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This Week's Citation Classic

Amsel G, Nadal J P, d'Artemare E, David D, Girard E & Moulin J.
Microanalysis by the direct observation of nuclear reactions using a 2 MeV Van de Graaff. *Nucl. Instrum. Methods* **92**:481-98, 1971. [Groupe de Physique des Solides de l'Ecole Normale Supérieure. Paris, France]

The principles of microanalysis of the direct observation of reactions induced by MeV charged particles are presented. Light nuclei from ^{2}H to ^{31}P may be measured with high sensitivity and precision in near surface regions of solids, both for their overall amounts and depth profiles. All technical details are described along with numerous applications. [The *SCI*® indicates that this paper has been cited over 165 times since 1971.]

G. Amsel
University of Paris
Ecole Normale Supérieure
Physique Solides GRP
F-75221 Paris 05
France

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"It was gratifying to hear that this paper was so often cited as it was the outcome of eight years of interdisciplinary teamwork. The ideas for this paper came in the 60s when, as a young nuclear physicist, I had the luck to work on semiconductor detectors soon after their discovery, while investigating the $^{16}O(d, \alpha)N^{16}$ and $^{18}O(p, \alpha)^{15}N$ reactions using self-supporting targets of anodic Al_2O_3. The spectacular process of anodic oxidation is fascinating — how do the oxygen and aluminum atoms move to produce further oxide growth? It suddenly occurred to me after the discovery of a very narrow resonance in $^{18}O(p, \alpha)^{15}N$, that the position of this resonance may be an indicator where the ^{18}O nuclei are in the target. I realized also that by oxidizing aluminum first in a natural and further in a ^{18}O enriched solution I may have an answer by locating the ^{18}O tracer nuclei in the final 'sandwich' oxide. The experiment was carried out on that very night and the answer was unambiguous: all the ^{18}O was near the metaloxide interface! Hence the oxygen either does not move or moves by a vacancy or interstitialcy type propagation mechanism. The simplicity of the experiment struck me and I soon realized the great potentialities of such an analytical technique. I also realized that I was more interested in solid state than in nuclear physics. Once my thesis was finished, I made a fast transition from our nuclear to our solid state lab.

"At the same time, several authors began using Rutherford backscattering (we call it 'Coulomb' in French) for microanalysis and the use of MeV ions grew out as a major tool in microanalysis, to which a periodic conference is devoted, called 'Ion beam analysis.' I got tremendous support from Centre National de la Recherche Scientifique (CNRS) and two directors of my laboratory, between 1960 and 1970 to set up a microanalytical facility. Several labs began a cooperation, which still lasts, to develop and use these techniques in many fields. Nadai and David did a wonderful job in developing the method in the frame of their PhD and d'Artemare, Girard and Moulin made an invaluable contribution through their technical skill to set up the system described in this paper.

"The main technical problem was due to the events of May 1968: the people of Van de Graaff had to come back six times to set up the new accelerator due to outbursts of general strikes and to students battling with police on our campus. Another difficulty was the reticence of many physicists: interdisciplinary work is hard to start. First, we had to succeed in our experiment to demonstrate its feasibility and attract people. After the publication of our paper CNRS gave me its silver medal, but I feel that this was recompensating all our group. The reason why the paper is so often cited may be that although it is the first general one on this method it contained the detailed principles for its use, both theoretical and experimental, and it presented enough applications to be convincing, bearing testimony for ten years of work. Maybe, it was not so bad to wait five years before publishing it."