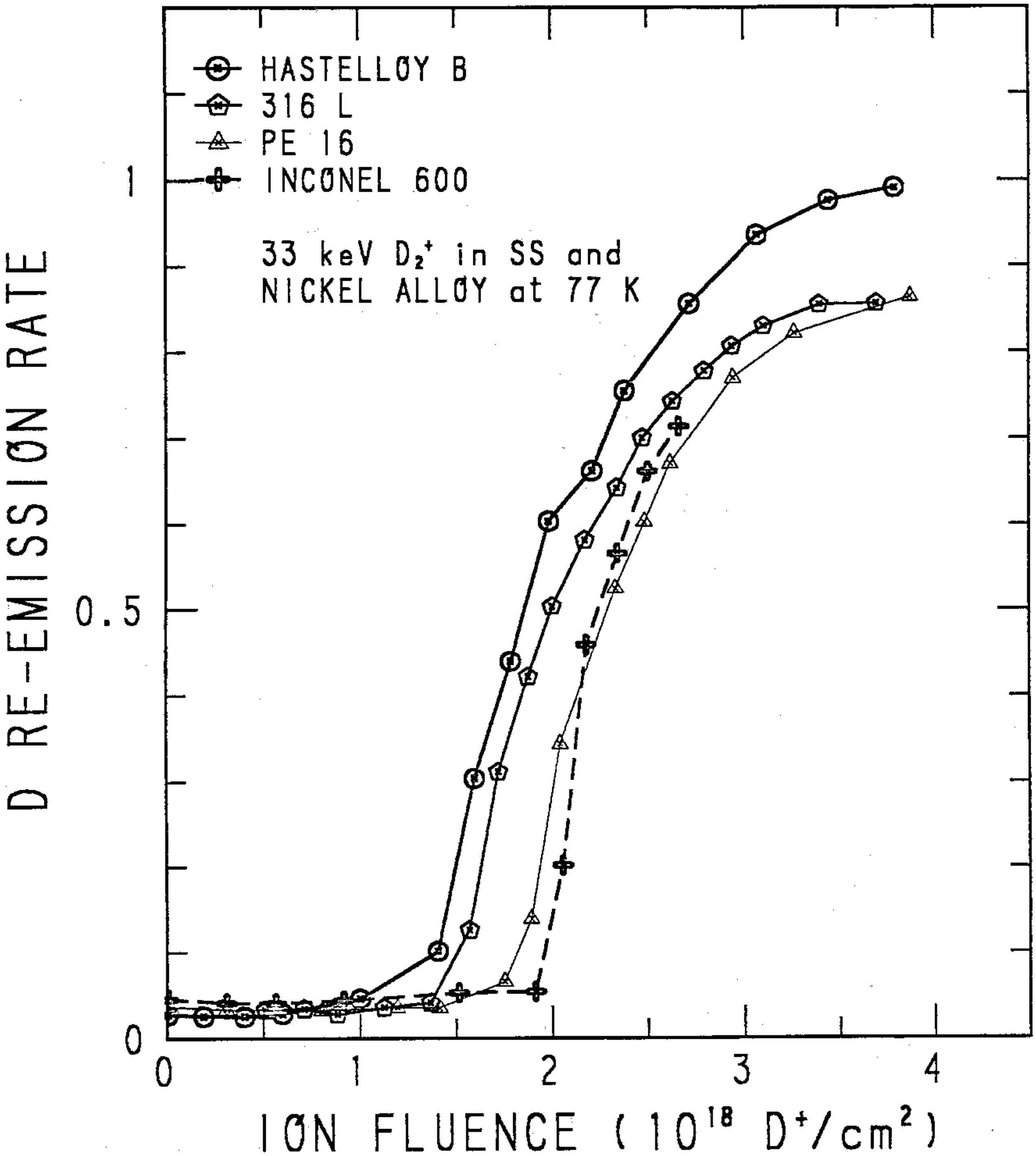


Fig. 8 Re-emission rate of $D_2$ during 33 keV $D^+$ bombardment of various stainless steels and nickel-based alloys at 77 K. (ref. 65)

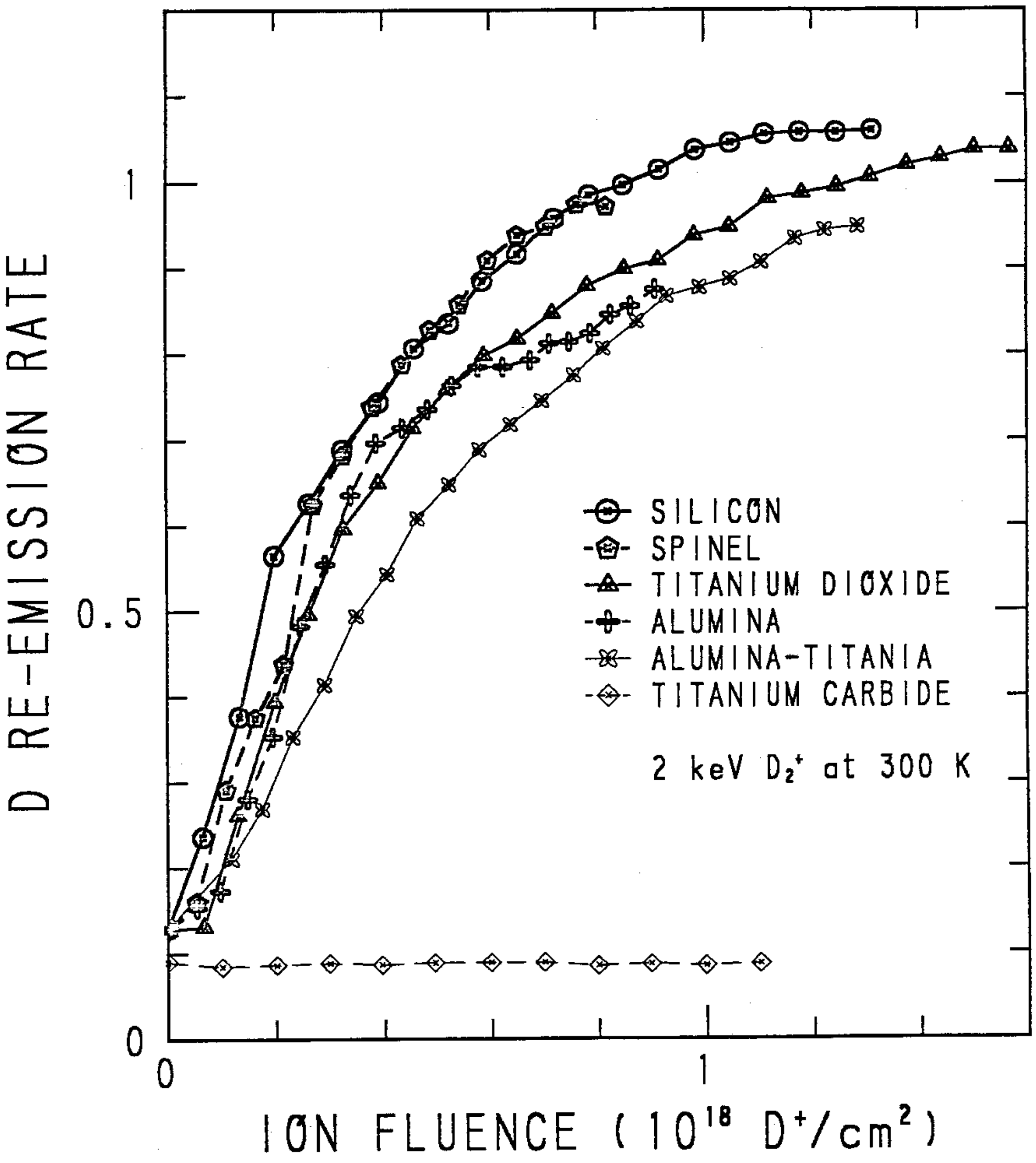


Fig. 9 Re-emission rate of $D_2$ as a function of deuteron fluence for 2 keV $D_2^+$ bombardments at 300 K. (ref. 91)

## 2.3 Target Temperature Dependence

Temperature dependence of re-emission rate during hydrogen bombardment have been measured on several materials such as carbon (Figs. 10 and 11), stainless steel (Fig. 12), Ni (Fig. 13), Mo (Fig. 14), SiC (Fig. 15), TiC (Fig. 16) and $TiO_2$ (Fig. 17). Trapping coefficient for Ti and Nb at various temperature are shown in Figs. 18 and 19, respectively. Temperature dependence of retention curve in stainless steel is exhibited in Fig. 20.

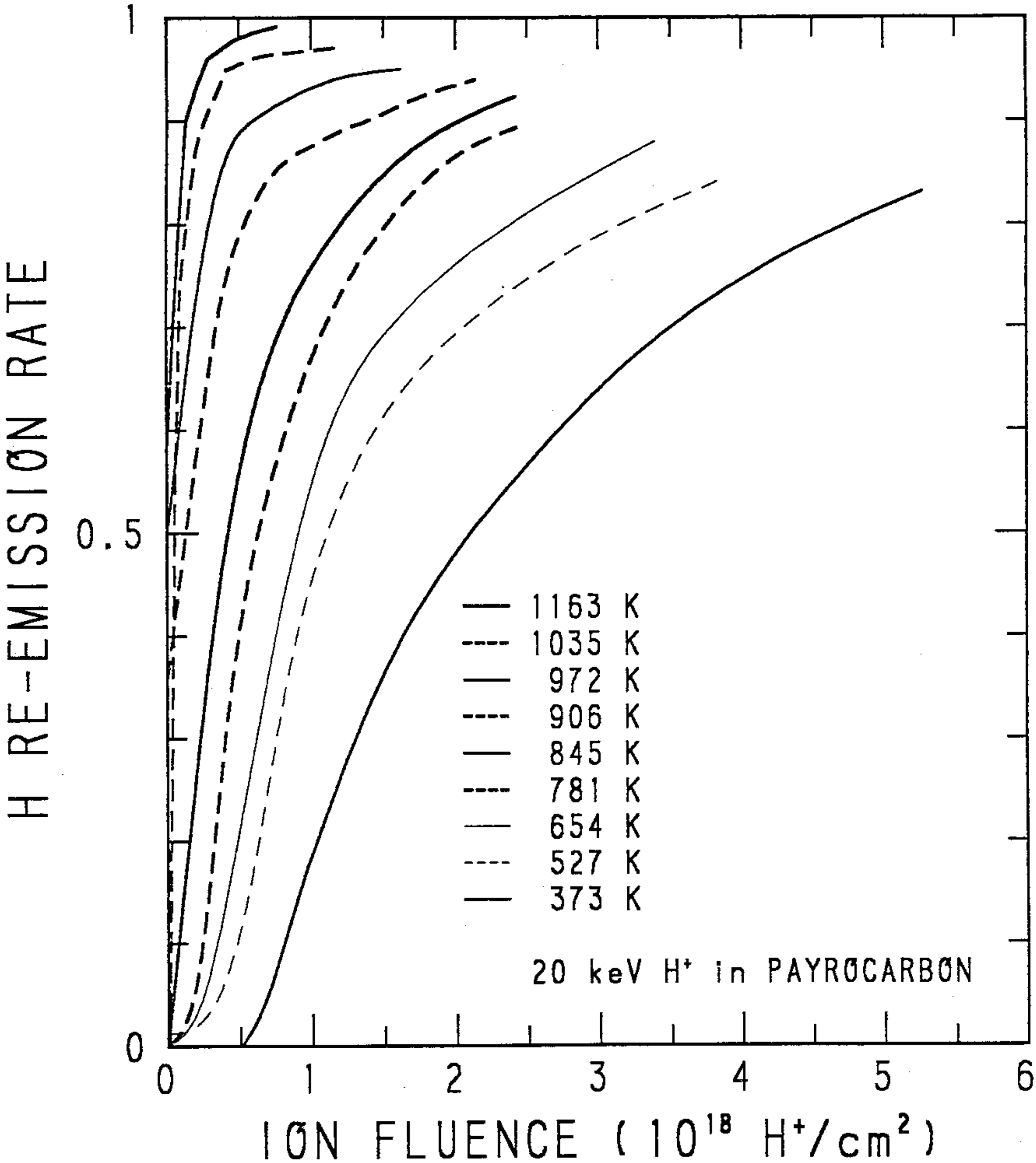


Fig. 10 Re-emission rate of $H_2$ from pyrocarbon during 20 keV $H^+$ bombardment, at different target temperatures. Dose rate is $4.2 \times 10^{15}/cm^2 \cdot sec$. (ref. 20).

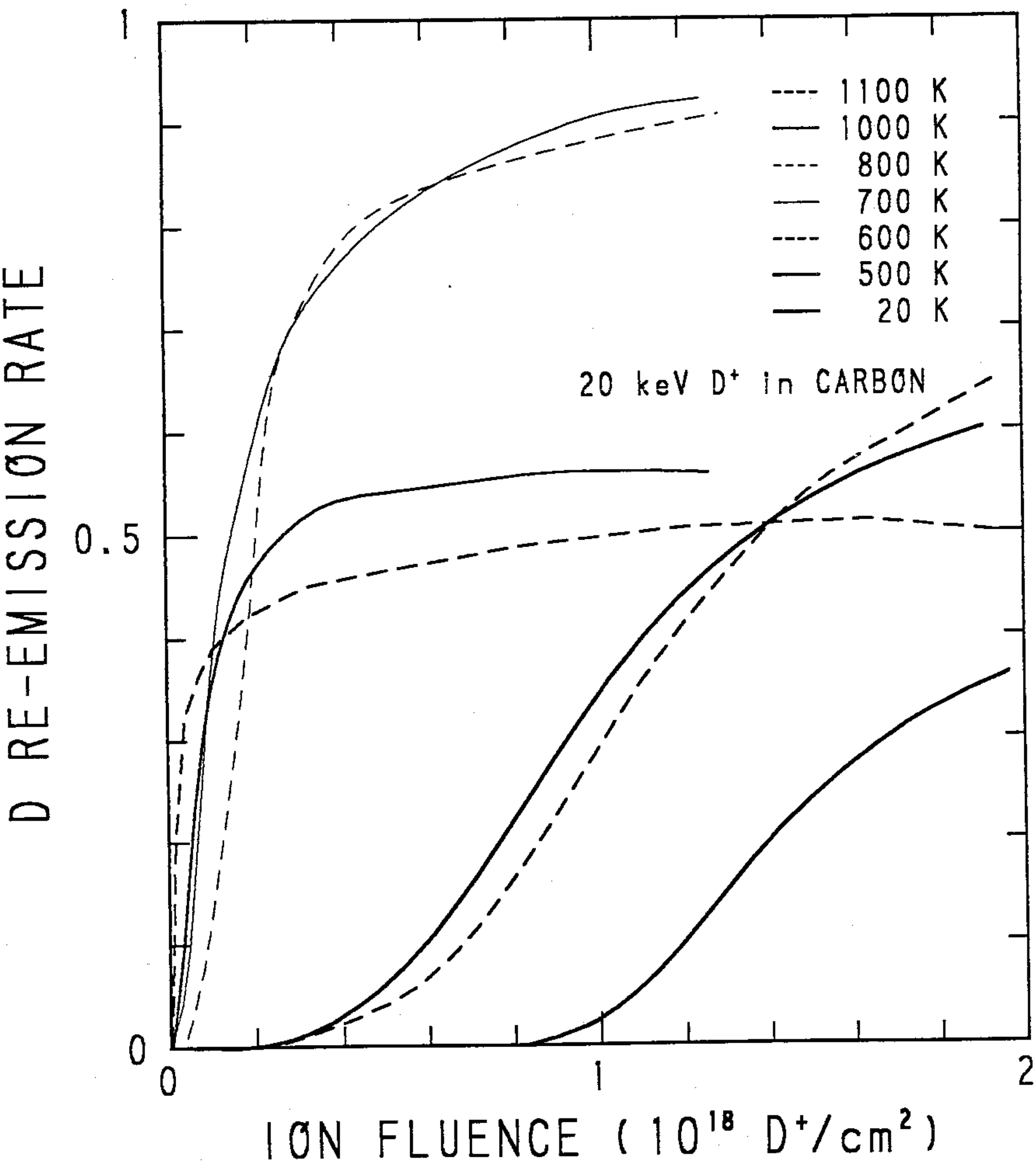


Fig. 11 Deuterium re-emission rate for carbon as a function of incident $D^+$ fluence for various temperatures. (ref. 21)

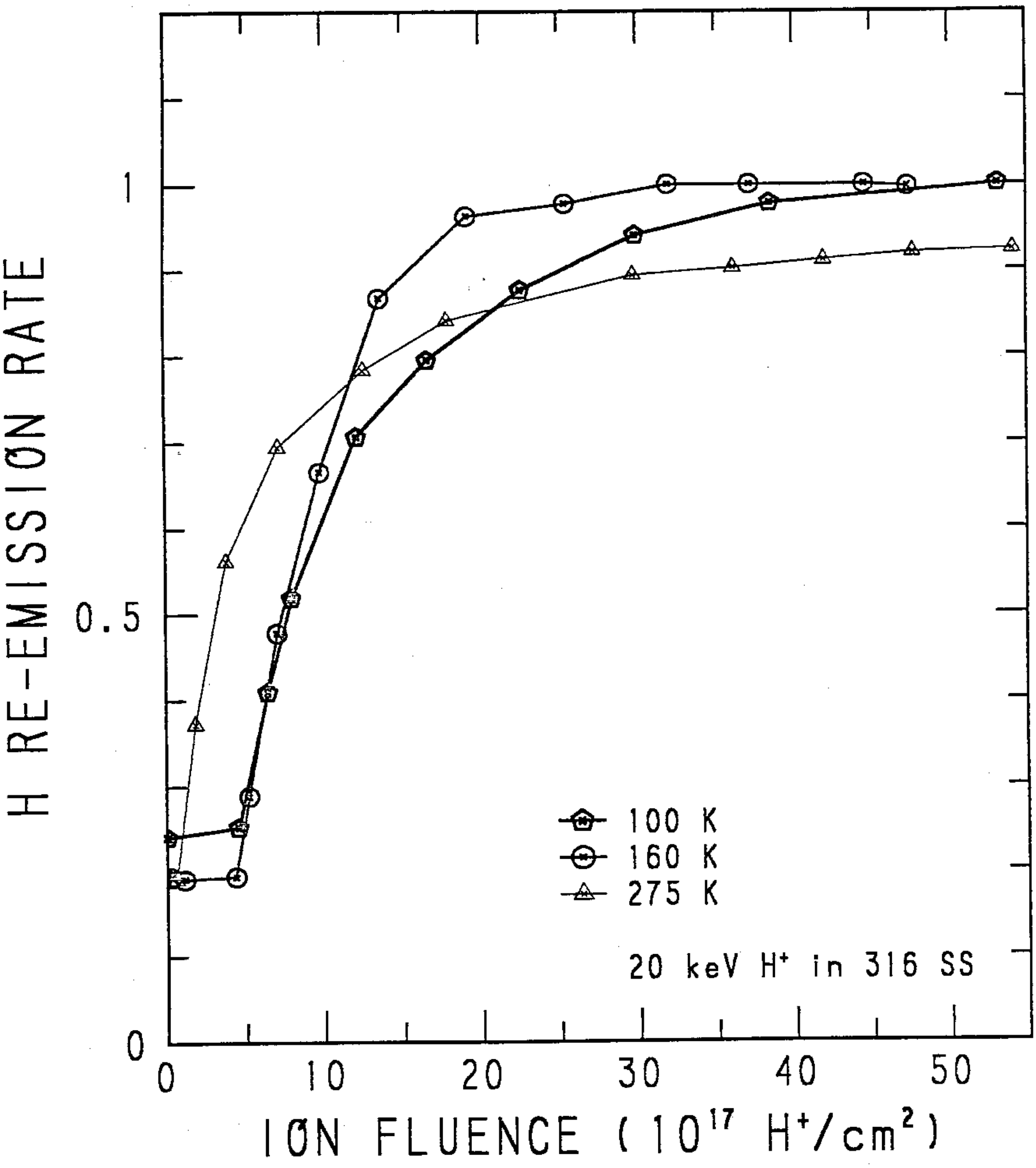


Fig. 12 Hydrogen re-emission rate from mechanically polished 316 stainless steel during 20 keV $H^+$ implantation as a function of fluence at three implantation temperatures. (ref. 27)

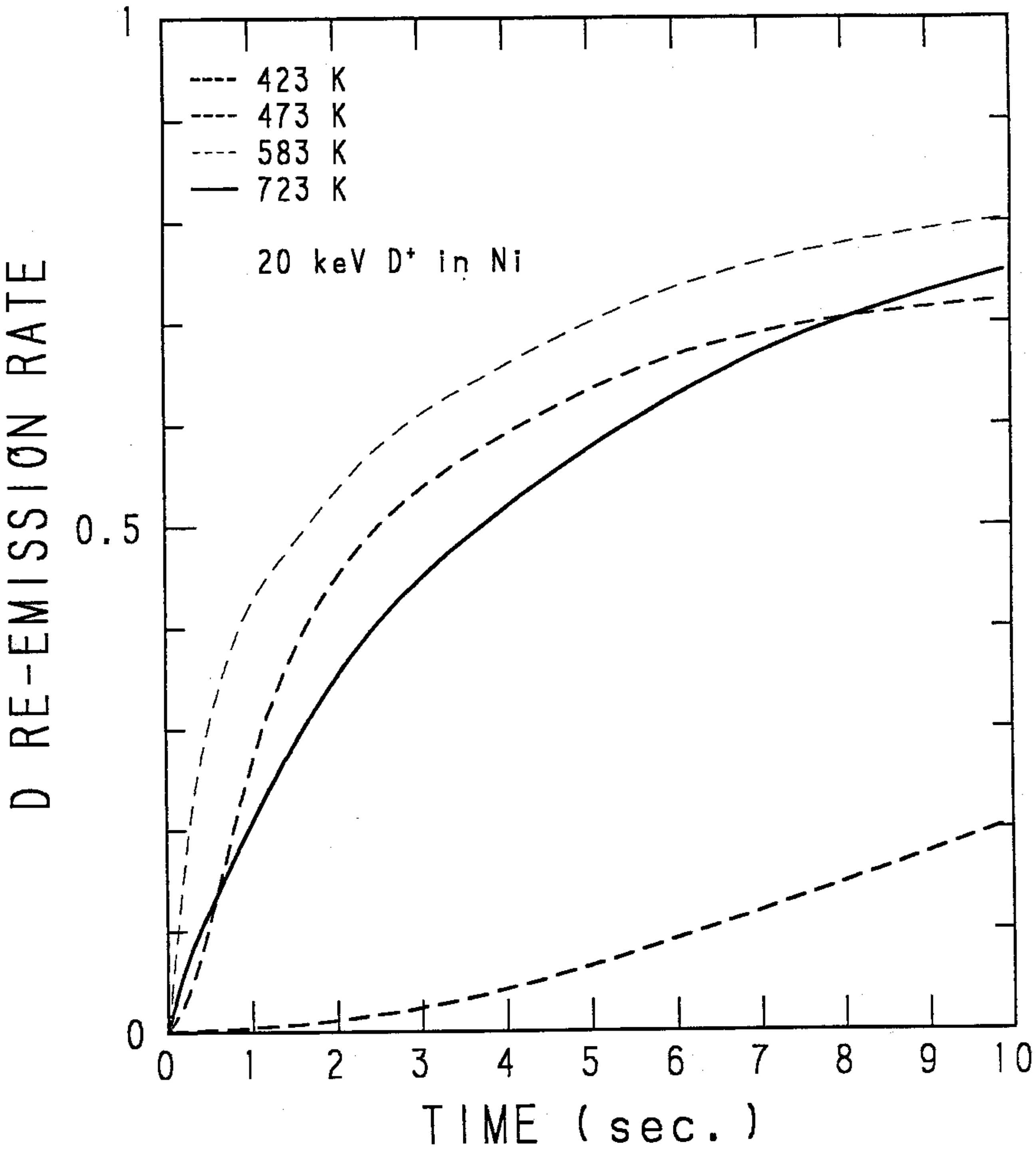


Fig. 13 Re-emission rate of deuterium from Ni during 20 keV $D^+$ implantation. (ref. 81)

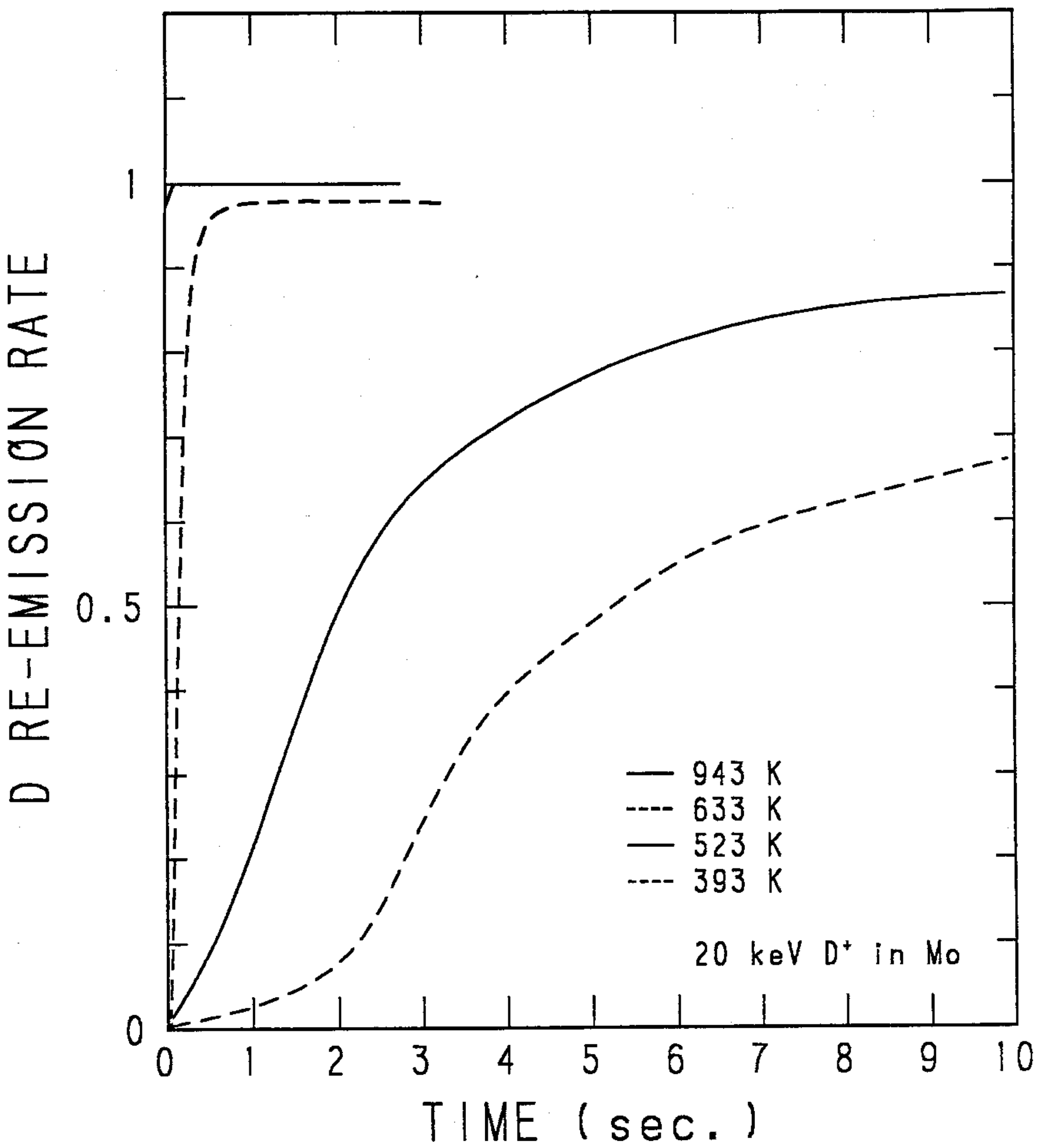


Fig. 14 Re-emission rate of deuterium from Mo during 20 keV $D^+$ implantation. (ref. 81)

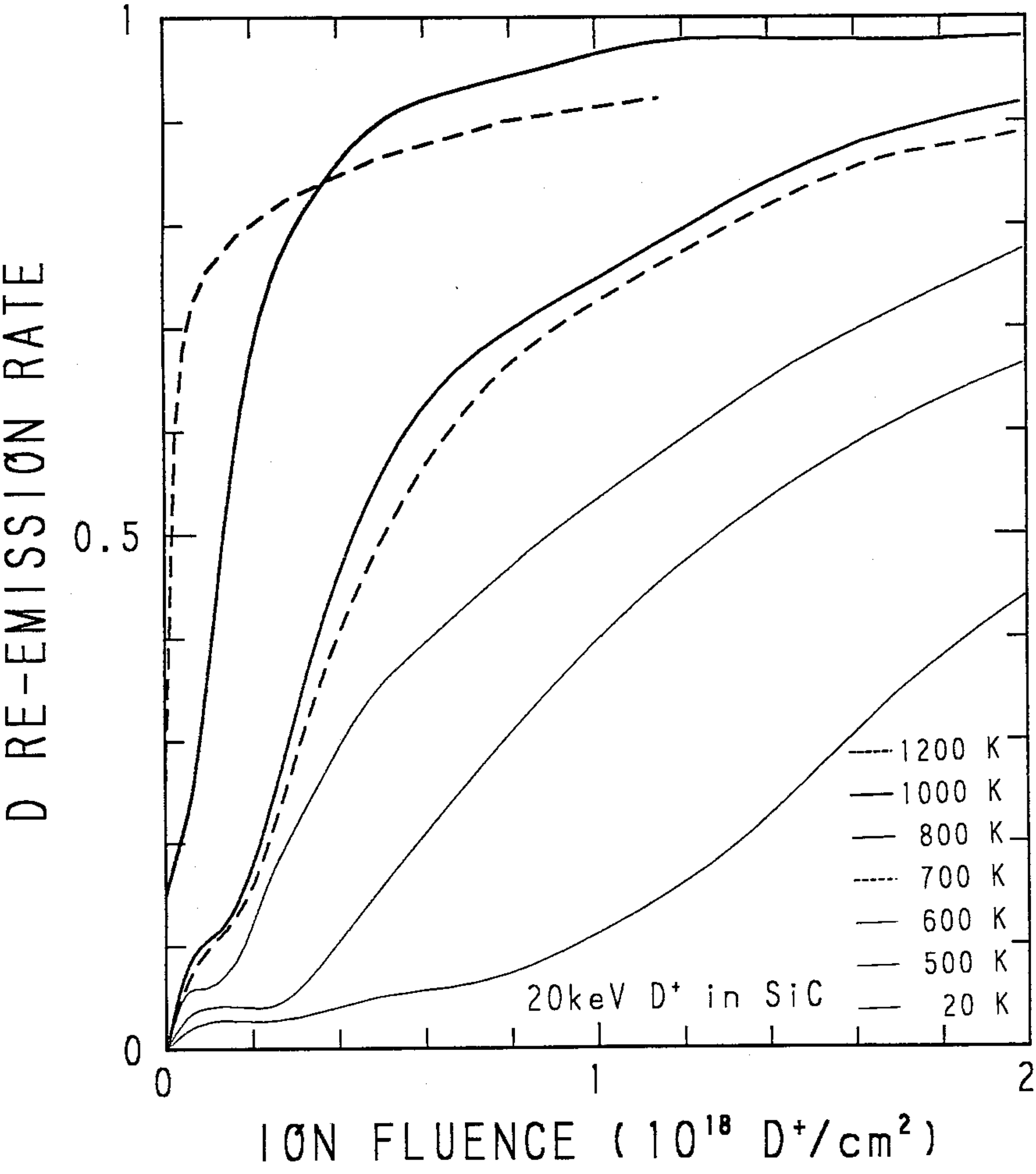


Fig. 15 Deuterium re-emission rate for SiC as a function of incident $D^+$ fluence for various temperatures. (ref. 21)

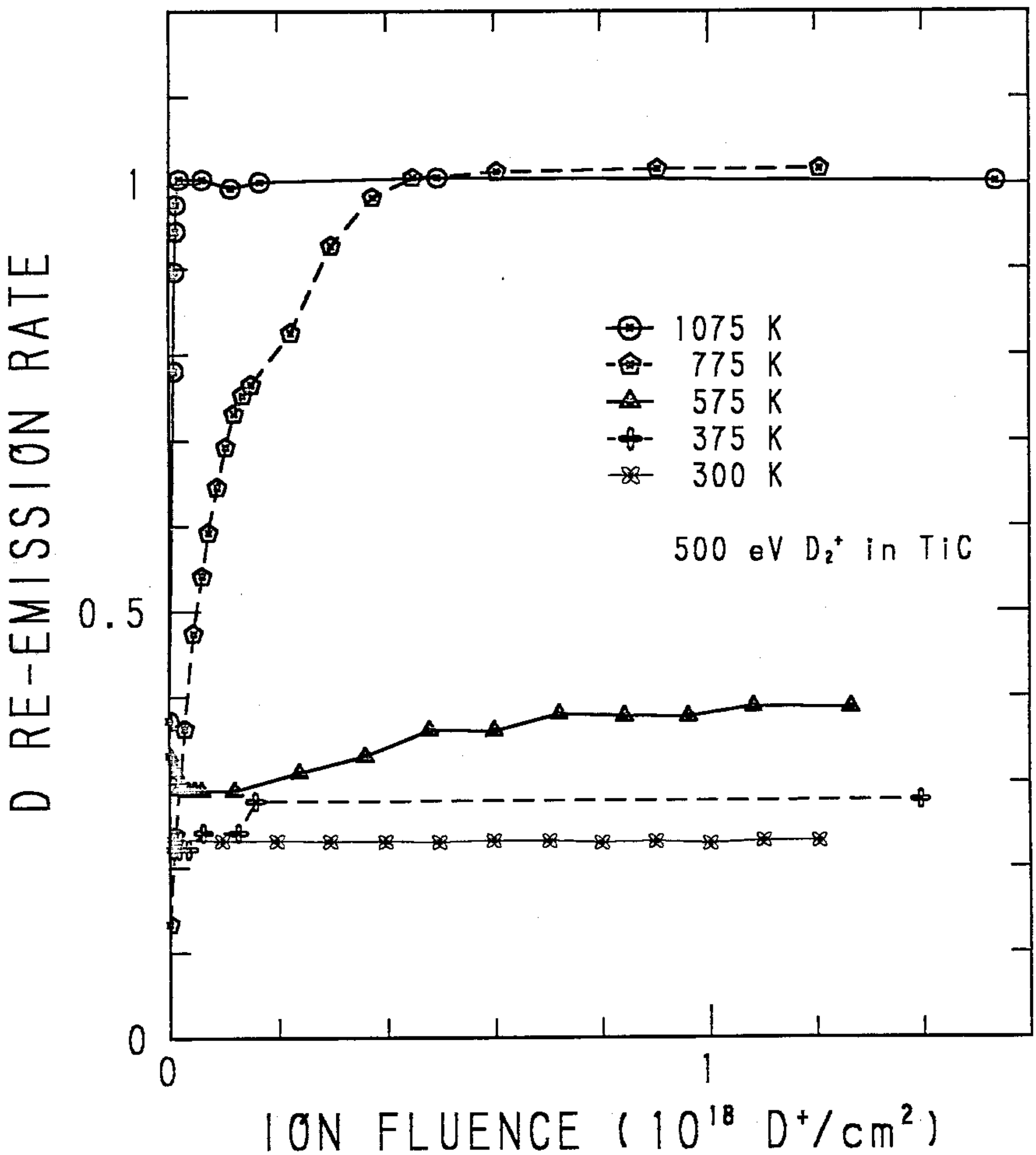


Fig. 16 Deuterium re-emission rate from TiC as a function of implantation temperature during 500 eV $D_2^+$ bombardments. (ref. 91)

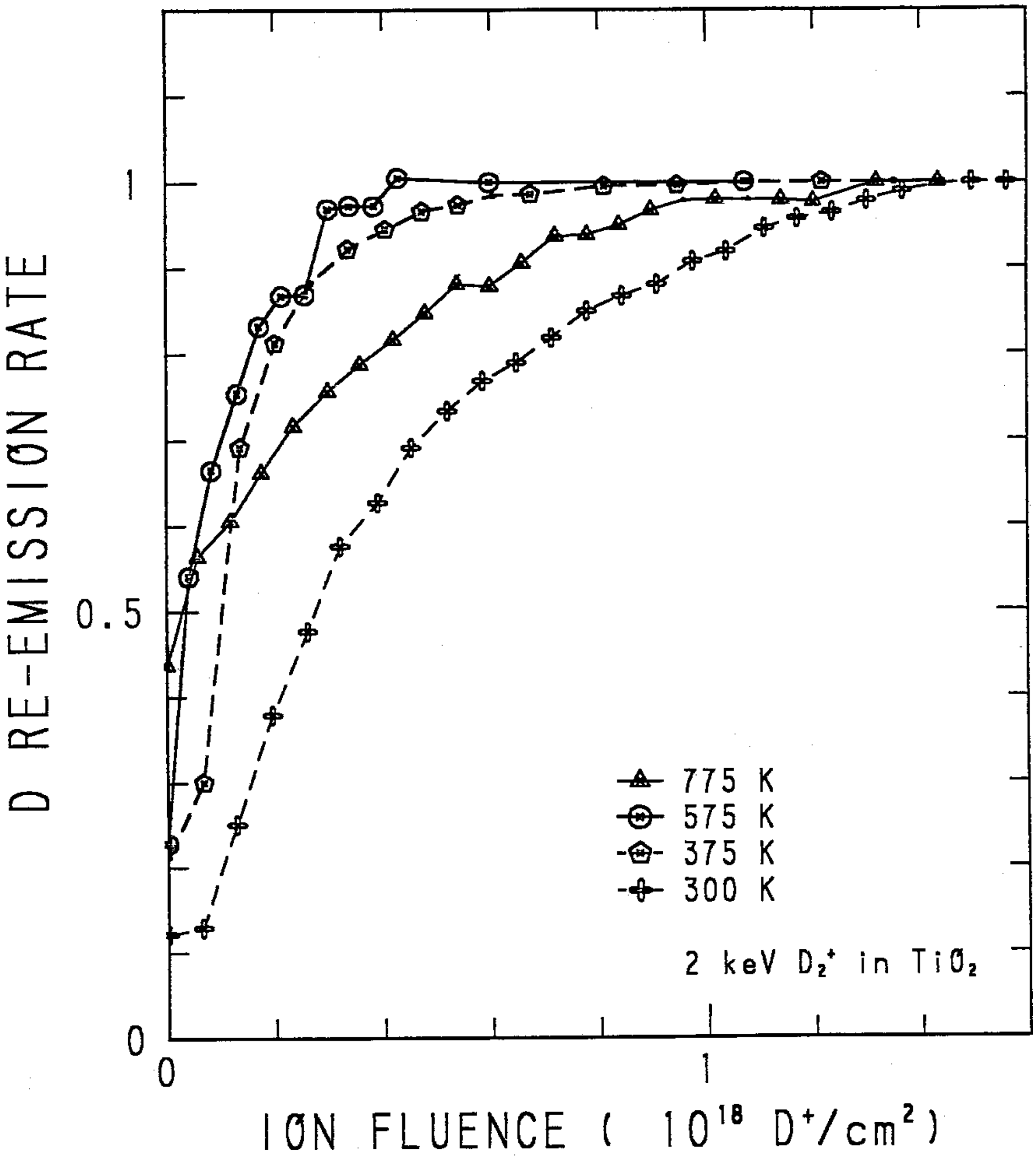


Fig. 17 Deuterium re-emission rate from $TiO_2$ as a function of implant temperature during 500 eV $D_2^+$ bombardments. (ref. 91)

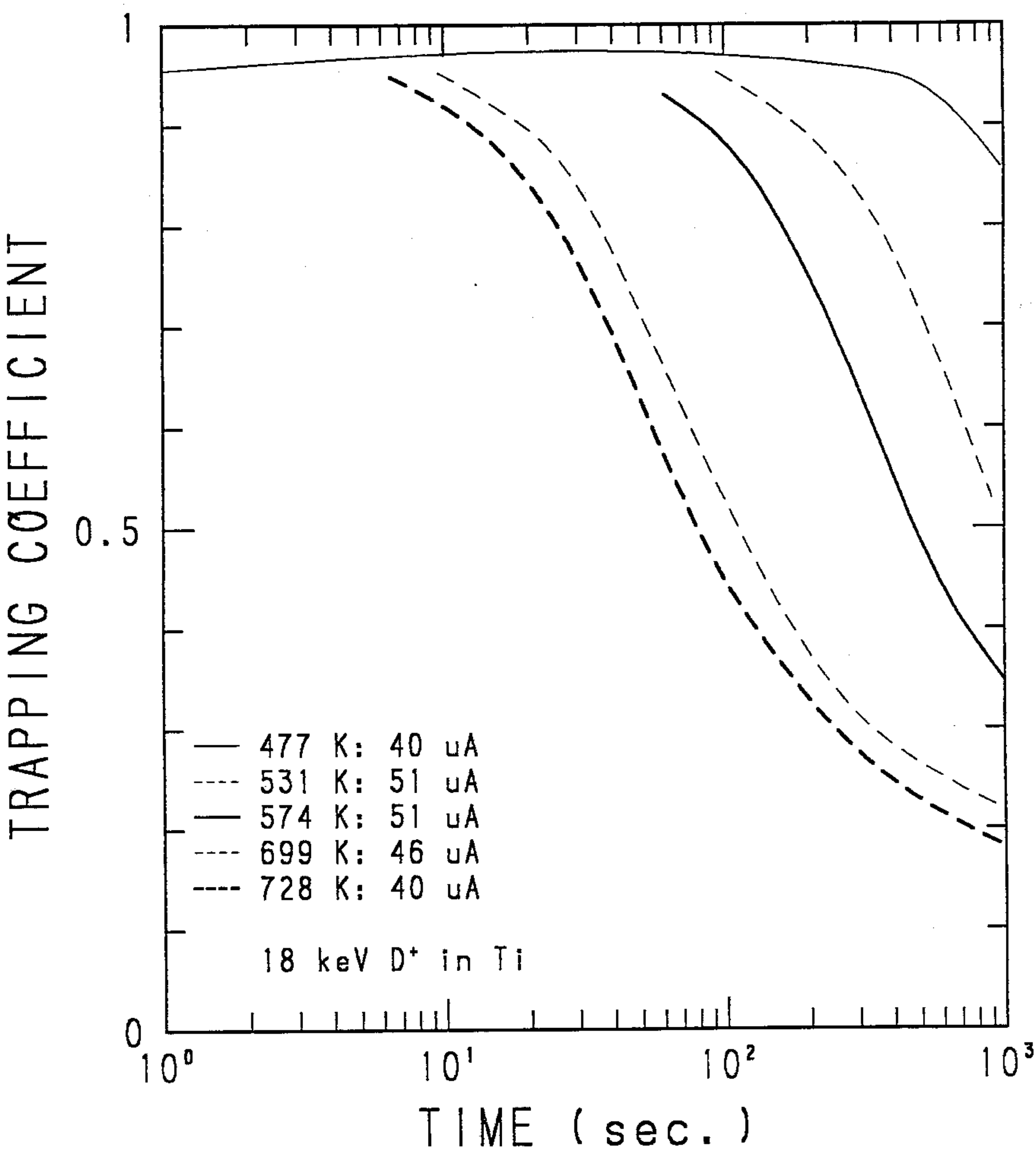


Fig. 18 Trapping coefficient as a function of time for a Ti target bombarded with 18 keV $D^+$. A fraction of 0.03 of the incident beam is assumed to be backscattered. (ref. 29)

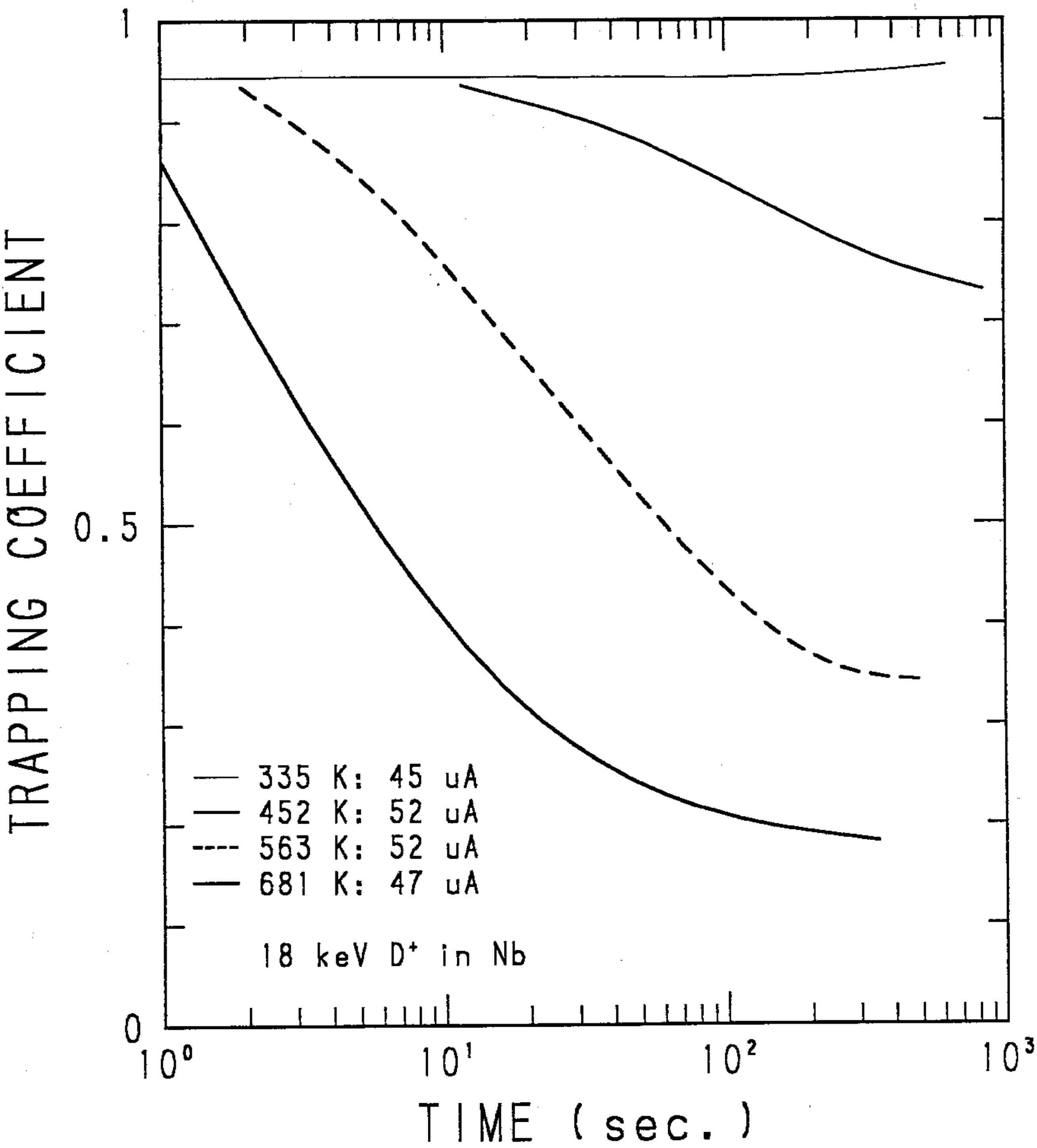


Fig. 19 Trapping coefficient as a function of time for a Nb target bombarded with 18 keV $D^+$. A fraction of 0.06 of the incident beam is assumed to be backscattered. (ref. 29)

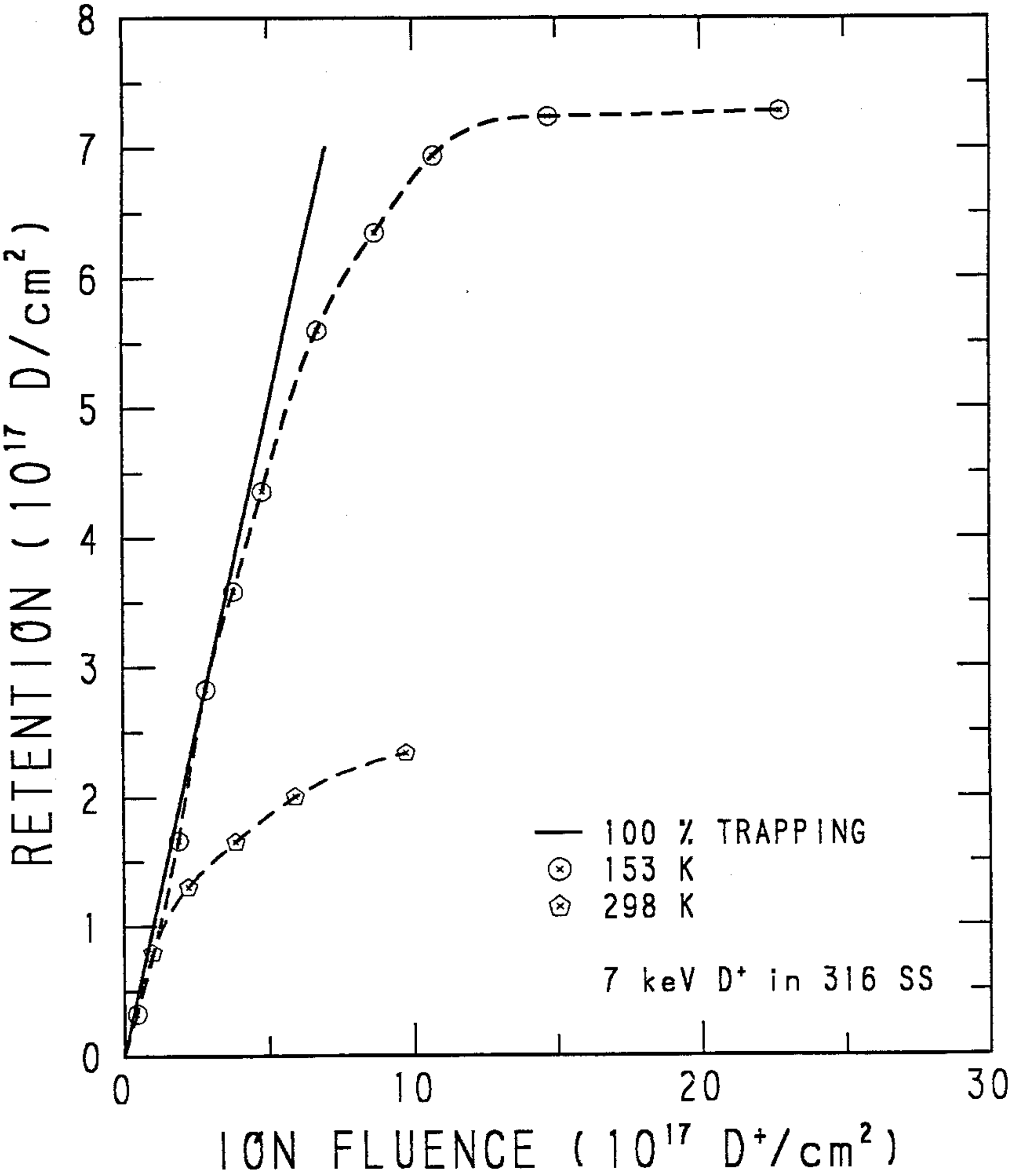


Fig. 20 Areal density of deuterium retained vs. fluence for 7 keV implantation of 316 stainless steel at 153 and 298 K. (ref. 31)

## 2.4 Incident Energy Dependence

Incident energy dependence of re-emission rate during hydrogen bombardment have been measured on several materials such as stainless steel (Figs. 21, 22 and 23), carbon (Fig. 24), alumina (Fig. 25) and TiC (Fig. 26). Retention curves for different projectile energies were measured in carbon (Fig. 27) and Si (Fig. 28).

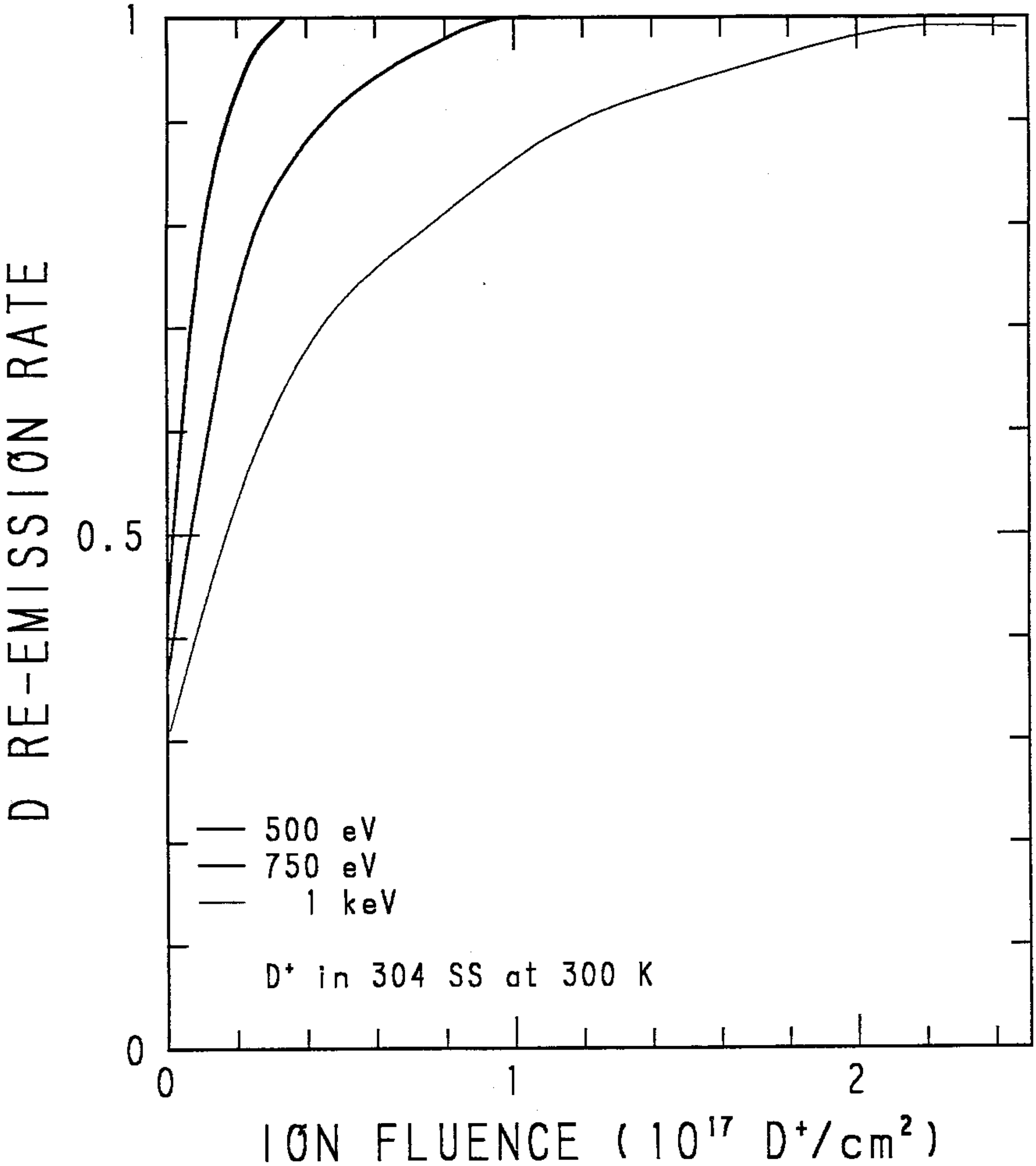


Fig. 21 Re-emission rate of deuterium from stainless steel bombarded by $D^+$ ions of various energies; the target temperature is 300 K. (ref. 72)

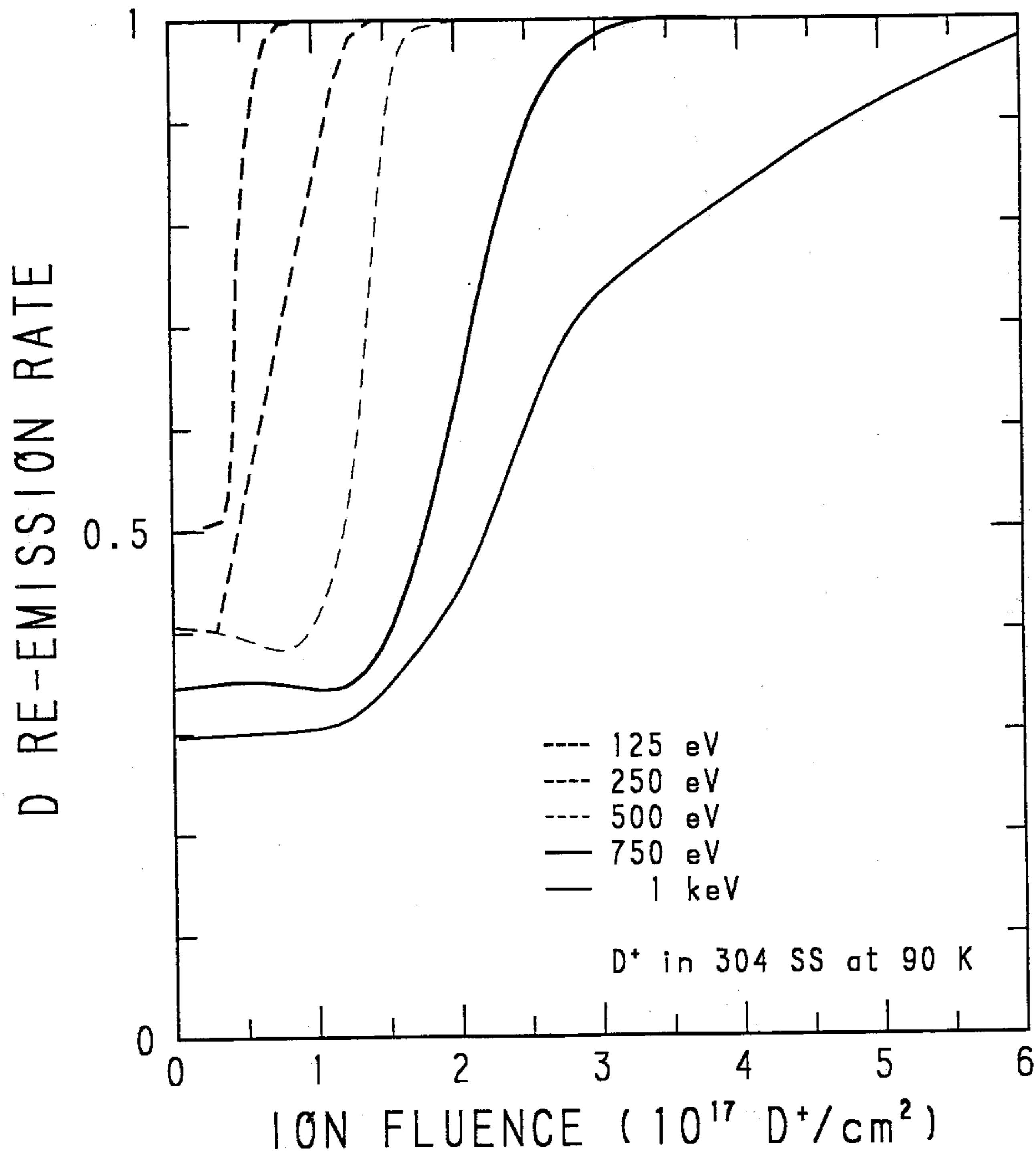


Fig. 22 Re-emission rate of deuterium from stainless steel bombarded by $D^+$ ions of various energies; the target temperature is 90 K. (ref. 72)

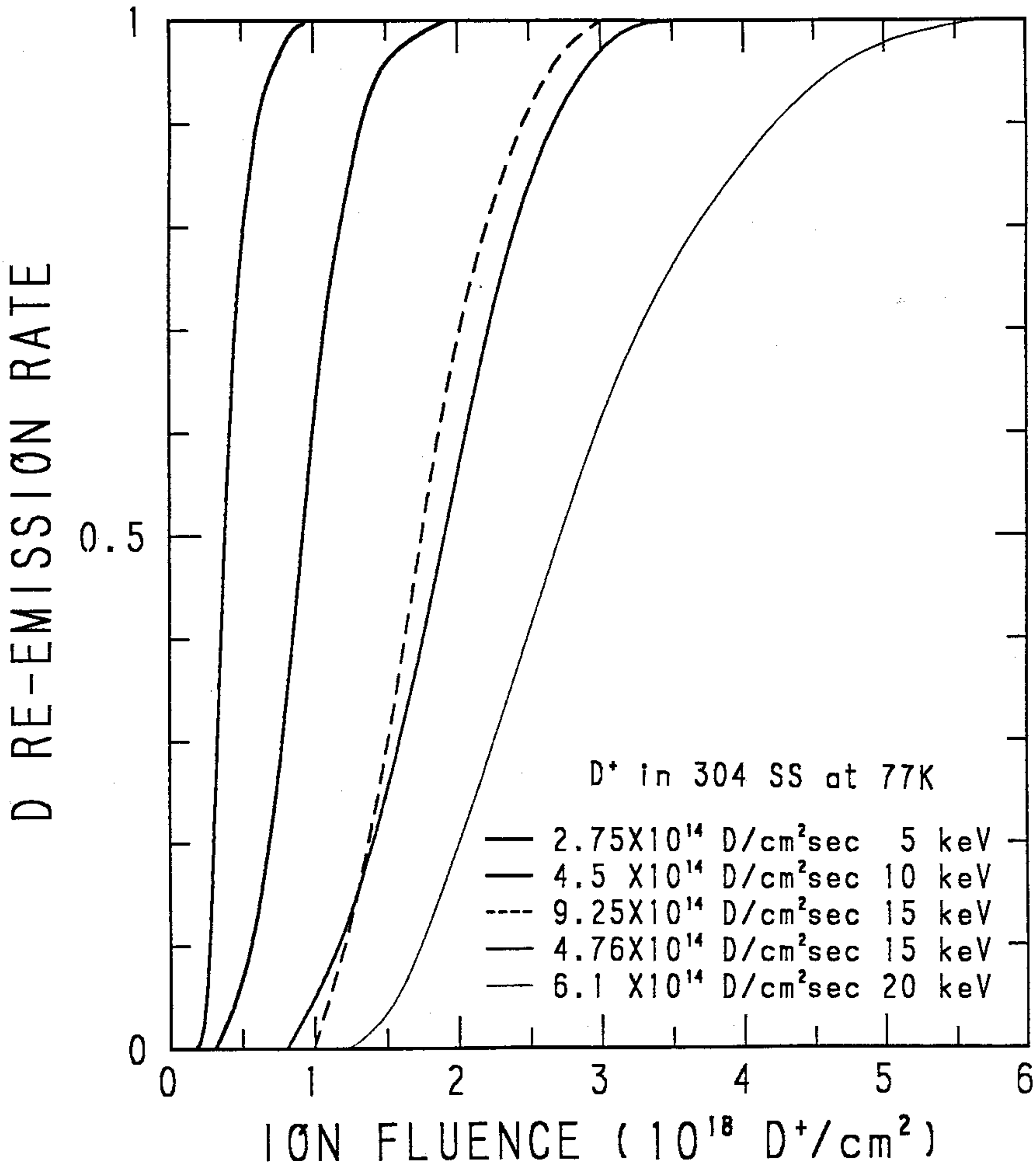


Fig. 23 Re-emission rate of $D_2$ from 304 stainless steel targets during bombardment by deuterons of various energies. (ref. 33)

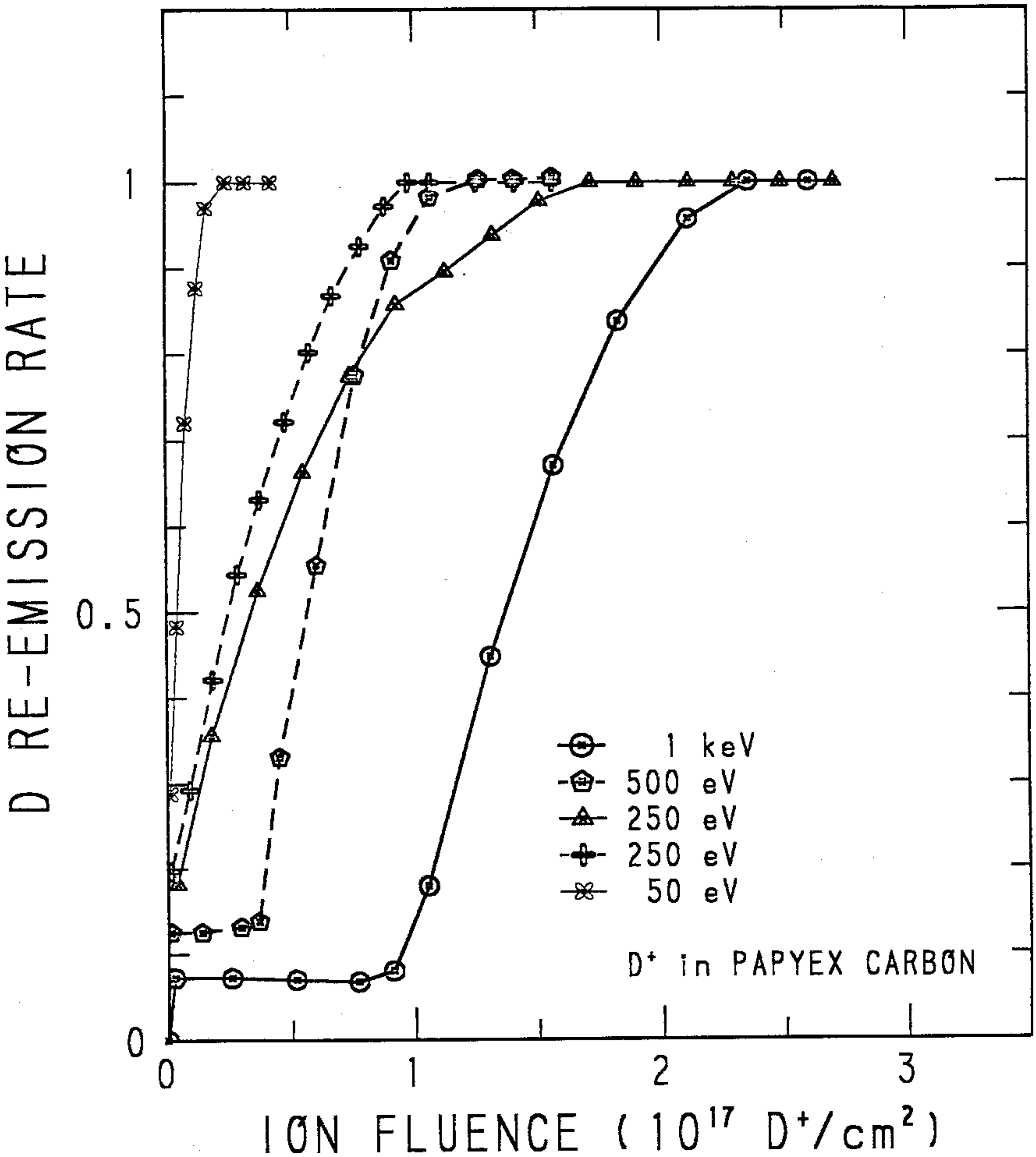


Fig. 24 Re-emission rate of deuterium during implantation in carbon for different energy. (ref. 51)

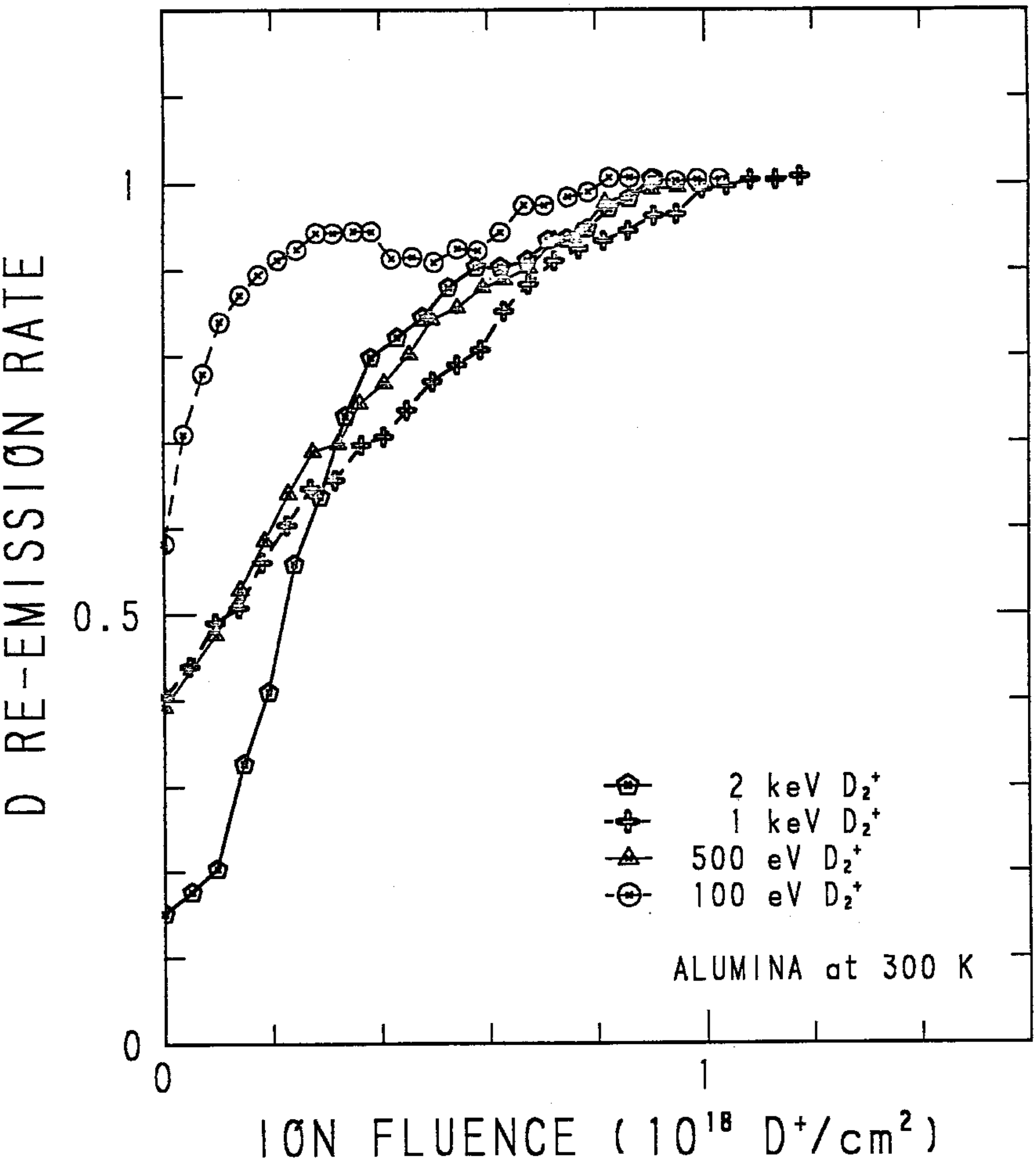


Fig. 25 Re-emission rate from alumina as a function of deuteron fluence; the target temperature is 300 K. (ref. 91)

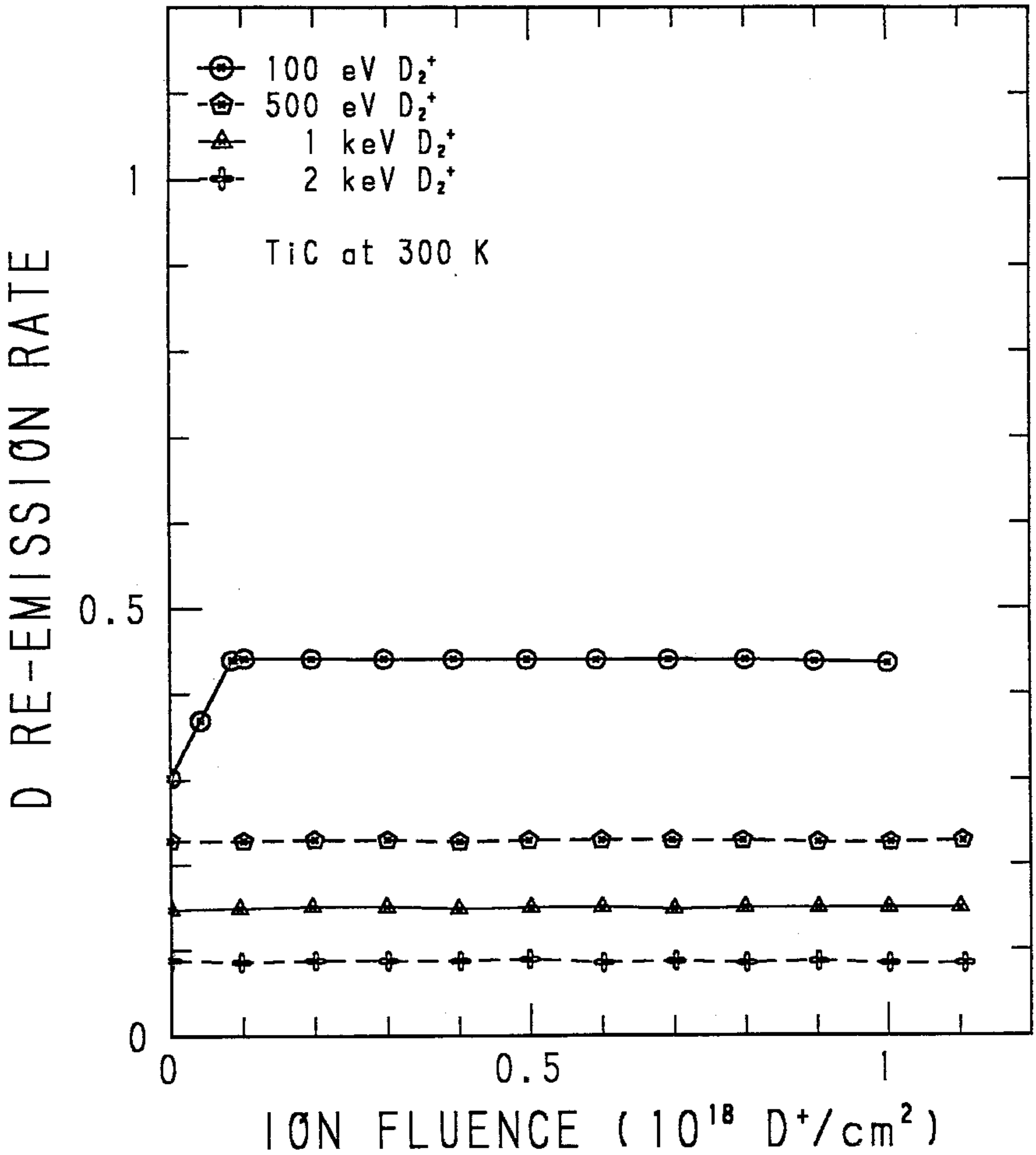


Fig. 26 Beam re-emission from titanium carbide as a function of deuteron fluence; the target temperature is 300 K. (ref. 91)

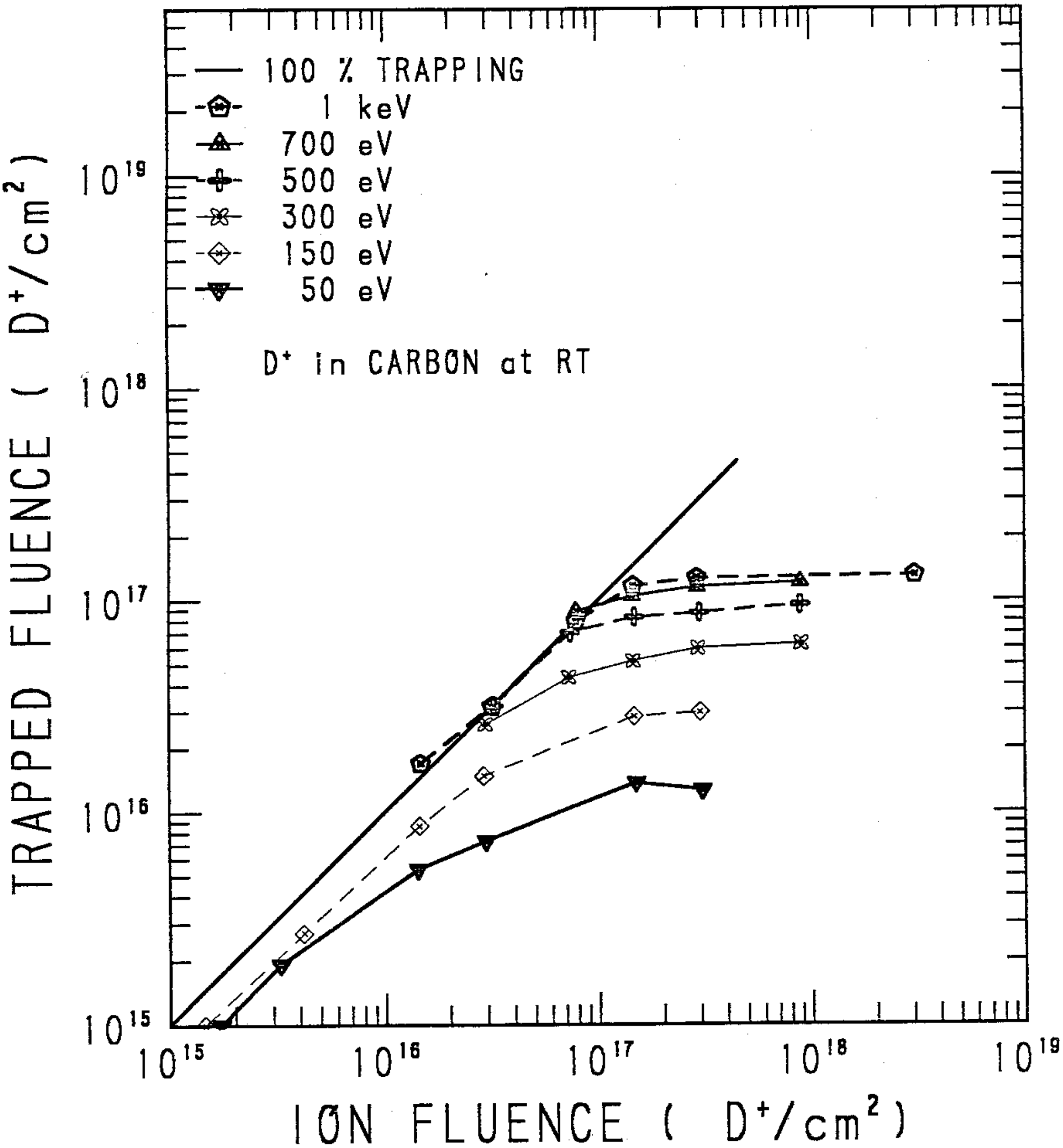


Fig. 27 The amount of deuterium in carbon (Papyex) trapped as a function of the implantation fluence for different implantation energies measured with the nuclear reaction technique. (ref. 51)

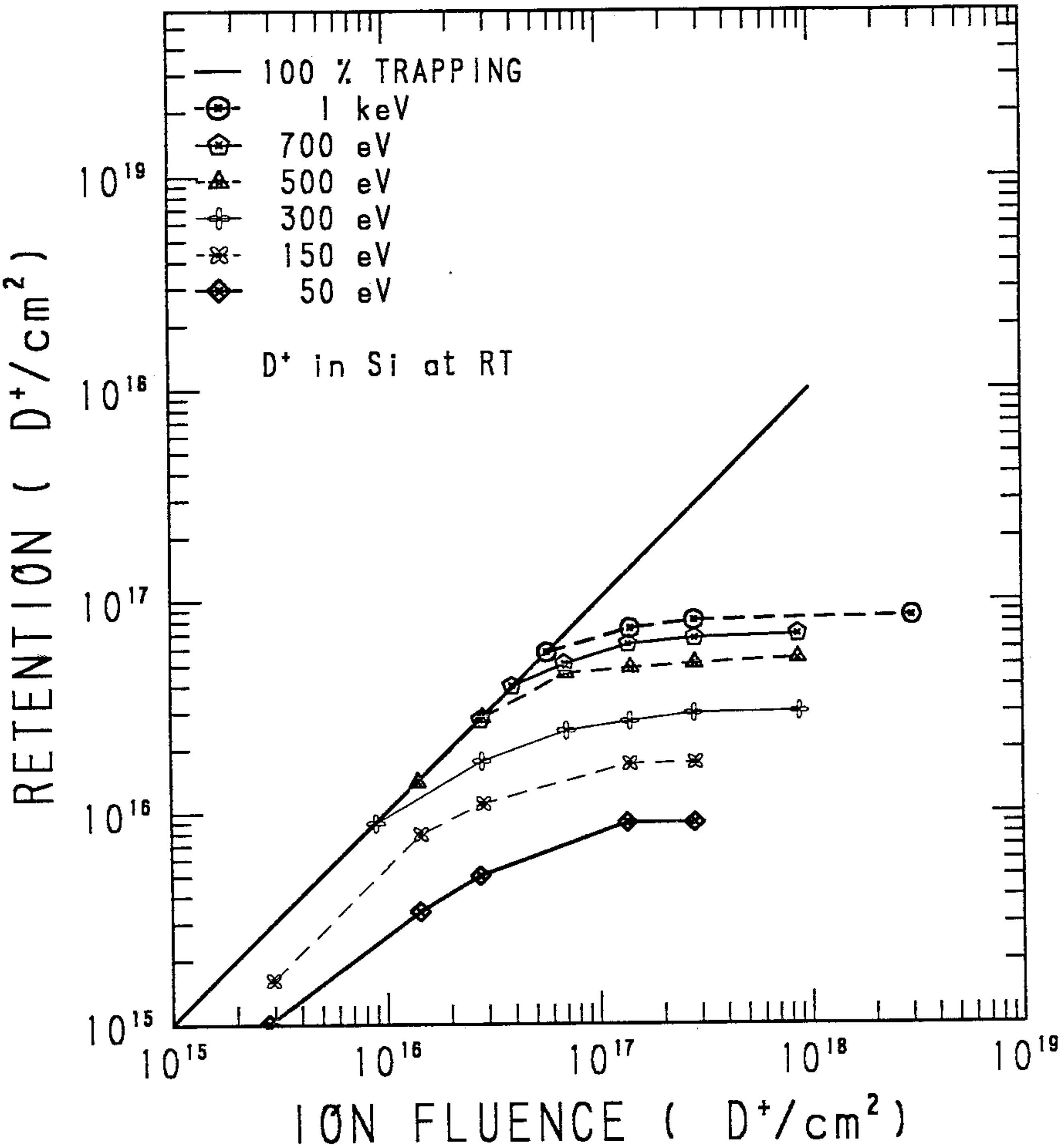


Fig. 28 The amount of deuterium trapped in a Si single crystal with normal incidence on a (111) plane, as a function of the implantation fluence for different implantation energies measured with the nuclear reaction technique. (ref. 54)

## 2.5 Damage Effects

Damage effects on retention curve was measured in carbon for different incident energies as shown in Fig. 29.

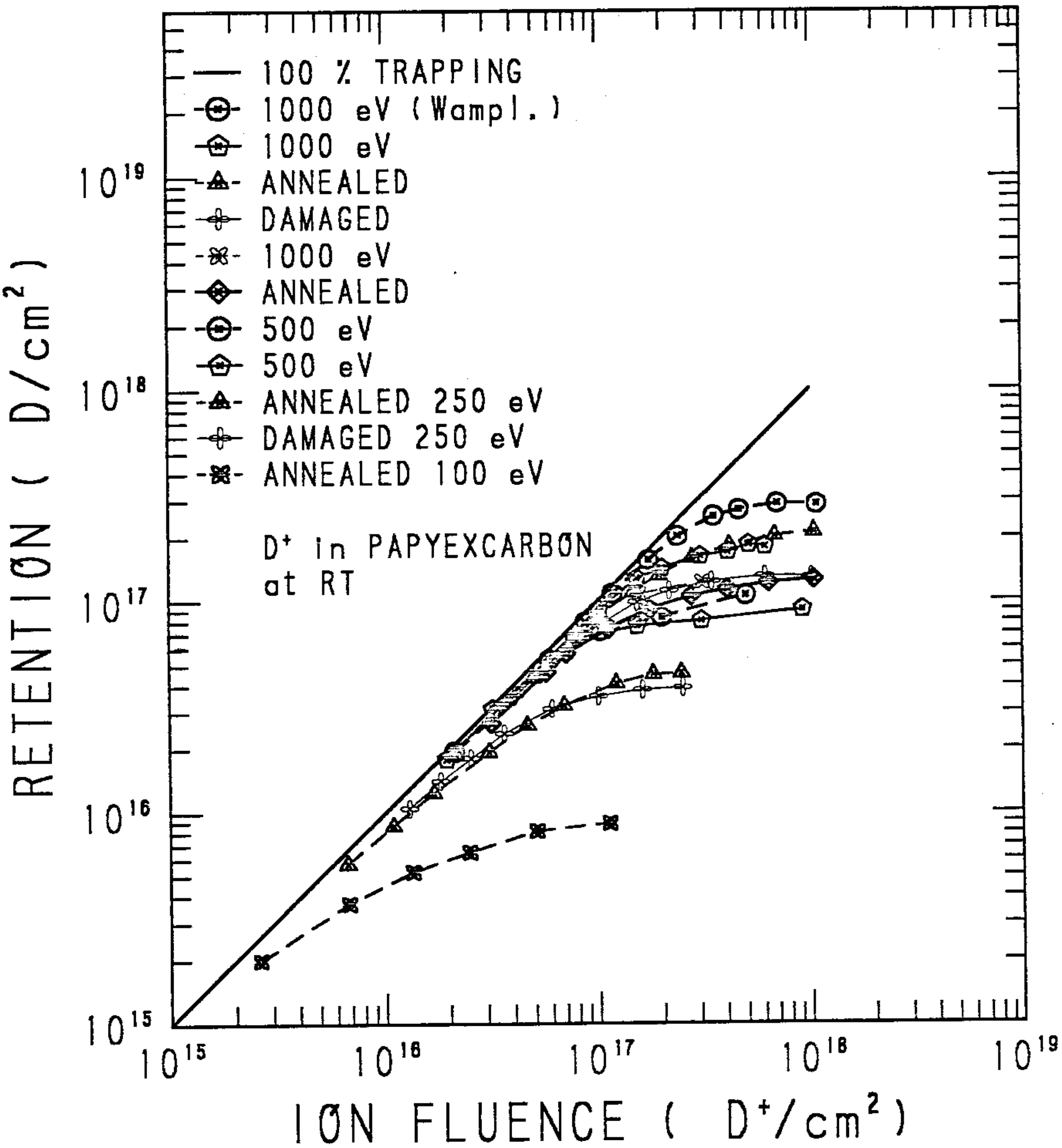


Fig. 29 The amount of deuterons in annealed and damaged carbon samples as a function of fluence for various incident beam energies. (ref. 97)

## 2.6 Ion-Induced Release

Ion-induced release or isotope exchange measurements were conducted in 316 stainless steel (Fig. 30) and Pd (Fig. 31) at low temperature and TiC at room temperature (Fig. 32).

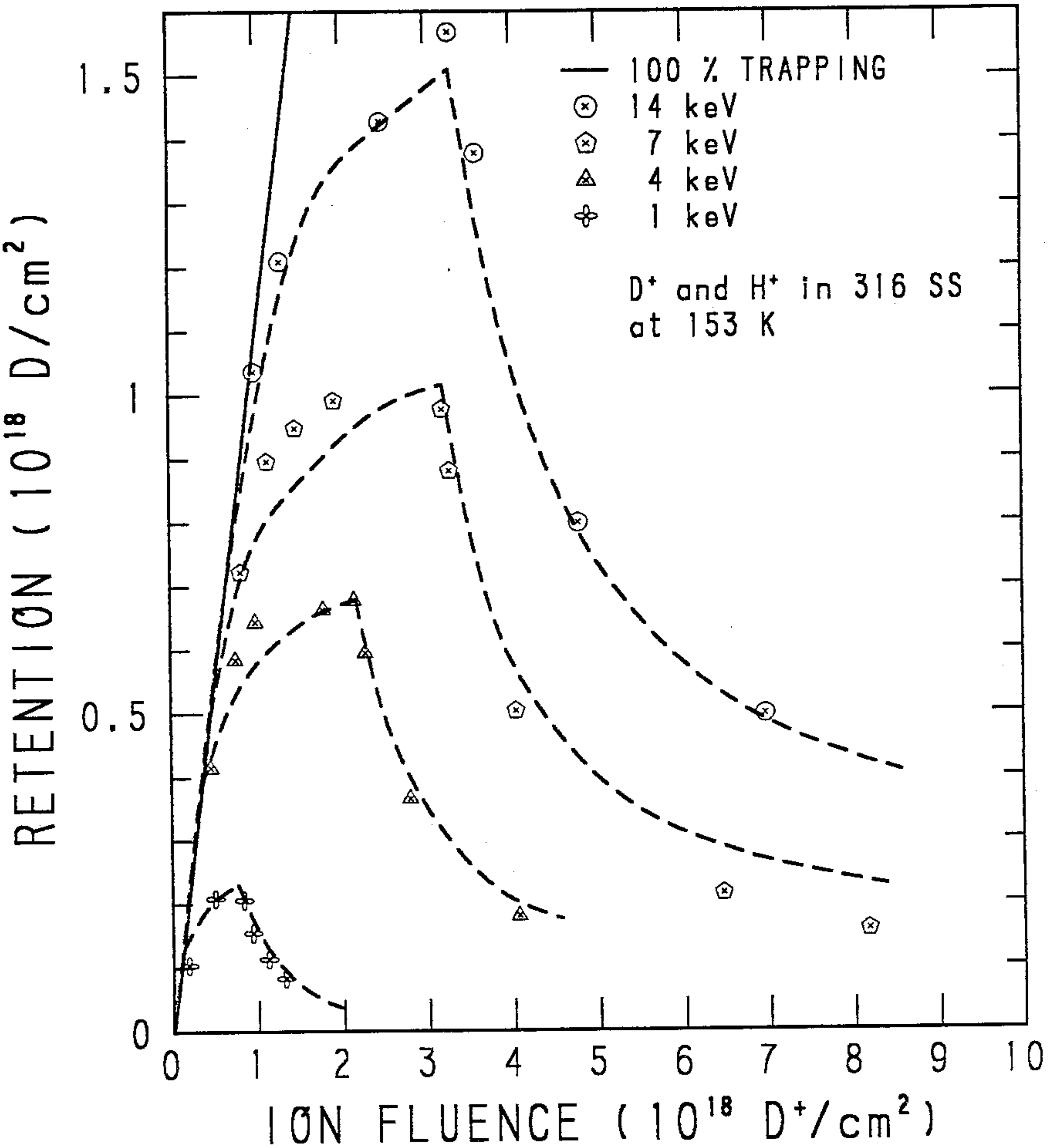


Fig. 30 D saturation and isotope exchange curves for 316 stainless steel at several incident energies. (ref. 57)

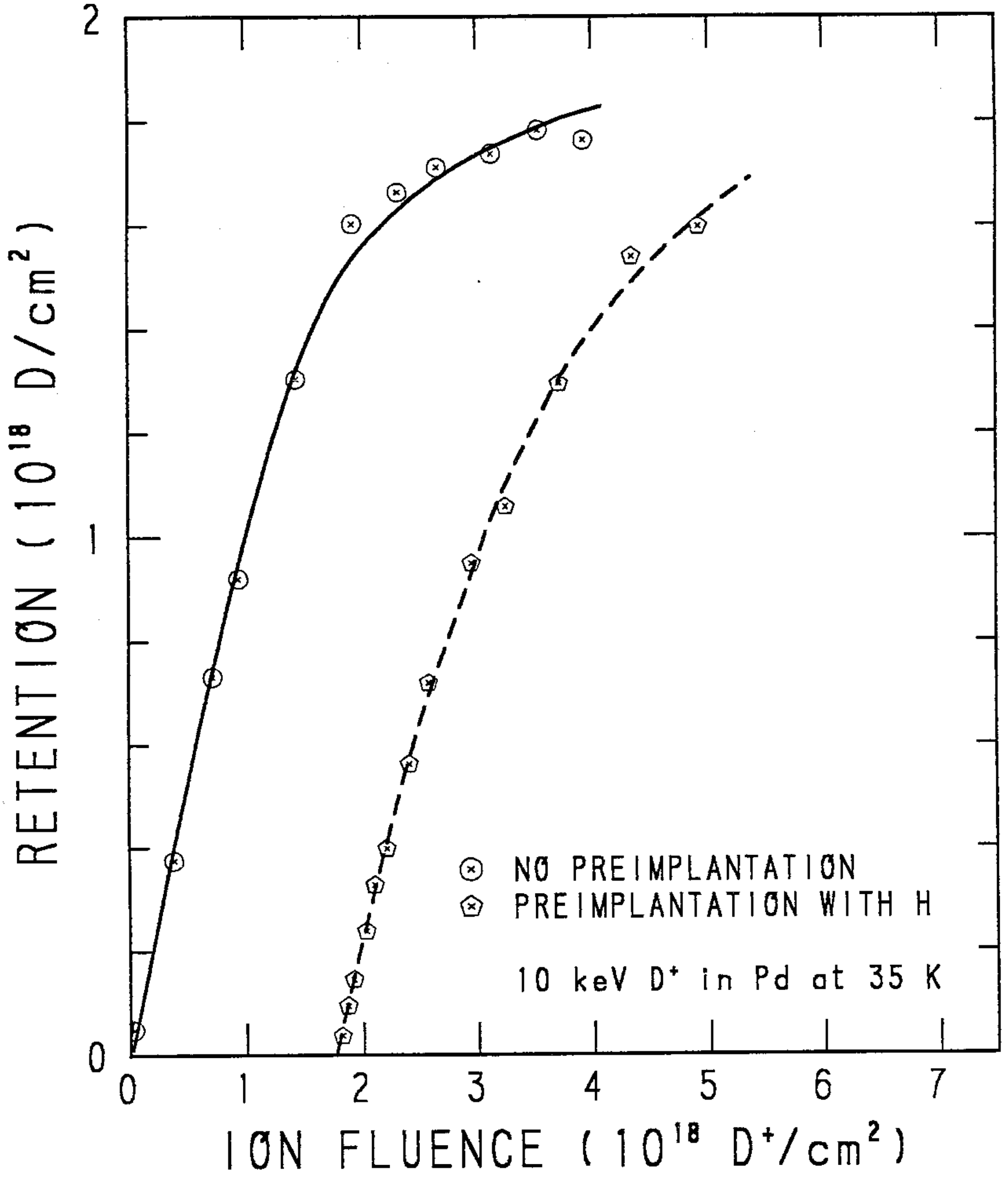


Fig. 31 Saturation under deuteron bombardment of Pd and isotope mixing after preimplantation with protons. (ref. 94)

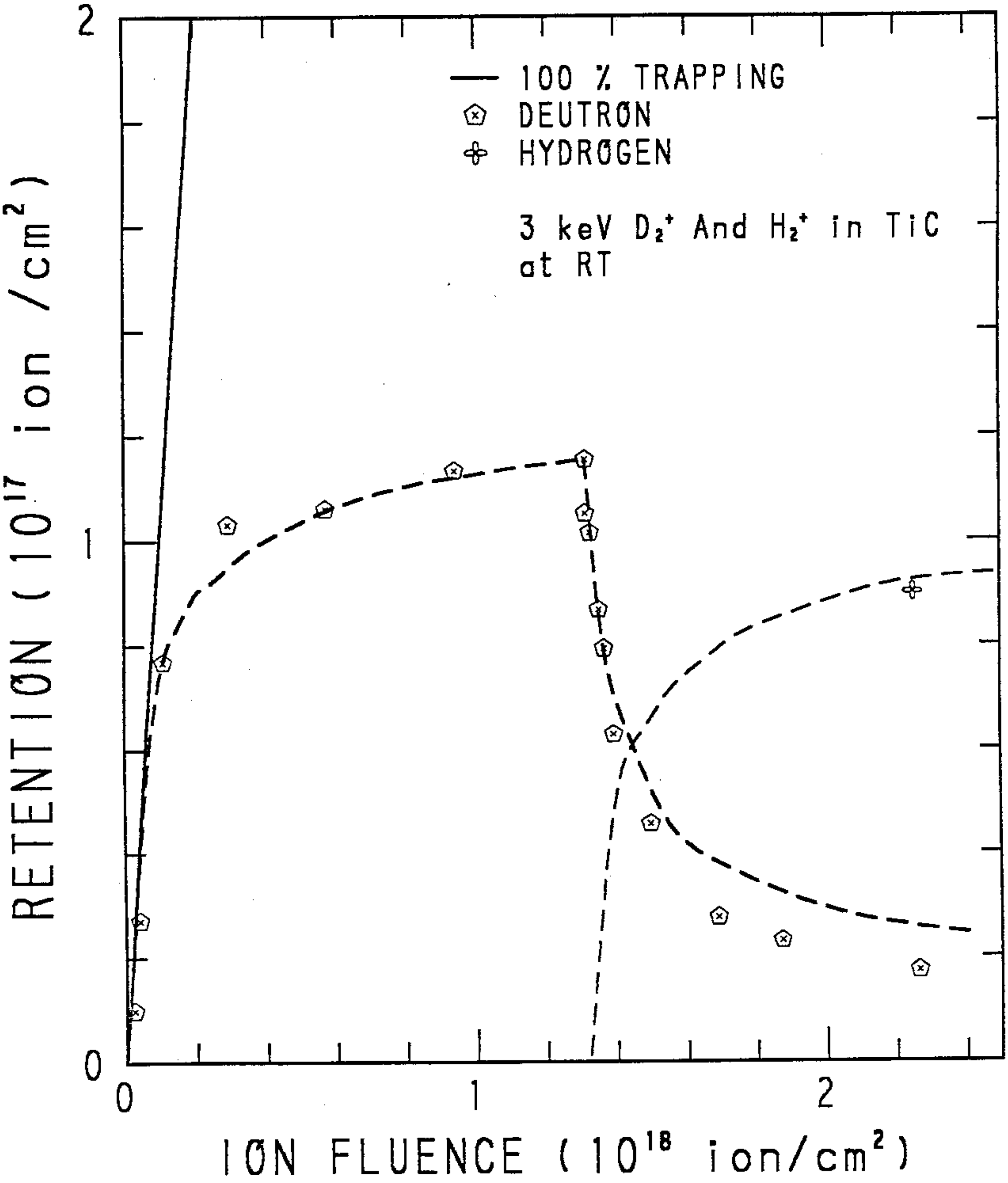


Fig. 32 D saturation and isotopic replacement curves for 3 keV $D_2^+$ and $H_2^+$ in TiC. (ref. 57)

## 3. Table of Trapping and Re-emission Data

| Specimens (Temp.) | Projectiles Species | Energies | Techniques | Remarks | Ref. |
|---|---|---|---|---|---|
| SS, Ti (173 - 740 K) | $D^+$ | 60 keV | GR | Dose and Target Temperature Dependences | 1) |
| Mo, Ti, Ta, Zr (300 - 2000 K) | $H^+$, $D^+$ | 3 - 30 keV | GR, TDS | Ion Dose and Energy Dependences | 2) |
| Ni (77 - 570 K) | $D^+$ | 18 keV | GR, TDS | Dose Dependence, Damage Effects | 3) |
| Ni (77 - 900 K) | $D^+$ | 18 keV | GR, TDS | Damage Effects | 4) |
| Nb (100 - 973 K) | $He^+$ | 300 keV | GR, TDS | Target Temperature and Microstructure Dependences | 5) |
| W (300 - 2400 K) | $He^+$ | 250 keV | GR | Damage Effects | 6) |
| 316 SS (100 - 973 K) | $He^+$ | 300 keV | GR | Target Temperature Dependence, Blister Formation | 7) |
| Mo (600 - 2000 K) | $He^+$ | 7 - 80 keV | GR | Ion Dose Dependence, Blister Formation | 8) |
| Mo, V, 316 SS (100 - 1473 K) | $He^+$<br>$H^+$ | 300 keV<br>150 keV | GR | Target Temperature Dependence | 9) |
| Mo (RT - 750 K) | $D^+$ | 5 - 35 keV | GR, TDS | Target Temperature Dependence, Damage Effects | 10) |
| V, Nb (673 - 1473 K) | $He^+$ | 300 keV | GR | Target Temperature Dependence, Blister Formation | 11) |
| Nb, Pd | $He^+$ | 10 - 300 keV | Theory | Re-emission Rate as a Function of Dose, Ion Energy Dependence | 12) |
| Nb (RT) | $^3He^+$ | 1.5 - 15 keV | NRA | Ion Energy Dependence, Depth Profiling | 13) |

| Specimens (Temp.) | Projectiles Species | Energies | Techniques | Remarks | Ref. |
|---|---|---|---|---|---|
| C (300 - 800 K) | $D^+$ | 6 - 15 keV | NRA | Ion Energy Dependence, Depth Profiling | 14) |
| Al, SAP 930 (150 - 773 K) | $He^+$ | 300 keV | GR | Target Temperature and Microstructure Dependences, Blistering | 15) |
| Ti (RT - 523 K) | $H^+$ | 0.3 - 8 keV | Weight Change | Ion Energy Dependence | 16) |
| Zr (423 K) | $D^+$ | 0.3 - 6 keV | Weight Change | Ion Energy Dependence | 17) |
| Mo (250 K) | $D_2^+$ | 100 eV - 2 keV | GR, TDS | Ion Dose and Energy Dependences | 18) |
| Al (33 - 350 K) | $H^+$, $D^+$ | 5 - 10 keV | NRA | Target Temperature Dependence, Depth Profiling | 19) |
| C (300 - 1900 K) | $H^+$, $D^+$ | 1 - 5 keV | Weight Change | Ion Energy Dependence | 20) |
| C, SiC (293 - 1973 K) | $D^+$ | 20 keV | GR, TDS | Target Temperature Dependence | 21) |
| Si (RT - 1073 K) | $H^+$, $He^+$ | 150 - 300 keV | GR | Ion Dose Dependence, Damage Effects | 22) |
| Nb (293 - 723 K) | $D^+$ | 8 - 16 keV | NRA | Damage Effects, Depth Profiling | 23) |
| Mo (RT) | $H^+$ | 8 keV | NRA | Damage Effects, Depth Profiling | 24) |
| Nb (293 - 1273 K) | $^3He^+$ | 9 - 15 keV | NRA | Target Temperature Dependence, Depth Profiling | 25) |
| Al (353 - 958 K) | $He^+$ | 20 keV | GR | Target Temperature Dependence, Blister Formation | 26) |

| Specimens (Temp.) | Projectiles Species | Energies | Techniques | Remarks | Ref. |
|---|---|---|---|---|---|
| 316 SS, 302 SS (100 - 605 K) | $H^+$ | 20 keV | TDS | Target Temperature and Microstructure Dependences | 27) |
| Mo, Nb (RT) | $H^+$, $D^+$ | 8 keV | NRA | Damage Effects, Depth Profiling | 28) |
| Nb, Zr, Ti, Pd (230 - 1000 K) | $D^+$ | 18 keV | GR | Target Temperature Dependence | 29) |
| 316 SS (RT) | $D^+$ | 7 keV | NRA | Time Dependence, Depth Profiling | 30) |
| 316 SS (153 - 313 K) | $D^+$ | 7 keV | NRA | Ion Dose and Temperature Dependences, Depth Profiling | 31) |
| C (300 - 1050 K) | $D^+$ $H^+$ | 5 - 30 keV | GR, TDS | Radiation Induced Release, Methane Production | 32) |
| 304 SS (77 - 1000 K) | $H^+$, $D^+$ | 5 - 30 keV | GR | Ion Energy Dependence, Ion-Induced Release | 33) |
| 316 SS (150 K) | $H^+$, $D^+$ | 1 - 14 keV | NRA | Ion-Induced Release | 34) |
| 314 SS, 304 SS (RT - 1200 K) | $D^+$ | 15 - 750 eV | TDS | Ion Dose and Energy Dependences | 35) |
| V, Nb, Ta, Ti, Zr, Li | Hydrogen Isotopes | | Theory | Ion Dose and Temperature Dependences | 36) |
| Graphite (RT - 1223 K) | $D^+$, $He^+$ | 8 keV | TDA, RBS | Ion Dose and Temperature Dependences | 37) |
| Al, Mg (30 - 300 K) | $H^+$, $D^+$ | 5 - 20 keV | NRA | Damage Effects, Depth Profiling | 38) |
| Zr (50 - 500 K) | $D^+$ | 10 - 30 keV | NRA | Target Temperature Dependence, Depth Profiling | 39) |

| Specimens (Temp.) | Projectiles Species | Energies | Techniques | Remarks | Ref. |
|---|---|---|---|---|---|
| Nb (RT) | $^3He^+$, $^4He^+$ | 30 - 50 keV | NRA | Ion-Induced Release, Ion Energy Dependence | 40) |
| 316 SS 90 - 600 K) | $D^+$ | 0.33 - 1 keV | TDS | Ion Dose and Microstructure Dependences | 41) |
| 316 SS (297 - 700 K) | $D^+$ | 1 - 10 keV | TDS | Ion-Induced Release, Depth Profiling | 42) |
| Ni, Cu, Ag, Au, Pt, Be, Zr, Fe, Nb, Mo (273 - 1473 K) | $^3He^+$ | 0.2 - 340 keV | NRA | Depth Profiling, Ion Energy and Temperature Dependences | 43) |
| C, Si (RT) | $D^+$ | 20 - 7000 eV | Theory | Incident Energy Dependence, Depth Profiling | 44) |
| $TiB_2$ (RT - 873 K) | $H^+$ | 60 - 210 keV | NRA | Damage Effects, Depth Profiling | 45) |
| Be (RT) | $D_2^+$, $He^+$ | 5 keV | IBA | Dose Dependence, Depth Profiling Radiation Enhanced Oxidation | 46) |
| 316 SS, Ti (RT) | $D^+$, $T^+$ | 60 - 200 eV | Theory | Retained Hydrogen Concentration | 47) |
| Fe (70 - 500 K) | $D^+$ | 15 keV | NRA | Damage Effects, Depth Profiling | 48) |
| Ti, Ti-6Al, Ti-6Al-4V (RT - 423 K) | $D^+$ | 3.3 keV | NRA, SIMS | Depth Profiling, Time and Temperature Dependences | 49) |
| BeO, $Al_2O_3$ (140 - 470 K) | $D^+$ | 5 keV | NRA | Ion Induced Release | 50) |
| C, Si (RT) | $D^+$ | 50 - 1000 eV | NRA, GR, TDS | Incident Energy Dependence | 51) |
| Si, C (RT) | $H^+$, $D^+$ | 40 eV - 400 keV | NRA, SIMS | Depth Profiling, Energy Dependence | 52) |

| Specimens (Temp.) | Projectiles Species | Energies | Techniques | Remarks | Ref. |
|---|---|---|---|---|---|
| 304 SS, Inconel 625<br>TZM, Ti-6Al-4V<br>(RT - 423 K) | $D^+$ | 3.3 keV | GR, TDS, NRA | Target Temperature Dependence | 53) |
| Ni<br>(30 - 500 K) | $D^+$ | 10 keV | NRA | Damage Effects, Depth Profiling | 54) |
| 304 SS<br>(295 - 375 K) | $D^+$ | 2 keV | TDS, NRA | Time and Temperature Dependences | 55) |
| $VB_2$, TiC, $TiB_2$, B,<br>316 SS<br>(153 K, RT) | $D^+$, $H^+$ | 1 - 14 keV | NRA, GR | Radiation Induced Release,<br>Incident Energy Dependence | 56) |
| TiC, $TiB_2$, $VB_2$, $B_4C$,<br>B, Si, C<br>(RT) | $H^+$, $D^+$ | 1.5 keV | NRA | Dose Dependence, Ion-Induced Release | 57) |
| Graphite<br>(RT) | $H^+$, $D^+$ | 1 keV | GR | Energy Dependence, Ion-Induced Release | 58) |
| C<br>(RT) | $D^+$ | 8 keV | Theory | Ion Dose Dependence, Damage Effects | 59) |
| Al, Pt, BeO, $Al_2O_3$<br>(RT) | $^3He^+$, $^4He^+$ | 10 - 40 keV | GR | Energy and Incident angle Dependences | 60) |
| SS<br>(<150 K) | $D^+$, $H^+$ | 1 - 14 keV | Theory | Radiation Induced Release | 61) |
| Graphite<br>(295 - 900 K) | $H^+$ | 0.3 keV | GR | Dose and Temperature Dependences | 62) |
| Ni, Pd, Mo, Ta<br>(33 - 38 K) | $D^+$ | 10 keV | NRA | Dose Dependence, Blistering | 63) |
| Zr<br>(70 - 500 K) | $D^+$ | 10 keV | NRA | Depth Profiling, Time and<br>Temperature Dependences | 64) |

| Specimens (Temp.) | Projectiles Species | Energies | Techniques | Remarks | Ref. |
|---|---|---|---|---|---|
| Inconel 600, Nimonic PE16, Hastelloy B, 316L SS (77, 300 K) | $D^+$ | 33, 36 keV | GR | Dose Dependence, Blistering | 65) |
| TiC, 304 SS<br>Graphite | $D^+$<br>$^3He^+$ | 0.5, 1.5 keV<br>3 keV | NRA | Depth profiling, Electron Beam Annealing, Temperature Dependence | 66) |
| Ni, Be (300 - 975 K) | $H^+$<br>$He^+$ | 2 keV<br>4 keV | GR | Re-emission for various H/He Flux Ratio | 67) |
| Ti (140 - 500 K) | $D^+$ | 6.7 keV | NRA | Depth Profiling, Temperature Dependence | 68) |
| Graphite (RT) | $D^+$ | 1 - 8 keV | IBA (NRA,ERD,RBS) | Ion-Induced Release, Depth Profiling | 69) |
| Mo (160 K) | $D^+$<br>$^3He^+$ | 4 - 8 keV<br>4 - 16 keV | NRA | Ion-Induced Release, Depth Profiling | 70) |
| Mo (160 K) | $D^+$<br>$^3He^+$ | 8 keV<br>4 keV | NRA | Ion-Induced Release, Depth Profiling | 71) |
| 304 SS (90 - 500 K) | $D^+$ | 0.125 - 1 keV | GR, TDS | Energy and Temperature Dependences, Ion-Induced Release | 72) |
| C (RT) | $H^+$, $D^+$ | 10 - 30 keV | GR | Ion Energy Dependence, Ion-Induced Release | 73) |
| Ti, $TiB_2$, TiC (375 - 775 K) | $D^+$ | 3.3 keV | GR, TDS, NRA | Temperature Dependence, Depth Profiling | 74) |
| V (RT - 373 K) | $^3He^+$ | 300 - 750 keV | NRA | Damage Effects, Depth Profiling | 75) |
| V, Nb, Ta (RT - 373 K) | $^3He^+$ | 250 - 730 keV | NRA | Damage Effects, Depth Profiling, Temperature Dependence | 76) |

| Specimens (Temp.) | Projectiles Species | Energies | Techniques | Remarks | Ref. |
|---|---|---|---|---|---|
| Si | $H^+$ | 1.5, 20 keV | Theory | Hydrogen Retention, Isotope Exchange | 77) |
| B, C, Si, TiC, $TiB_2$, $B_4C$, $VB_2$ (RT) | $H^+$, $D^+$ | 1.5 keV | NRA, ERD | Hydrogen Retention, Isotope Exchange | 78) |
| C, TiC (300-873 K) | $H^+$, $D^+$ | 1.5 keV | NRA | Retention, Release, Isotope Exchange | 79) |
| Mo (RT) | $H^+$ | 10, 20 keV | NRA | Depth Profiling, Damage Effects | 80) |
| Ni, Mo (393-1073 K) | $D^+$ | 20 keV | GR | Temperature Dependence, Peameation Rate | 81) |
| 304 SS (303-677 K) | $H^+$ | Glow discharge plasma | Pressure gauge | Temperature Dependence, Recycling Constant | 82) |
| C (RT) | $H^+$, $D^+$ | 1.5 keV | SIMS | Ion-Induced Release, Damage Effects | 83) |
| C (RT) | $D^+$ | 300 - 3000 eV | SIMS, NRA | Deuterium Retention, Depth Profiling | 84) |
| 304LN SS, 12R72HV SS (RT) | $D_3^+$ | 6 keV | NRA | Retention, Helium Damage Effects | 85) |
| Mo (RT) | $H^+$, $D^+$ | 0.5 - 6 keV | GR | Ion-Induced Release, Damage Effects | 86) |
| Fusion Materials | | | Theory | Hydrogen Retention, Neutron Damage Effects | 87) |
| Graphite, TiC (303-873 K) | $H^+$, $D^+$ | 1.5 keV | Theory | Hydrogen Retention, Isotope Exchange | 88) |

| Specimens (Temp.) | Projectiles Species | Energies | Techniques | Remarks | Ref. |
|---|---|---|---|---|---|
| Al, Mo, Ni, Ti, Si, SS | | | Theory | H Transport: Surface Recombination, Diffusion | 89) |
| $SiO_2$ (RT) | $H^+$, $D^+$ | 20 keV | ERD | Depth Profiling, Isotope Exchange | 90) |
| $Al_2O_3$, TiC, $TiO_2$, Si, Spinel (RT) | $D_2^+$ | 100 - 1000 eV | GR | Temperature and Energy Dependence | 91) |
| 304 SS (573-873 K) | D, $D^+$, $D_2^+$, $D_3^+$, $T_2^+$ | 0.2 - 5 keV | MS | Surface Recombination | 92) |
| Al (100-533 K) | $D_2^+$ | 680 keV | NRA | Depth Profiling, Damage Effects | 93) |
| Mo, Pd, Ta (35 K) | $H^+$<br>$D^+$ | 12, 18 keV<br>10 keV | NRA | Retention Depth profiling, Isotope Exchange | 94) |
| 304 SS, 310 SS (393-873 K) | $D^+$ | 15 keV | NRA | Defect Trapping, Surface Permeation | 95) |
| 304LN SS (RT-548 K) | $D_3^+$ | 6 keV | NRA | Retention, Helium Damage Effects | 96) |
| C (RT) | $D^+$ | 100 - 1000 eV | GR | Incident Energy Dependence, Damage Effects | 97) |
| 304 SS, C (333 K) | $D^+$ | 5 keV | NRA | Retention, Depth profiling, Surface Recombination | 98) |
| 304 SS (223-373 K) | $D^+$ | 5 keV | NRA, GR | Retention, Depth profiling, Surface Recombination | 99) |
| C (RT) | $D^+$<br>$H^+$ | 150 - 600 eV<br>3 keV | NRA | Ion-Induced Release | 100) |

| Specimens (Temp.) | Projectiles Species | Energies | Techniques | Remarks | Ref. |
|---|---|---|---|---|---|
| 304LN SS (308-368 K) | $D^+$, $D_3^+$ | 10 keV | GR | Temperature Dependence | 101) |
| 310 SS (RT-373 K) | $D^+$ | 2.5 - 10 keV | GR | Re-emission, Flux Dependence | 102) |

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